Tampere University

Florian Rey

IMPROVING ACCEPTABILITY TOWARDS AMBITIOUS CARBON PRICING POLICIES

Problems and possible solutions

Faculty of Management and Business
Master’s thesis
July 2019

ABSTRACT

Florian Rey: Improving acceptability towards ambitious carbon pricing policies: Problems and possible solutions
Master's thesis
Tampere University
Master in Public Economics and Public Finance (MGE)
July 2019

In this thesis, we investigate why carbon pricing is not being optimally implemented, despite a rare consensus from economists stating that carbon pricing is the most efficient tool to fight climate change. We focus on the question of the acceptability for carbon pricing. Even though this topic has for a long time been left aside of carbon pricing discussions, a growing number of researchers are now starting to focus on this aspect. Indeed, many scientists have come to the conclusion that the implementation of ambitious policies highly depends on public acceptability. This also strongly applies to the field of environmental policies. After a detailed review of literature, we have found two important issues in carbon pricing policies, which may explain the low levels of acceptability.

The first issue is its distributional consequences. Empirically, we have showed that there is yet no clear answer to whether a carbon tax is regressive or not. Still, many evidences seem to point to at least some level of regressivity. In order to increase people's acceptability, we have found that redistributing revenues through green investments is the best option. This is a quite surprising and interesting result, because our intuition would have suggested redistributing revenues in a progressive manner (for instance lump-sum transfers).

The second issue is people's fear for competitiveness disadvantages, which could theoretically translate into carbon leakage. For this question, we can give a more precise answer: no empirical study has so far been able to show any significant evidence of carbon leakage. This clearly shows that opponents of carbon pricing have overplayed this issue. Even if carbon leakage was to become an issue in the future (possibly as carbon prices increase), some useful solutions have already been proposed, in particular Border Carbon Adjustments (BCA).

Keywords: Carbon pricing, environmental policies, acceptability, distributional consequences, competitiveness, border carbon adjustments

Table of contents

Acknowledgements

Throughout the writing of this thesis, I have received numerous supports, both professional and personal. Those supports have taken various forms, but all contributed to the realization of this thesis.

First, I want to thank both of my supervisors; Professor Thierry Madiès (University of Fribourg) and Professor Hannu Laurila (University of Tampere).

The first steps of this thesis were done during my exchange semester at the University of Tampere. During those four months, Prof. Laurila helped me to focus my thoughts on one precise research question. I thank him for that. I also extend my thanking to the way he has welcomed me in Tampere, always being available when needed.

The actual writing of the thesis was done at the University of Fribourg. Throughout this process, Prof. Madiès offered me a very precious guidance. Therefore, I would like to express my sincere gratitude for his collaboration. All the useful remarks that he made have allowed me to improve this thesis.

I also would like to thank prof. Katri Sieberg (University of Tampere). Her course on the Tragedy of the Commons was very useful for this thesis.

This thesis is also signaling the end of my studies in the field of economics. Therefore, I would also like to greatly thank my family for their support throughout my studies. Words simply cannot express how important their help has been. My parents, Michel and Gabrielle, have been a huge support during those five years of university. They always pushed me to do my best. By all their small actions, they also gave me the opportunity to fully concentrate on my studies. I sincerely thank them for this. I would also like to thank my girlfriend, Justine. She has patiently listened to me for hours about this topic, often giving me interesting ideas and counterarguments. During the writing of a thesis, there are moments when one feels a bit discouraged. She has always found the words to re-motivate me.

Lastly, but very importantly, I would like to dedicate this thesis to my grandfather André. He probably is one of the reasons for my interest in collective issues. Unfortunately, I will not have the chance to show him my work. Nevertheless, I am convinced that he would have appreciated it.

List of Figures

List of Tables

List of boxes

Introduction

Why is carbon pricing not being optimally implemented, even though it is a "near-universal agreement among economists" that carbon pricing is needed to lower carbon emissions at a reasonable cost (Parry et al., p. xxv)? At a time where public concern for climate change questions is at its highest, this is a somehow frustrating, yet key question to ask.

When looking at the findings from Métivier et al. (2017), it appears that only 25% of the world's greenhouse gazes are covered by a carbon pricing mechanism. More alarming, more than 75% of emissions regulated by carbon pricing are covered by a price below €10. It is thus well below the price range of 40-80 USD recommended by Stiglitz and Stern (2017) in order to stay under the 2 degrees variation. This perfectly shows that only a few ambitious carbon pricing schemes have been implemented so far. Again, why? According to Klenert et al. (2018), "political (and thus public) acceptability is the biggest challenge to implementing ambitious carbon pricing". The really important question, and the one we address in this master thesis, is to identify which reasons create this lack of acceptability for carbon pricing, and how can they be solved. We identify two main concerns of citizens, which seem to lead to a reduction of acceptability towards carbon pricing.

The first concern, which we have identified in the literature, is a potentially regressive distribution of the costs of carbon pricing. Indeed, recent events[1] have showed that protests against carbon prices often originate from low-income households. Those households have little possibility to modify their consumption of emission intensive products, and therefore support a large share of the burden. We will analyze whether carbon taxes are regressive or not, both theoretically and empirically. Even though empirical results do not fully agree on the fact that carbon taxes are regressive, we will seen that many evidences tend to point in this direction. Therefore, we then discuss how revenues should be redistributed in order to solve this issue. Many possibilities exist: cutting existing taxes, lump-sum transfers (like it is the case in Switzerland) or investing in green technologies. Theoretically, lump-sum transfers or other social cushioning options could lead to a more progressive system. On the contrary, green spending does not lead to a more progressive tax scheme. The last step of our analysis is to see which option leads to the higher level of acceptability. We expected social cushioning to be highly favored by citizens, precisely because it reduces the regressivity of carbon taxes. Empirical results are surprisingly different: acceptability for carbon pricing is increased when revenues are used to increase green spending. This is an important result for

[1] For instance the ovement of the « yellow vests » in France.

policy-making decisions, especially when we know that in average, only a minority of carbon tax revenues is used for this purpose.

The second concern is the fact that in a world where carbon prices are applied unevenly across countries, carbon pricing might hurt a country's competitiveness. Why? Because industries may decide to relocate in countries where the carbon taxes are lower. This issue is called "carbon leakage". It relates to the problem of collaboration among countries. Indeed, if all countries were equally and with certainty implementing carbon pricing, none of them would suffer from a lack of competitiveness. But to this date, no legally binding international agreement exists, giving the possibility to countries to free ride on others' efforts. Stiglitz perfectly emphasizes the importance of this question in terms of public acceptability: "Even if the quantitative effects (of carbon leakage) are limited, the political consequences of plants and jobs moving to another jurisdiction because of its lower carbon price can be significant, and undermine support for strong carbon policies" (Stiglitz, 2018, p. 23). After describing the different channels of carbon leakage, we will turn to the empirical literature. This latter will give us a clear answer: carbon leakage does not seem to be a significant issue. Still, it may become problematic in the future: the increasing gap in carbon prices between abating and non-abating countries increases firms' incentives to relocate abroad. Some of those solutions, such as the climate club or Border Carbon Adjustments (BCA), also increase the incentives to cooperate between countries.

We go through both of those issues in details, both theoretically and empirically. For each of them, we attempt to make sound policy recommendations based on the available literature. Those policy suggestions remain focus on answering our research question: how can acceptability of ambitious carbon pricing policies be increased?

A good way to describe this thesis is also to explain what we will not do. A majority of the literature addresses the question of the efficiency of carbon pricing, with the highly debated question of the optimal price for carbon pricing. Rather, we will focus on why carbon pricing policies are not implemented optimally, and what can be done about that. Our choice of addressing the barriers to public acceptability can be justified by the idea of Klenert et al. (2018) that efficiency and equity will not be enough to ensure the success from carbon pricing, stating: "Acceptability first, efficiency and equity second".

1. Global warming and the case for carbon pricing

At the center of this thesis lies the discussion about carbon pricing acceptability, and the two issues we have identified in the literature. But before being able to start this discussion, we need elements that justify the relevance of our research question. This will be the role of this first part of the thesis.

First, we briefly present why reduction of greenhouse gases (GHG) emissions is an extremely important topic (1.1), by using the latest reports on global warming and previsions of future economic effects. Secondly, we discuss why carbon pricing is the instrument supported by economists to achieve GHG reduction (1.2). Lastly, we show the current state of carbon prices policies in the world (1.3). Those three elements lead us to a first conclusion: despite a near universal consensus that carbon pricing is needed to reduce GHG in a cost-effective manner, only few ambitious carbon prices policies are implemented. Why is it so? To conclude this introductive part of our thesis, we introduce the notion of acceptability (Klenert et al., 2018) as a potential answer to why so few ambitious carbon prices schemes are in place (1.4).

1.1. Global warming: Review of scientific knowledge

Global warming has become one of the most debated issue in our political and public agenda. At the center of this debate is the question of the human impact on climate. Is it possible to keep up economic growth, while reducing our greenhouse gases emissions? There is no consensus on this question yet. But there is one consensus that does exist among environmental scientists, and it is on the urgency to act in order to reduce global warming. We will not spend too much time on technical environmental elements. Nevertheless, a basic idea of current climate change discussion and its causes is necessary. This chapter is separated in three parts. First, we present the most relevant scientific conclusions on global warming. Secondly, we describe their consequences, in terms of economic impact on our societies. Lastly, we discuss the main causes of global warming, focusing on greenhouse gases (carbon dioxide).

1.1.1. Consensus on the urgency to act

Global warming describes the "long-term warming of the planet since the early 20th century, and most notably since the late 1970s, due to the increase in fossil fuel emissions since the Industrial Revolution" (NASA). Climate change is a broader term referring to a wide range of weather phenomena. Global warming is one of those phenomena, as well as extreme weather occurrences or sea level rise. We will both of those terms interchangeably in this thesis.

The Paris Agreement showed a worldwide desire to keep global warming "well below" the 2 degrees[2], as well as to limit the temperature increase to 1.5 degree above pre-industrial level. Currently, global human-induced warming has already reached 1 degree (IPCC, 2018 p. 51). Since climate change impacts regions unequally, this means that many regions of the world are already witnessing higher global warming. In fact, "20-40 % of the world population has already experienced over 1.5 degree of global warming in at least one season (Ibid. p. 53). Therefore, the latest report of the IPCC provides useful insights, as it focuses on this 1.5 degree level, and why it is important to remain below this line.

The consequences of climate change are getting more and more visible. Scientists have now clearly identified a link between global warming and its impact on human systems and well beings (Ibid, pp. 175-311). This link is done through multiple channels. First, global warming increases the likelihood of extreme temperature: the warmest days of the year are now 1 degree higher, and the coldest days are 2.5 degrees higher. Heat waves are also becoming

[2] This refers to a comparison with pre-industrial levels (1850-1900).

longer. The European heat wave of spring and summer 2018 is the perfect example of this. Even a Nordic country like Sweden suffered from record-breaking temperatures, leading to important wildfires. Secondly, global warming also impacts the water cycle. Indeed, heavy rainfalls have significantly increased alongside temperatures. This is a serious issue, as it can lead to flooding or landslides. A third important consequence is the occurrence of drought and dryness, increasing water stress on some regions. This provides a perfect example of the fact that climate change impacts regions unequally (and thus unfairly). Droughts have increased in the Mediterranean and West Africa, while decreasing in Central North America and Northwest Australia. An other issue linked with water is the rise of sea levels. With increased temperature, water expands. Also, melting from glaciers and ice loss in Greenland contribute to a rapid increase of sea level. Here, the same heterogeneity of effects is seen. For instance, the southeast American coast is witnessing a particularly quick sea level rise (10 times quicker than the world's sea level increase rate[3]). In Miami (USA), many measures had to be taken to try to slow down the damages caused by flooding: raising roads, installing water pumps and restoring wetlands. Ironically, most of those solutions are short term fixes than consume huge amount of energies. This will in fine only contribute to increasing global warming, and thus sea level's rise. In summary, global warming has many important consequences for human life. From water and food availability (because drought and heat complicate agricultural production) issues, to deportation of population (sea levels rise will make some regions inhabitable), it requires both mitigation and adaptation efforts. Mitigation efforts refer to addressing the causes of climate change. The main mitigation objective is to reduce GHG emissions. Adaptation defines the fact of preparing our societies for the current and future consequences of climate change. It aims at reducing our vulnerability towards global warming consequences. Raising the roads in Miami is an example of adaptation measures. In this thesis, we focus on mitigation.

It should now be clear that global warming has strong consequences for human life and societies. Nevertheless, this finding has already been known for many years. In fact, the previous report from the IPCC (2007) was already describing an "unequivocal global warming", calling for stronger mitigation and adaptation efforts. The difference with the latest report is maybe the emphasis on the urgency to stay under the 1.5 degree increase. A key finding of the special report on the 1.5 degree is that there is a huge difference between 1.5 and 2 degrees increase. In fact, nearly all the consequences we mentioned earlier would be

[3] https://www.businessinsider.com/miami-floods-sea-level-rise-solutions-2018-4?IR=T

highly increased. This additional 0.5 degree will lead to higher extreme temperatures, more frequent heavy rainfalls and a quicker rise of sea level. For instance, moving from a 1.5 to a 2 degree variation would increase sea level by 10 centimeters. Climate refugees would thus increase. Food and water provision would also become much more complicated. Unfortunately, the report from the IPCC emphasizes that based on available predictions; the limit of 1.5 degree will be crossed between 2030 and 2052 (IPCC, 2018, p. 66). In simple terms, it means that in the worst scenario (which is supported by most of the current data), the world has only 11 years left before to cross this threshold.

1.1.2. Economic costs of global warming

As already mentioned before, this consensus on the issue of global warming has been known for a few years. Nevertheless, it has so far failed to generate enough actions. We will now show the economic consequences of climate change. This might be a better way to draw attention towards the need for mitigation effort. Estimating the costs of climate change is done by calculating the costs of not acting to reduce global warming (or inversely, the benefits of acting). As Ciscar et al (2011) describe it, estimating those effects is an extremely complex empirical task. Uncertainty on "climate change, demographic change, economic development and technological change" (Ibid, p. 2678) requires different scenarios and assumptions.

Two different kinds of models have been used to assess the economic costs of climate change (OECD, 2015, pp. 19-20): Computable General Equilibrium (CGE) models and Integrated Assessment Models (IAM). CGE models contain a very detailed description of the various sectors of the economy. It allows assessing the impact of climate change at a sectorial level. For instance, impacts on agricultural productivity, health expenditures (and numerous other sectors) can be differentiated. IAM "focus more on the interaction between the economic and biophysical system" (Ibid, p. 20) and are then more appropriate when assessing the aggregated impact of climate change.

Ciscar et al. (2011) have empirically assessed the economic impact of climate change on the European economy. Authors combined climate data with a detailed multi-sectoral economic model of Europe. Empirically, this is done in three steps. First, data were gathered from climate models. Secondly, those data are used to run "physical impact models" on five key sectors: agriculture, tourism, human health, coastal systems and river basins. Lastly, the economic impacts found in those models are introduced in a CGE model. In order to tackle uncertainty issues, two different scenarios on GHG emissions had to be analyzed: one with high emissions and one with low emissions in the future. One of the very concerning results is the impact of climate change on agricultural production[4]. Under the high emission scenario, agricultural production would lead to a decrease of 10 % of agricultural production in the European economy. Even within Europe, large regional disparities would occur: Southern Europe's agricultural production would decrease by 27 %, while Northern Europe's production would increase by 52% (Ibid, p. 2680). For the overall European economy, scenarios with high emissions and high sea level rise lead to an annual GDP loss of 65 billions of euros, or a welfare loss of 1%. The scenario with low emissions leads to an annual GDP loss of 20 billions of euros, and a welfare loss of 0.2% (Ibid, pp. 2681-2682). Once again, disparities occur. No matter which scenario, northern Europe is positively impacted, while Southern Europe suffers the most.

Some other empirical analyses have combined CGE models and IAMs, in order to benefit from each model's advantages. This is the case of the OECD analysis (2015), which provides a very detailed model of climate change impact on the world's countries. They focus on economic sectors that are very similar to those seen in the work from Ciscar et al. (2011), but extend it to more countries and a longer time horizon. Increasing the time horizon is interesting, as it allows seeing the non-linear effects of climate change more precisely. Indeed, many sectors respond slowly to a small increase of temperature, but react in a stronger way once a certain threshold is crossed. This is the case of agricultural production (OECD, 2015, p. 55). The results of the analysis project a GDP loss of 1 to 3.3 % (depending of the level of global warming, which is assumed to be between 1.5 and 4.5 degrees) by 2060. By 2100, damages could reach 10 % of the world's GDP. Once again, some important disparities occur between regions. Africa and Asia are the most negatively affected, while some regions with higher latitudes (Canada, Russia and Nordic countries) even manage to benefit from global warming (especially because of tourism revenues). In line with the results from Ciscar et al., this report also found that agriculture is one of the most hardly impacted sector (pp. 57-59). Labor productivity and sea level rise (by 2060) will be the two other sectors generating high costs.

[4] See Ciscar et al. (2011), pp. 2680-2681 for detailed results on other sectors.

Box 1: The case of Switzerland

In Switzerland, the effects of global warming are already being felt (Confédération Suisse, 2018, pp. 6-7). Nine of the ten warmest years ever recorded have occurred in the twenty-first century. Amounts of snow and ice are reducing, and hot days and heavy precipitations are becoming more intense and frequent. If the world meets the goals of the Paris agreement, future warming in CH will be between 2.1 and 3.4 degrees. On the contrary, it could reach 6.9 degrees if no global mitigation happens. This means that without a global reduction of GHG emissions, warming could be three times higher in CH (Ibid, pp. 7-8). Switzerland will also experience longer periods of drought in the summer, and more heavy precipitations in the winter. Lastly, the occurrence of extreme events (which generate high and non-linear damages) will also increase. From an economic perspective, Switzerland will be impacted through different channels (OcCC, 2007, pp. 5-7). First, the energy sector will require less energy for heating in winter, and more for cooling in the summer. Also, the reduction of available water will reduce the production of hydraulic energy. Secondly, tourism will face important changes. Indeed, some low-altitude skiing resorts will disappear in the long term. High-altitude resorts will likely benefit from higher demand. Regarding agriculture, changes of 2-3 degrees should lead to positive results in CH. On the contrary, if warming is higher than 3 degrees, agricultural production will decrease (primarily because of insufficient water resource and decreasing crop yields). Overall, it is clear and unequivocal that global warming will have consequences and costs for Switzerland. Thus, understanding how to better reduce the world's GHG emissions appears as a key topic for Switzerland.

1.1.3. Causes of global warming

We have briefly presented the current scientific knowledge about climate change and its future consequences. It is also important to understand what causes this global warming, in order to discuss the potential solutions.

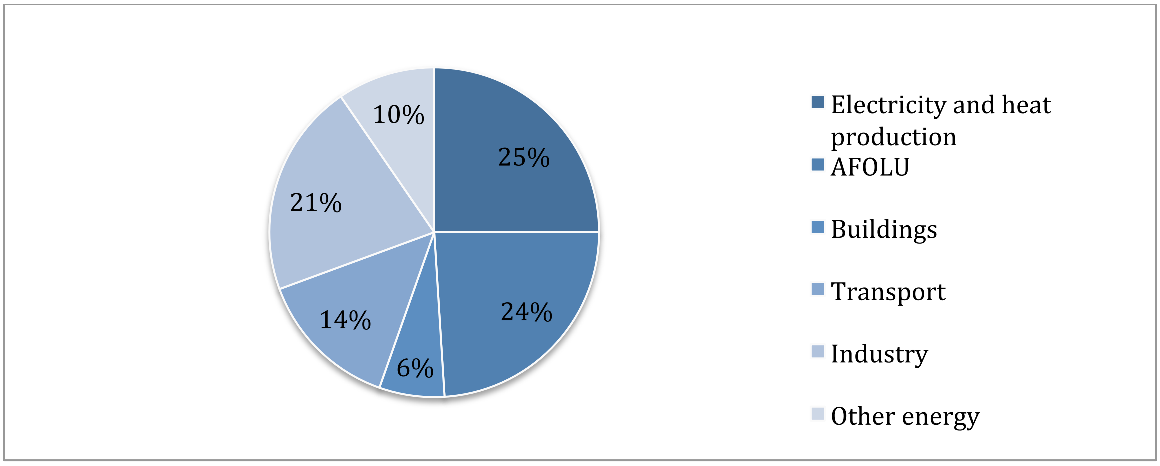
The first consensus, which is supported by 97% of the scientists, is that human activities are causing global warming (Cook et al., 2016). Another clear result is that "anthropogenic greenhouse gases emissions are extremely likely to have been the dominant cause of the observed warming since the mid twentieth century" (IPCC, 2014, p. 5). In fact, "more than half of the observed increase in global average temperature from 1951 to 2010 was caused by increase in GHG emissions" (Ibid, p. 48). We will see below which gases create the greenhouse gas effect. To simply explain the issue, the greenhouse effect is a natural process that warms the Earth's surface. GHG "trap" in our atmosphere some of the radiation going back from Earth to space. Thus, they increase the Earth's temperature. Without it, the Earth would be too cold for life to be possible. The problem arises when human activities lead to too high levels of greenhouse gases. Those gases then trap too much of the sun's energy into our atmosphere, which leads to what we call "global warming".

Four types of gases are so-called "Greenhouse gases", which lead to the greenhouse gas effect (Ibid, p. 46). The most important gas (and the one we mostly focus on in this thesis) is carbon dioxide (CO_2). It represents 76 % of total GHG emissions, and has the particularity of staying in the atmosphere for a very long period (80 % of CO_2 emissions remain in the atmosphere for 200 about years, the remaining 20 % remains up to 30'000 years). Carbon dioxide is released by both fossil fuel combustion (coal, oil and gasoline) and deforestation (respectively 65 and 11 % of total GHG). Methane (CH_4) is responsible for about 16 % of GHG emissions. It is released through agricultural production (mainly livestock) and fossil fuel extraction. It remains only 12 years in the atmosphere. Nitrous oxide (N_2O) contributes to around 6 % of GHG emissions. Like CO_2, it remains in the atmosphere for a long period of time (114 years). It is used mainly in agriculture (fertilization of soils) and industrial processes. Lastly, fluorinated gases[5] ("F-gases") represent the remaining 2 % of GHG. They are found in chemical production used mostly in refrigeration systems. Some of those F-gases remain in the atmosphere for tens of thousand of years, which explain why they are strictly regulated.

Despite growing mitigation policies, total GHG emissions have increased more than ever between 2000 and 2010 (IPCC, 2014, p. 46). The increase was fostered by the energy (47 %), industry (30 %), transport (11 %) and building (3 %) sectors. Figure 1[6] shows a static distribution of GHG emissions in 2010. This is a trend that has continued from 2010 to 2018. In fact, the amount of carbon emissions reached an all-time high in 2018, increasing of 2.7 % compared to 2017.

[5] The most common type of F-gases are hydrofluorocarbons (HFC).
[6] AFOLU stands for Agriculture, Forestry and Other Land Use.

Figure 1: Total GHG emissions in 2010



Source: Author's own representation, based on data from IPCC (2014), p. 46

Among the top GHG emitters (World resources institute), China is now at the highest level (27 % of the world's emissions). With the United States (15 %), the European Union (10 %), India (7 %) and Russia (5 %), they already amount to 65 % of the world's GHG emissions. While some developed countries or regions are clearly attempting to reverse this trend, other developing countries are increasing their GHG emission. For instance, the European Union has decreased its emissions by 0.7 % in 2018, while India has increased by 6.3 %. Absolute levels of CO_2 emissions are relevant because "the absolute amount of GHGs emitted is what ultimately affects atmospheric concentrations of GHGs" (World resources institute). Therefore, those largest absolute emitters play a very large role in the global warming effect. Nevertheless, analyzing CO_2 emissions per capita can also be instructive, mainly because it allows taking away the demographic impact. The largest per capita emitters are by far countries involved in oil refinement (Qatar, Kuwait, Bahrein,…). The United States are ranked 11th, with each of its citizen emitting an average of 16.5 metric tons. This is much higher than the average of OECD countries (9.5) and the European Union (6.4). Switzerland emits 4.5 metric tons per person. The lowest per capita emitters are typically low-income sub-Saharan African countries. For instance, Uganda emits 0.1 metric tons of CO_2 per capita. This is line with the idea of the existence of an environmental Kuznets curve. According to this idea, the relationship between income and pollution emissions has the form of an inverted U. Growth at early stages of development rapidly lead to an increase of emissions. Indeed, low-income countries do not have the resources needed in order to produce goods in an environmentally friendly way. In addition, early stages of development usually involve the development of agricultural production and resources extraction, which generate high levels of emissions. From a certain threshold of income, “structural change towards information-intensive industries and services, coupled with increased environmental awareness, better technology and higher environmental expenditures” lead to a decrease of emissions (Dinda S., 2004, p. 434).

To summarize this technical chapter, it is clear that GHG emissions are the main contributors to global warming. Also, consequences of global warming will have an important cost in the future. We have seen that the distribution of those costs will be uneven across regions. In order to limit those negative consequences, humans will have to find solutions to decrease their GHG emissions. According to the special report of the IPCC, meeting the 1.5 degree target will require cutting GHG emissions by 45 % by 2030 (compared to 2010 levels). Also, net zero emission will have to be reached by 2050 (IPCC, 2018, pp. 105-115). Those are extremely ambitious goals, especially after having showed that GHG emissions are still increasing and have reached an all-time high in 2018. This current trend only increases the effort that will be needed by 2030 and 2050 to respect the goals of the Paris Agreement. With those elements in mind, discussing how to reduce the world’s GHG emissions seems like a pressing topic.

1.2. Environmental policies: carbon pricing and its main alternatives

In this chapter, we analyze the different options available to policymakers in order to reduce CO_2 emissions. First, we present the different criterions used to evaluate these different options (1.2.1). Secondly, climate change mitigation strategies have largely evolved in the past fifty years. We will describe this evolution (1.2.2), as it allows us to give a definition of carbon pricing and its alternatives. We also show why it is commonly agreed among economists that carbon pricing is the most efficient tool to reduce carbon emissions. To do so, we use the criterions which will have been presented previously. Lastly, since this thesis questions the reasons why "ambitious" carbon pricing schemes are so rarely implemented, we need to go one step further and define what ambitious carbon pricing means (1.2.3).

1.2.1. Evaluation of environmental policies

Before to describe the different environmental policies that have existed, we need to understand which criterion are used to evaluate them.

1.2.1.1 Cost Effectiveness

Cost effectiveness is the criterion dominating the discussion on environmental policies: Does the instrument reduce pollution at the smallest possible cost? If the answer is yes, then the opportunity cost of this instrument is minimized. It is a necessary condition for an optimal allocation of resources. In order for the policies to be cost-effective, it has been mathematically proven[7] that "the marginal cost of abatement (MAC) has to be equalized over all polluters (least cost theorem of pollution control)" (Perman et al., 2003, p. 203).

The intuition behind this result is straightforward. Let's assume a given abatement level at which two firms have a different marginal cost of abatement. This is often the case in reality. For instance, one firm might have an activity that absolutely requires more fuel-based energies (which lead to a lot of emissions). For such a firm, cutting their emissions will be extremely difficult (and thus costly), resulting in a higher MAC than the other firm. We name those two firms A and B, with respective MAC of 60 and 100. This simply means that at this given level of pollutions, it has cost 60 $ to A to reduce their pollution level by one more unit, and 100 $ to B. Thus, we see that the MAC are not equalized among the two polluters. Would it be possible to reduce the costs of depollution, of course without increasing the actual level of pollution? It is very clear that the answer is yes. Indeed, if A reduces his pollution by one unit, it will cost him 60 $. To remain at the same level of pollution, B can now re-increase his

[7] Detailed proof can be found in Perman et al. (2003), pp. 242-246

pollution by one unit. By doing so, B reduces his cost of 100 \$. In total, the overall cost has been reduced of 40 \$ (100 – 60), while staying at the same level of pollution. Further cost saving can be achieved by transferring more abatement effort from B to A, as long as A's MAC is lower than the MAC of B. At the moment when the MAC of the two polluters are equalized, the society has reached a cost-efficient reduction of pollution.

Let's prove it with a simple example. We have an initial situation where firm A emits 40 units of pollution and firm B emits 50 units. The total emissions are then 90, and is noted M^t. The government wants to reduce pollution by 40 units, and reach the level M^* of 50 units. M^t_i is the emission level of firm i (A or B), when no regulation is in place. M^*_i is the emission level of firm i (A or B), when regulation is in place.
The abatement level of each firm is then $Z_i = M^t_i - M^*_i$. Each firm has different abatement cost : $C_A = 100 + 1.5 Z_A^2$, from which $MC_A = 3 Z_A$

$C_B = 100 + 2.5 Z_B^2$, from which $MC_B = 5 Z_B$

To find the least cost solution, we need to satisfy $Z_A + Z_B = 40$ (1), and $MC_A = MC_B$ (2). Equation (1) simply verifies that the overall pollution reduction is 40. Equation (2) ensures that the MAC are equalized among the two polluters. It is then easily obtained that $Z_B = 15$, and $Z_A = 25$. Total abatement cost is 1700 (662.5 for B, and 1037.5 for A).

Any other distribution of abatement effort automatically results in higher abatement costs. (Perman et al, 2003, p. 205). For instance, abatement equally shared among the two firms (20 for each firm) would lead to a total cost of 1800. Similarly, if the abatement were done only by the firms with the lowest marginal abatement cost (A), the total cost would be 2500.

This simple numerical example shows well that for cost-efficiency to be achieved, the marginal cost of abatement has to be equalized for all polluters. Also, we see that cost effective abatement does not lead to equal abatement by all polluters: a higher effort is requested from polluters with lower marginal abatement cost. This criterion will be useful later, as it is the main reason why economists favor economic instruments.

1.2.1.2 Other criterions

Even though cost effectiveness is by far the most present evaluation criterion in the literature, there are other ones that can be useful. Economic criterions (like the cost-effectiveness) have the advantage of giving clear answers, but can become problematic when benefits and costs are not easily transferred in monetary terms. Here we mention five criterions found in multiple textbooks, which seemed relevant to the analysis of environmental policies.

Dynamic efficiency

The first one is dynamic efficiency. Dynamic effects are defined as the long-term effects of a policy on Research and Development, innovation, and implementation of new technologies. As the role of environmental policies is to change behavior and incentives towards reduction of pollution, the impact of the different instruments on innovation appears important. If an instrument leads to an increase of environmental friendly innovation, it can be said to be dynamically efficient. Such an instrument would allow a reduction of pollution in the production process, increasing even more the benefits of this policy.

Equity

The second criterion, and one that will be particularly important in this thesis, is equity: Are the costs and benefits of the policy equally distributed? (Mickwitz, 2003, p. 427). Mainly, we are interested in "end-results equity". The important question is to know who truly supports the burden of the carbon tax. If carbon pricing "burdens lower-income households as a share of their income relatively more than it burdens higher-income households, then the policy is regressive" (Morris and Matur, 2015, p. 99). This question of the distribution of costs will be the topic of the second part of this thesis, as it is the first limit towards acceptability of carbon pricing that we have identified. As stated in Perman et al. (2003, p. 237), "the distributional consequences of a pollution control policy instrument will be very important in determining which instruments are selected in practice". The reader will find only limited discussion on equity in this first part of the thesis, since we will cover this subject extensively in our second part.

Flexibility

Flexibility is also put forward as an important characteristic of a policy instrument. This is due to the growing complexity of environmental problems. Flexibility is defined as the capability for an instrument "to be adapted quickly and cheaply as new information arises, as conditions change, or as targets are altered" (Perman et al., 2003, p. 203). We have seen in chapter 1.1 that pollution happens through different sources, at various locations and in different sectors. This current trend of constant evolution of pollution sources makes flexibility a particularly important evaluation criterion. This implies that this flexibility allows the policy to be effective in a changing environment, without a too high cost of adjustment.

Dependability

Dependability is the fourth criterion. Perman et al. (2003) define it by asking the question "To what extent can the instrument be relied upon to achieve the target" (p. 251). Basically, let's imagine that a country wants to reduce it pollution by X tons of CO_2 emissions. If one policy allows the country to reach this goal with certainty (no matter how much information the country has on the costs of abatement and other relevant elements), then this policy instrument is dependable. As the main goal of environmental policies is to decrease GHG emissions, this criterion appeared to us as an extremely important one. This is particularly true given the current urgency to reduce GHG emissions. Surprisingly, it is one that is much less debated than cost-efficiency. Nevertheless, we will use it in our analysis, particularly when differencing the effects of emission taxes and transferable permits.

Double dividend

The last criterion that might be important, and to which we will also refer during this thesis, is the one of the double dividend. The double dividend refers to the idea of having two positive effects from an instrument that redistributes revenues (like an tax on GHG emissions) (Perman et al., 2003, pp. 175-176). The first one is the environmental benefit: emissions are reduced because their costs increase. The second benefit happens when the revenues of the environmental taxes are used to reduce existing distortionary taxes (for instance a tax on labor or capital). This increases efficiency, as distortionary effects of taxation are reduced. A so-called "weak dividend" refers to the fact that this redistribution reduces the existing distortionary effect (compared to a situation with no redistribution of the revenues). Its existence is commonly agreed in the literature. In a "strong" double dividend, the net benefits of environmental taxation are zero (or positive), so that this instrument becomes an absolute "no regret" mechanism (Ibid). The empirical existence of this strong double dividend is strongly debated in the economic literature.

1.2.2. Evolution and comparisons of environmental policies

Now that we are aware of how environmental policies can and should be evaluated, we present the three main types of environmental policies available to policymakers. We discuss them in a chronological order (from the oldest to the more recent one). This allows us to see the progression in the implementation of environmental protection. For each of the three categories, we use the evaluations criterions seen previously in order to discuss each policy's advantages and disadvantages. Of course, we describe more in details carbon pricing policies, as they are at the center of our thesis.

1.2.2.1 Command and Control Regulations

Environmental policies began in the 1970s under the form of Command and Control (CAC) regulations. In the United States, this approach became particularly present and remained popular until the end of the eighties. The Clean Water Act (1972) and the Clean Air Act (1963) are two examples of this, and are still used today. CAC refer to the use of direct controls over polluters, and has been the "dominant method of reducing pollution in most countries" (Perman et al., p. 209). Many types of CAC regulations exist. First, the government can set up non-transferable emissions licenses. Initial quotas of pollution are allowed to firms, but those do not have the right to exchange (buy or sell) those quotas. Imposing specific technology requirements is a second possibility. One well-known example was the obligation since 1975 in the USA for cars to install catalytic converters.

Very intuitively, those types of regulations do not respect the cost-effectiveness criterion (Perman, 2003, p. 213). Indeed, they require the same efforts from each polluter, no matter their abatement cost. This cannot lead to the equalization of marginal abatement cost among all firms. In the end of the 80s, CAC regulations outcomes led to growing disappointment. The large variety of pollutions made it very costly for government agencies to regulate pollutions effectively. This high administrative cost was one of the largest disadvantages of CAC. Also, CAC can limit innovation (which could lead to less polluting technologies), as firms often had the obligation of using a particular technology. It is also very clear than no double dividend is possible with CAC regulations. Why? Simply because the double dividend happens through an efficient use of the revenues of environmental policies. On the contrary to economic instruments (see below), CAC regulations do not generate any revenues. Indeed, neither quotas nor specific technology requirements imply a transfer of resources from the polluters to the government. To summarize, CAC regulations are clearly not efficient in terms of costs, dynamic efficiency and flexibility. Also, they are unable to generate any double dividend, since they do not transfer any revenues to the government. Those disadvantages likely led to the growing interests for economic instruments between 1970 and 1995.

1.2.2.2 Economic instruments

A. Definition of carbon pricing

The main idea of economic instruments is to "create incentives for individuals or firms to voluntarily change their behavior"(Perman et al., 2003, p. 217). This is done by altering the structure of payoffs. The idea of changing incentives comes from the existence of negative externalities in polluting activities. Negative externalities occur when the activities of an agent lead to a loss of welfare for another agent, and this loss is uncompensated (Maradan). As a consequence, the quantity produced (in our case, the quantity of pollution) is too high (compared to a situation where this externality would be compensated for), because the producer does not bear the full cost of its production (pollution). Pollution is thus a typical example of market failure.

There are two different types of economic instruments[8]: an emission tax (or carbon tax) and a marketable emission permits scheme (or cap-and-trade). Those two policies are commonly called carbon pricing. Even though we will see that there are differences between them, the basic idea of those two policies remains the same: putting a price on carbon emissions, so that polluters internalize the externality created by their emissions. Indeed, without a price on carbon emission, a firm benefits from its emissions (since it allows them to produce goods and then make profits), while the costs are supported by the entire world. This results to a level of emissions that is higher than the social optimum, and thus requires putting a price on those emissions. A carbon tax and a cap-and-trade both fill this role, although they do it in slightly different ways. In a carbon tax, the price is set directly by the emission tax. In a cap-and-trade, the price is not fixed directly by the government. Rather, the government decides of a quantity of permits distributed. It is then the interaction between this supply and the demand of permit emissions that sets the price of the permits. In this thesis, we will often use the term *carbon price* in a general way, meaning that it can apply to both carbon tax or cap-and-trade systems. In both cases, it describes the price which a polluer needs to pay in order to keep polluting. We now discuss both of those policies (carbon tax and cap-and-trade) more in details.

Emissions taxes

It is easier to explain the principle of the emission tax through a graphic. In figure 2, M represents the level of pollution. The marginal benefit and damages of pollution are aggregate and economy-wide ones (not for a particular firm). Note that the marginal benefit of pollution is exactly the same as the Marginal Abatement Cost (MAC)[9]. Without a cost on pollution, firms will pollute until marginal benefit of pollution reaches zero ($\hat{M}$). In this case, the actual level of pollution would be much higher than the optimal level of pollution (M*). By adding a

[8] Subsidies are also a third option. Since it has almost the exact consequences than taxes and is rarely used in practice, we will not discuss them.

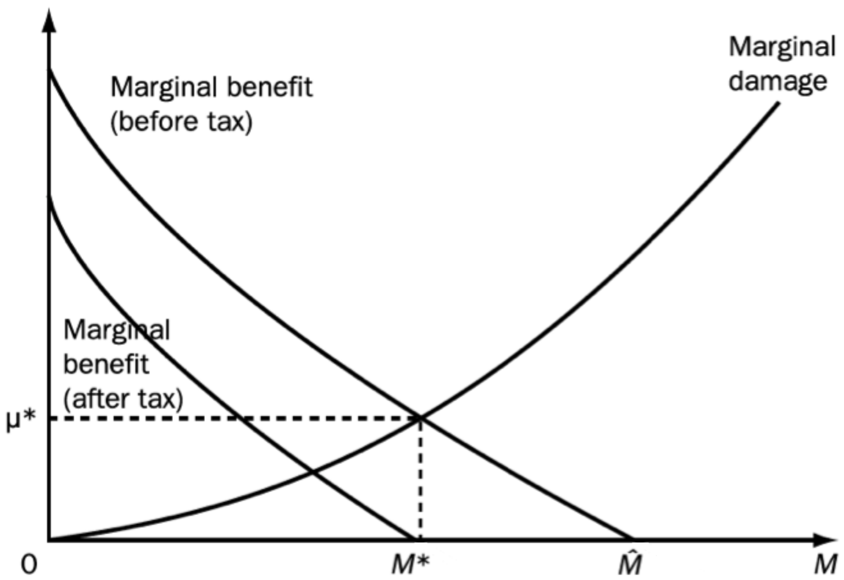
[9] The MAC is more often used in the literature. But in fine, the benefit of polluting is exactly the same as what firms forgo when the reduce pollution.

tax of μ* on each unit of pollution, firms will pollute until the marginal benefit (before tax) equals the tax rate. Above this level, the marginal benefit of polluting (after tax) is zero.

The tax modifies the incentives of the polluter. By internalizing the externality, the tax "induces the pollution generator to behave as if pollution costs entered its private cost function" (Perman, 2003, p. 218). When the tax is appropriately designed, the efficient pollution level (M^*) is reached.

It is important to see that environmental improvement is done in a cost-effective manner. Indeed, all firms will choose a pollution level that equates their MAC and the tax rate. Since the tax rate is the same for everyone, it also means that the MAC is equalized among polluters. This automatically satisfies the cost-efficiency criterion seen in chapter 1.2.

Figure 2: Effects of an emission tax on pollution level



Source: Perman et al. (2003), p. 217

Marketable emission permits

Taxes are referred to as "price-based instrument". On the contrary, marketable permits are "quantity based" instrument. The idea is to fix a limit on the total emissions that can be emitted. This total quantity is then divided in permits of emissions and distributed to firms. The key difference with non-transferable licenses seen in CAC regulations is that permits can now be exchanged between firms. This creates a market where the price of the permit is determined by demand and supply of emission permits. Firms not holding enough permits will buy them on the market, as long as the price is lower than their MAC. Thus, firms with high MAC will tend to be more active buyers on the market. On the contrary, firms holding too many permits will sell as long as the market price is higher than their MAC. The price that emerges from the market will play the same role as the tax rate in an emission tax. This guarantees that cost-efficiency is also respected in a cap-and-trade system (Perman, 2003, p. 224).

The implementation of a cap-and-trade can differ from one case to an other, as there are a few characteristics that must be chosen. The most debated one is the initial allocation of the emission permits. Permits can be allocated through a bidding auction[10], or be freely allocated ("grandfathering") based on past outputs of emissions. This choice does not impact the future price of the permits. Indeed, the price is fixed by the amount of permits distributed (and its interaction with the demand for permits). Whether those permits are sold or freely distributed at the beginning should intuitively have no incidence on the future market price of the permits. Nevertheless this difference (biding auction or grandfathering) highly impacts the distribution of costs of a cap-and-trade. If grandfathering is in place, money is only transferred between the polluters themselves (through the exchange of permits). As we will see it a bit later, prices in carbon pricing mechanisms tend to be relatively low. Thus, grandfathering would impose only a very small cost on the polluters. On the opposite, if the permits are auctioned, firms have to transfer revenues to the government, which implies an actual transfer of resources from the polluters to the citizens. This allows revenue recycling, and thus reduction of existing distortionary taxes. It has been estimated that "the cost of reducing emissions by 10 percent would be more than three times higher under grandfathered allowances than under a tax, or equally an auctioned permit" (Cramton and Kerr, 2002, p. 339). Auctioning should also increase the dynamic efficiency of cap-and –trade scheme (Ibid, p. 340). Unfortunately, strong lobbying groups have often been successful at keeping grandfathering in place. The EU ETS scheme (the largest cap-and-trade system in the world) is a good example of that, as most of its permits were allocated for free at its beginning. Now, 43 % of its permits are still allocated for free. This percentage is scheduled to progressively go down, reaching 30 % in 2020 (European Union commission).

Another important design choice for transferable permits is the allowance or not of "banking". Allowance banking is defined as the right for a polluter to keep unused allowances and use them in a later period. For example, if a firm does not emit as much emissions as it was allowed in a particular year, the unused allowances can be used in the next years. Some

[10] For more details, Cramton and Kerr (2002) explain in details the most efficient bidding mechanisms (pp. 336-338)

intermediate level of banking is typically predicted to improve efficiency (Haites, 2006, p. 13), mainly because banking improves price stability. Indeed, if the actual level of emissions is lower than the cap fixed, prices of allowance should fall to zero at the end of each allowance period. It is not the case anymore if allowances can be banked. Stability of prices is also important for dynamic efficiency, as it allows firms to have a better view of the future. This facilitates decisions to invest in new technologies (Ibid, p. 19). Nevertheless, if the allowance bank is too high, "it reduces economic efficiency and defers realization of the environmental goal of the trading scheme" (Ibid, p. 24). We might think that banking allowances has no impact on the total emissions levels. Whether emissions are done in the first year or the next few ones should keep emissions levels constant. This is true for a trading scheme with a cap remaining constant. But in reality, the goal of any trading scheme is to eventually lower his cap, so that emissions are gradually reduced. If firms have accumulated large amounts of allowances in the past, the reduction of emissions will be differed until all those banked allowances have been used. This could be an important limit to the dependability of trading schemes with large bank allowances.

B. Emission taxes or marketable emission permits? The role of uncertainty

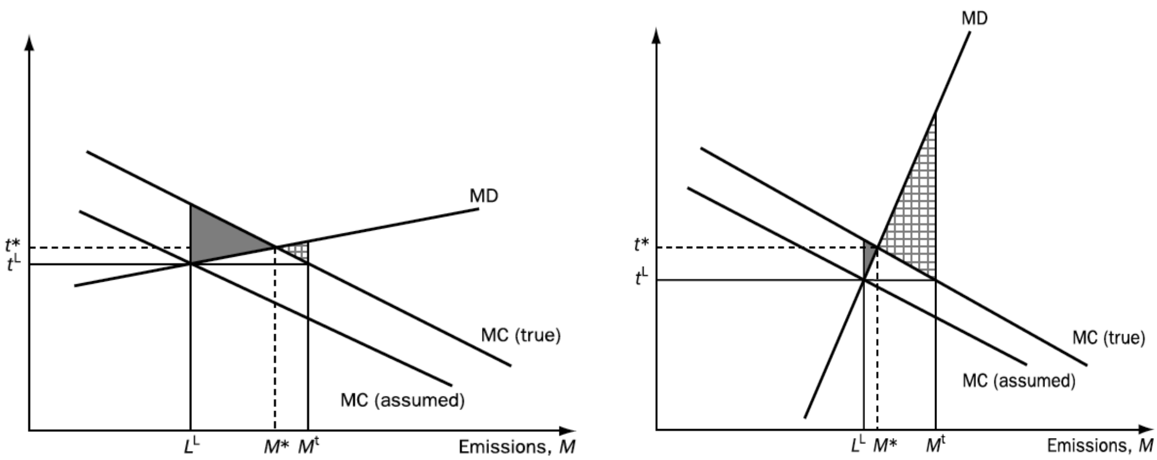
Even though we will often discuss carbon pricing as if emission taxes and marketable permits were similar, their effects can actually differ. Under perfect certainty[11], those two instruments will lead to the same result. This is easily understood by looking back at figure 2. With perfect certainty, we assume that the government knows the MAC and MDC of the firms. In this case, the government has two options in order to reach its pollution goal (let's assume he wants to reach the optimal level M*). First, he could set up a carbon tax, with a tax rate of μ*. Secondly, he could allocate a number of permits with would add up to M*. It is clear that both solutions would lead to the same result. The difference appears once the assumption of perfect certainty is removed. This implies that the government no longer exactly knows the MAC and MDC of polluters, and has to estimate it. This creates a possibility that the government wrongly estimates the MAC or the MDC.

First, in the case of a wrong estimation of the MDC, both instruments will lead to the same result. The choice of the instrument has no consequences when the MDC is not certain (Perman et al., 2003, p. 256).

[11] We define perfect certainty as the case where the government knows the MAC and MDC of all polluters.

On the contrary, the effects of a wrong estimation of the MAC will vary according to the choice of the instruments and the relative slopes of the MAC and MDC. First, imagine a situation where the slope of the MAC is steeper than the MDC. This means that a reduction of pollution would generate higher abatement costs than environmental benefits. In this case[12], the use of a price-based instrument will generate less welfare loss than quantity-based instrument. Why? Simply because transferable permits would force the polluters to reduce pollution, no matter the cost. The slope of the MAC tells us that this cost will be high. On the contrary, an emission tax will still allow the polluters to produce emissions, but will require them to pay the tax. This situation is depicted on the left graphic of figure 3 below. The dark area represents the loss when permits are used, while the squared area is the loss generated by the use of a tax.

Figure 3: Permits versus emission tax with wrong estimation of MAC



Source: Perman et al. (2003), p. 254

The graphic on the right of figure 3 represents the opposite situation, in which the slope of the MDC is steeper than the MAC. In this case, an increase of pollution will generate an important cost to the society. For this situation, transferable permits are more efficient, because they do not allow pollution level to go above the desired threshold, preventing those high damages from happening.

To make the link with the evaluation criterions seen in the previous chapter, it is clear that emission permits offer more dependability than carbon taxes. If the government sets a level of emissions and distributes it between polluters, this emission level will not be crossed. On the contrary, it is harder to predict the exact environmental effects of a carbon tax: polluters still

[12] Keep in mind that we here face a wrong estimation of the MAC.

have the possibility to pay the tax in order to keep polluting. This dependability can thus be a disadvantage in the case where MAC would be underestimated by the government. In this case, a cap-and-trade would generate an important welfare loss.

If we look back at the environmental evidence presented in chapter 1.1, it was clear that the damages of global warming would increase rapidly and non-linearly in the future. This required clear reduction of GHG emissions as soon as 2030. Because of this evidence, transferable permits might be a better option in order to quickly reduce GHG emissions. This advantage held by permits in terms of dependability is a strong argument in favor of their application.

Nevertheless, Nordhaus (2007) makes the opposite argument. According to him, price-based instrument are a better solution. Why? Because costs of abatement depend on the flow of emissions, while benefits depend on the stock of GHG. Simply said, since benefits of abatement depend on the level of GHG emitted up to now, "the marginal benefits of emissions reductions are close to independent of the current level of emissions reductions" (Nordhaus, 2007, p. 37). On the contrary, the marginal costs of abatement are highly sensitive to current reduction of emissions. Those elements tend to imply that we are currently in the situation on the left side of figure 3: the slope of the MAC is steeper than the MDC. Therefore, carbon taxes seem to minimize the welfare loss.

A potential issue for quantity-based instrument is that MAC is not the same across countries. We have seen that when the slope of MAC is steep, the costs of using permits also increase. Developing countries, which highly rely on fossil fuels in order to catch up developed economies, might find difficult (and costly) to reduce emissions. For those countries, quantity-based instrument would generate an important cost. This opens the question of redistribution between countries.

C. Characteristics of an ambitious carbon-pricing scheme

At the center of this thesis lies the problem that not enough ambitious carbon pricing policies are being implemented[13]. One of the key word used in this statement is the adjective *ambitious*, as it introduces an important issue: the way a carbon policy is designed can strongly impact its results. We just saw why economists favor economic instruments as a tool to reduce CO_2 emissions. Nevertheless, this assumes that the carbon tax (or cap-and-trade) is

[13] This will be presented in chapter 1.3.

actually designed in an ambitious way. If for some reasons[14], policy makers do design carbon pricing schemes in the opposite manner (with low ambitious), it is evident that they will not lead to large emissions reduction anymore. One very intuitive example is the choice of the price of the carbon tax. Indeed, if the carbon tax rate is set at a very low level, the carbon tax will not induce a change of behavior for the firms. It is thus extremely important to be able to differentiate ambitious and non-ambitious carbon pricing schemes. In this subsection, we discuss four important characteristics of carbon policies that strongly determine their level of ambition.

The price of the emissions

An ideal way to measure ambition would be the actual reduction of GHG it creates, compared to a "business-as-usual" (BAU) scenario (Pechar et al. 2018, p. 6). Nevertheless, this requires an accurate modeling of BAU scenario, which can be problematic.

Therefore, the carbon price can be used as a proxy for the ambition of the carbon scheme (Ibid, p. 7). Since the price is supposed to have a direct influence on GHG emissions level, it testifies from the ambition of the scheme. The price also acts as a signal for firms to invest in low-emission technologies. Which price should then be set in order to achieve bold objectives? The high-level Commission on Carbon Pricing, led by Joseph Stiglitz and Nicholas Stern, tried to identify carbon price corridors[15] leading to the respect of the Paris agreement. After a vast review of literature, they conclude that carbon price should be at least between 40-80 $ per ton of CO_2 by 2020, and between 50-100 $ by 2030 (Stiglitz and Stern, 2017, p. 50).

For a carbon tax, it is easy for a government toset the desired carbon price. Indeed, it can directly modify this price by increasing the tax rate. For a cap-and-trade system, we saw that the price is determined by the interaction between supply and demand of emission allowances. It is then not a surprise that for a carbon market, the level of the emission cap is "central to the stringency and initial ambition of the instrument" (OECD discussion paper, 2017, p. 6). Therefore, policymakers should choose to emit a quantity of allowances that will lead to the price corridors suggested by Stiglitz and Stern.

It is important to note that the initial price is not the only important level to be considered. The price trajectory also matters. Indeed, gradually increasing the price of the tax is a sign of ambitious. In addition, a progressive carbon tax rate could have a positive effect on

[14] In this thesis, we will focus on the effect of acceptability (see part 2 and 3).

[15] The term "Price corridor" is used in the economic literature to describe a price range.

acceptability: "designing a price or cap trajectory that starts relatively low and increases over time has the added benefit of increasing initial political palatability" (Pechar et al., 2017, p. 7). The Canadian federal carbon tax is a perfect example of this type of progression. It will progressively go from 10 $ in 2018 to 50 $ in 2019, increasing of 10 $ each year. For a cap-and-trade scheme, this means that the quantity of emissions should be gradually reduced, leading to an increase of the price.

The coverage of the policy

The price is not the only determinant of an instrument's ambition. The coverage of the carbon price[16] is also a key design feature. "Broad coverage makes a system more efficient at providing least cost emissions reductions, as well as helping to provide a more stable price" (OECD discussion paper, 2017, p. 6). An instrument that would leave aside major economic sectors (for example because of potential negative competitiveness issues) cannot be said to be ambitious. Carbon taxes tend to cover more sectors than cap-and-trade programs. Nevertheless, emission taxes often do not cover the electricity or industrial sector, which are two of the highest polluters. In fine, if looking at the share of emissions covered, it seems that cap-and-trade cover a larger share of the economy than emission taxes (but at a lower carbon price) (Pechar et al., 2017, p. 12).

The stability of the price of emissions (only for emission trading scheme)

We mentioned previously that price stability was important for the dynamic efficiency of a carbon market. Indeed, firms need a stable and sure prediction of future carbon prices. Thus, introducing a mechanism that fixes a price floor (and possibly a price ceiling) also contributes to its ambition.

Modifying the cap based on economic circumstances is also an option in order to keep the price stable. For instance, during an economic crisis, economic output usually goes down. If no mechanism reduces the number of emission allowances, the supply of allowances will exceed the demand. Allowance prices would automatically drop, which lowers the efficiency of the carbon market scheme. The EU ETS is a perfect example of this issue. The economic crisis of 2008 reduced economic output, and thus the demand for pollution allowances. (Figure 4 a). This unbalance of the market created a surplus of allowances. Those extra allowances directly led to a decrease of permits prices in the next few years (Figure 4 b).

[16] This discussion on coverage is also for valid for cap-and-trade policies.

Therefore, ambition of a carbon pricing scheme can be enhanced by adapting the quantity of allowances to the economic circumstances.

Figure 4 (a): Fundamental demand and supply side balance in the EU ETS

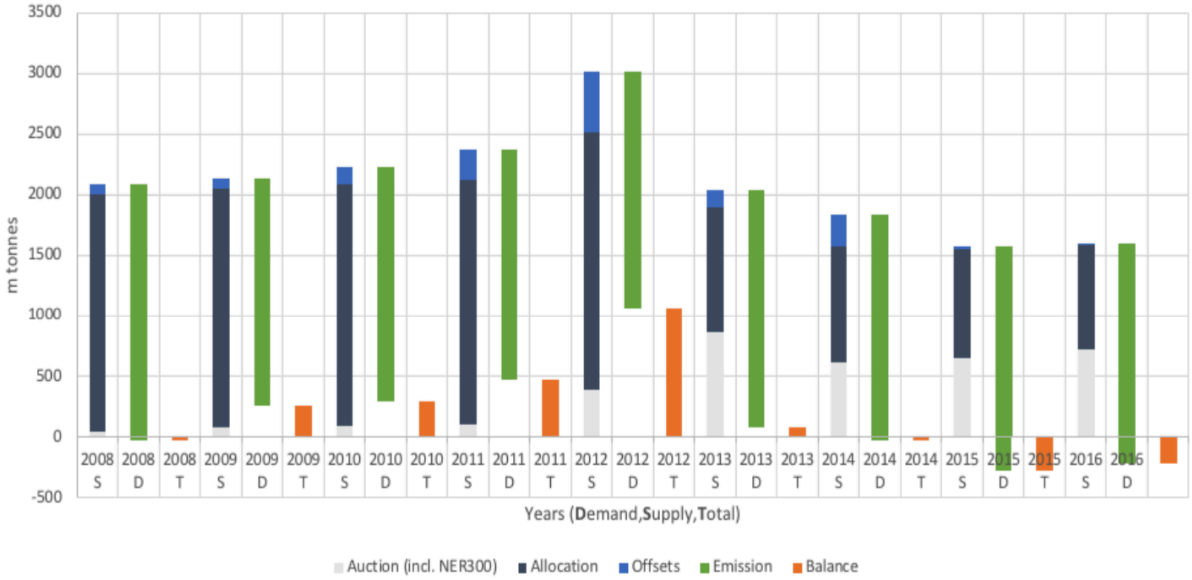
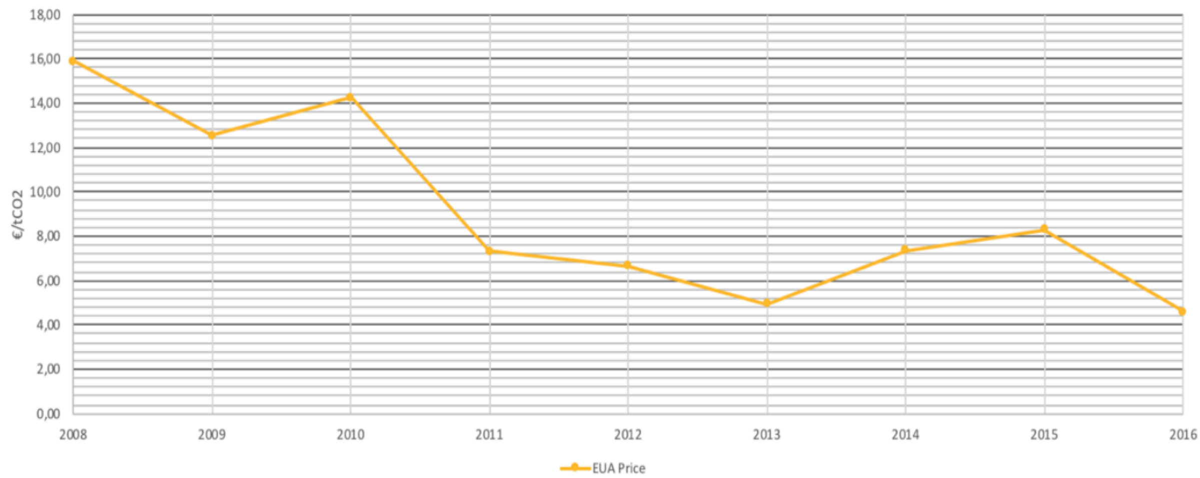


Figure 4 (b): Evolution of EU ETS allowance prices



Source: The Oxford Institute for Energy Studies, 2018, p. 7

Initial allocation of permits (only for emission trading scheme)

Lastly, the initial allocation of permits also impacts the ambition of the system. We saw earlier that grandfathering (free allocation of permits) reduced the cost for polluters. On the contrary, an auction maximizes the cost and dynamic efficiencies of a quantity based instrument[17]. As a consequence, auction is a sign of true environmental ambition.

1.2.2.3 Voluntary Environmental Programs

Even though CAC regulations and economic instruments have been by far the two most often used policy tools to reduce pollutions, voluntary environmental programs (VEP) are also an option. Since the 90's, VEPs have emerged as an important tool in environmental policy. In the United States, there is currently more than 200 VEPs at national and regional levels (Darnall and Sides, 2008, p. 97). VEPs are "programs that encourage organizations to voluntarily reduce the environment impact beyond legal requirements" (Ibid, p. 96). The important point is that it simply encourages voluntary action, and doesn't force firms to take actions. The idea is to create "incentives for businesses to produce environmental public goods" (Potoski and Prakash, 2012, p. 124). But what's to gain for firms? In theory, participating in a VEP should "create a credible, low-cost way for firms to signal their environmental stewardship" (Ibid, p. 124). We assume that the firms' stakeholders (mainly consumers) will agree on paying more for a product, when they know that it has been produced in a way that respects the environment. Some governments also offer tax incentives for participation in successful VEPs. Thus, participation of businesses is not driven by pure ethical reasons, but mostly by the possibility of improving its image and margin of profits.

What are the main theoretical advantages of VEPs? First, they are supposed to be less costly and easier to enforce than command and controls regulations (Ibid, p. 125). Particularly, the "heterogeneity of pollutants' sources and types" and the growing complexity of production processes make it harder to set up mandatory regulations. Secondly, VEPs allow for a greater flexibility in how each firm reaches its pollution reduction goals. This allows them to invest in new techniques, which might be more efficient than the ones imposed by command and controls policies. Those innovations can then be spread across the industry (spill-over effects). The last argument we will mention is maybe the most important one. Voluntary approach reduces the "environmental information asymmetries" in the market (Carmin and Darnall, 2005, pp. 74-76). On regular market for goods, the quality of a product is signaled by its price. A higher price is usually the sign of a higher-quality product. But if the consumer wants to know the environmental cost of a product (and the environmental commitment of its

[17] See our discussion on this topic in chapter 1.2.2.2.

producer), there is a lack of information about it. VEPs membership can thus signal to the consumers, investors (and all other stakeholders) that a firm is making efforts in some environmental aspect. But all VEPs are not equals in terms of characteristics. It is important that the stakeholders are able to differentiate between different VEPs, so that they know which ones are more credible than others. If this differentiation is not feasible, it might "threaten the long term credibility of VEPs as a tool for environmental protection and as market mechanisms" (Ibid, p. 75).

Even though the idea of VEPs is very interesting, it faces one big issue. This issue is the existence of a trade-off between participation level and average effect per participant. By increasing the stringency of a voluntary environmental program, participation drops while the average effect per participant increases. Multiple authors mention the existence of this trade-off (Potoski and Prakash, 2011, p. 134). One possible implication of this trade-off is that two different types of VEPs could emerge, each with different role and goals. Potoski and Prakash (2006) develop a typology of voluntary programs. Based on their analysis, programs can be categorized through two aspects. The first one is the club standards, which can be either stringent or lenient. The second element is the credibility of enforcement rules (credible or not-credible). This creates 4 types of voluntary programs, two of them being clearly effective[18] (Potoski and Prakash, 2006, pp. 62-67). The first type is what they call "Mandarins" (stringent; credible). Those programs attract only a small number of environmental leaders, because of high entry requirements. But they should produce large effects per participants, because of strong monitoring. Those programs could foster innovation in pollution reduction, because it brings together highly motivated firms. One important disadvantage is that the low numbers of participants make it hard and costly to create a brand image for the VEP. This could lead to those programs evolving as "niche players", where consumers are already well informed (Ibid, p. 64). The second type of programs is called "Bootcamps" (lenient; credible). Those VEPs have the advantage of attracting more firms, because entry costs are lower. Even though the effects per participants are also lower, the fact that it is disseminated through important shares of industries makes it important. Credible enforcement rules also provide shrinking.

Those two types of programs could indeed be beneficial, but will not be sufficient in order to fight global warming. We have seen that reducing GHG in order to stay under the 2 degrees would require a drastic reduction by most of the polluters, which could definitely not be done

[18] The couples (stringent; not-credible) and (lenient; not-credible) are theoretically ineffective (and inefficient).

through voluntary programs. Nevertheless, this could be a good addition to environmental policies (but not as a substitute to economic instruments or CAC, rather as a complement).

The goal of this sub section was to present the different policy instruments available for environmental protection. For each instrument, we have presented their main advantages and disadvantages, based on the criterions identified in 1.2.1. It should now be clear why "a well-designed carbon price is an indispensable part of a strategy for reducing emissions in an effective and cost-efficient way" (Stiglitz and Stern, 2017, p. 9). Here, the word *well-designed* can relate to our discussion on the ambition of carbon pricing policies. Those allow reducing emissions at the smallest possible cost, which is a condition for an optimal allocation of resources. Even though we do not want to go too much in details in the question of efficiency of instruments, it was necessary in order to justify the choice to discuss the importance of carbon pricing in the future. Empirically, Tietenberg has been able to show that the ratio of costs of using command and control regulations versus economic instruments ranged from 2 to 20 (Perman et al., 2003, p. 235). Economic instruments should also increase dynamic efficiency. Carbon pricing also provides a "continuous and stronger economic incentive for adoption and R&D on improved abatement technologies than CAC regulations" (Baranzini et al., 2017, p. 4). Indeed, empirical evidences support a positive relationship between carbon prices and the development of more energy-efficient technologies (Ibid, p. 4). We also mentioned that economic instruments were more flexible than CAC regulations, as they could address more heterogeneous sources of pollution. In terms of dependability, no real difference is seen between economic instruments and CAC regulations. We willingly left the equity criterion out of this first part of the thesis, as it will be largely debated in the second part.

1.3. The current global failure to implement ambitious carbon pricing schemes

Our discussion on the different types of environmental policies has allowed us to see the advantages of carbon pricing. Given the current urgency to reduce GHG emissions, it seems evident that carbon pricing should be implemented worldwide. The goal of this chapter is to show that it is not the case in practice. First, we present the main international treaties in place (1.3.1). Indeed, those treaties influence the actions that countries take at the national level, and are thus relevant. Secondly, we use current data to describe the current implementation of carbon pricing policies worldwide (1.3.2). This leads us to the finding that only a few ambitious carbon pricing schemes are in place.

1.3.1. The role of international treaties

So far, we have treated GHG emissions as if it was the concern of one united entity. In reality, it is not the case. Since the geographical location of the pollution impacts is independent of the location of the emission source (Perman et al., 2003, p. 321), one country action will impact all the other countries of the world (no matter how distant they are from the emissions). "Where environmental impacts spill over national boundaries, there is typically no international organization with the power to induce or enforce a collectively efficient outcome" (Ibid, p. 298). Therefore, international treaties are the only tool available in order to increase global cooperation and the implementation of carbon pricing. In this chapter, we only present the main international treaties that have been implemented. The issue of international cooperation will be addressed more in details in the third part of this thesis.

The UNFCCC and the Kyoto Protocol

International treaties transfer responsibilities to countries in order to meet targets at the national level. The United Nations Framework Convention on Climate change (UNFCCC, 1992) was the first big step towards global cooperation, setting the non-binding objective of reducing carbon emissions. The goal is "to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (Article 2 of the Convention). It is said to be non-binding because none of the country has any obligation to achieve determined reduction of GHG emissions. Also, any country can withdraw from the treaty at any time without any cost (Article 25). All signatories meet every year at the Conferences of the Parties (COP), trying to foster cooperation and assess improvements achieved. The main advantage of the UNFCCC is that it gave a clear definition of how futures treaties (protocols or agreements) should be negotiated. It also required countries to have an inventory of their emissions, in order to have clear initial data. The Kyoto Protocol[19] was the first treaty leading to legal binding agreement. Its first goal was to reduce carbon emissions by 5.2 % from 2008 to 2012, through an international carbon market. The treaty specified clear quantitative objectives for each developed countries. On the contrary, developing countries were not bounded to any reduction commitments. For the second period (2012-2020), participants have committed to reduce their carbon emissions by 18% compared to 1990 level. Nevertheless, this never entered into force, as not enough countries agreed to ratify for the second period. Even though these goals seem promising, the Kyoto protocol faces the problem that only a fraction of the world's emissions are covered. Only developed countries had to commit to binding agreements. In the second period, Canada, the USA[20], Russia, Japan and New Zealand also all refused to ratify. Thus, the treaty covers only 14 % of the world's emissions (European Council). Barrett (2014) fiercely criticizes this treaty. The main problem was that absolutely no cost was imposed to countries who did not ratify or who withdrew from the agreement (Ibid, p. 271). A second problem was that the amount of pollution permits allocated was extremely high, which allowed polluting countries to simply buy them at a low cost from other countries. This was particularly true because of the economic transition of Russia and Central Europe (Perman et al., 2003, p. 335). Those countries developed more energy efficient technologies, which has left them with a large amount of unused permits. Those permits have then been sold to other developed countries, who had less incentives to reduce GHG emissions. Those reasons explain why "the Kyoto Protocol impact on global carbon emissions has been statistically indistinguishable from zero" (Barrett, 2014, p. 272).

Paris Agreement

The COP15 at Copenhagen ended up as a failure to reach a new binding agreement. Particularly, a strong disagreement between developed countries and developing ones completely blocked the negotiation process. Developed countries wanted developing countries to also commit to strong emission reductions. After this failure in 2009, a lot of hope was lying on the 2015 COP in Paris. The Paris Agreement acknowledged a common desire and an urgent need to "hold the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursue efforts to limit the temperature increase to

[19] Signed in 1997, entered in force in 2005.
[20] Thu USA had also not ratified for the first period.

1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change" (Article 2). Looking at the treaty more in details, it urges countries to "undertake and communicate ambitious efforts"(Article 3). We saw in the previous chapter what defined ambitious carbon pricing policies. In this particular treaty, no obligation of broad coverage, maximum level for emissions allowances, or minimum effective price on carbon emissions is found. In other words, all the elements that define an ambitious environmental policy are missing. The only requirement is for parties to successively improve their Nationally Determined Contributions (NDC) (Article 4). Those NDCs are at the center of the Paris Agreement, and represent each country's goals in terms of emissions reduction. The countries can then freely choose the instrument they want, in order to reach those NDCs. Even though the Paris agreement is "clearly a legally binding agreement, its key mitigation obligations remain voluntary" (Lawrence, 2017, p. 277). In order to illustrate this, here is the second point of article 4:

"Each Party shall prepare, communicate and maintain successive nationally determined contributions that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions."

The last phrase perfectly testifies of the issue: "Parties shall pursue domestic mitigation measure" does suggest a binding obligation to pursue mitigation policies. But, and here is the key weakness of the treaty, having the goal of meeting the objectives is sufficient. No clause stipulates that those objectives must (or at least "shall") be met (Ibid, p. 280). Another potential problem of the Paris Agreement is that each country is free to withdrawn without any sanction (article 28). In the third part of our thesis, we will discuss the consequences of those elements on incentives of countries.

Looking at the latest report of the Climate Action Network Europe (2018), none of the European countries are currently in line with their goals and pledges at the Paris Agreement. After having seen how costly the consequences of climate change could become, this is an alarming result. Central and eastern European countries are particularly late and low ambitious. More wealthy countries such as Germany, Belgium, Danemark and the UK also appear to have slowed down on their effort for climate change. Even a country like France, which has been strongly rutting for stronger collective action, has only accomplished 17% of the progress that would be needed to meet its 2020's target. Those appear as good examples of the current failure of global cooperation.

1.3.2. Worldwide implementation of ambitious carbon pricing

As a reminder, we have so far showed two important elements. First, GHG emissions will cause large damages to our societies and economies, and thus those emissions should be rapidly reduced. So far, international cooperation seems to be failing this task. Secondly, carbon pricing is an indispensable tool for environmental policies, mainly because it allows reducing emissions at the smallest possible cost. By combining those two elements, it would be rational to guess that carbon pricing is developing rapidly all over the world. Let's analyze what is truly happening. In this section, we use available worldwide data on the evolution of carbon pricing schemes. We not only look at how many carbon pricing mechanisms are in place, but most importantly at how many ambitious ones are implemented.

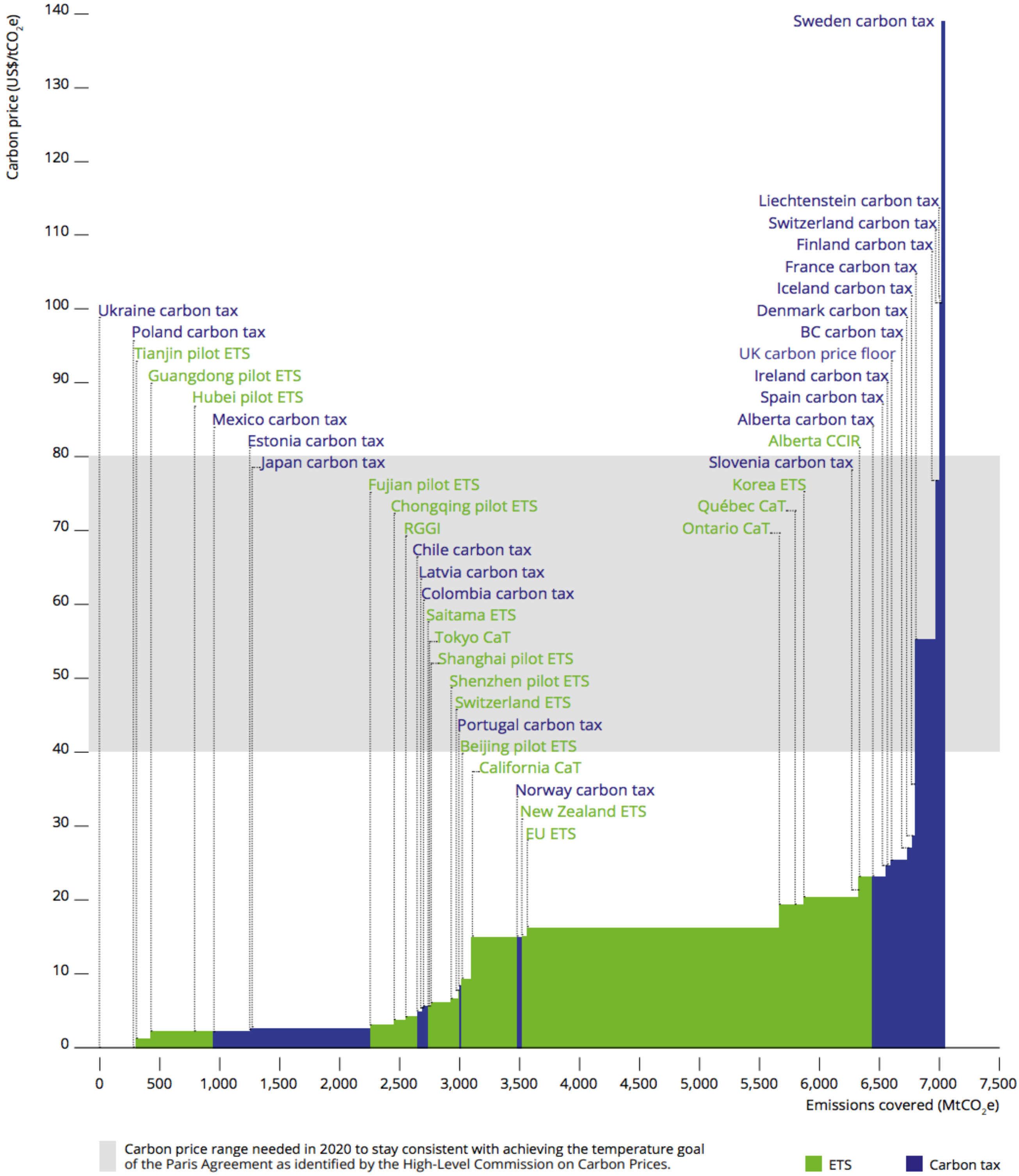
Carbon pricing is currently in place in 45 national and 25 subnational jurisdictions (World Bank, 2018, p. 17). Emissions covered are schedule to reach 20% of total world's GHG emissions. The EU ETS by itself covers 4% of the world's emissions, and is the largest carbon pricing ever implemented so far. The Chinese ETS system is supposed to be effective by 2020 (they are currently proceeding to tests where credits are being exchanged for free) and should then become the largest one. Even though 20% of the world's emissions might look small, it is close from the target of 25% (for 2020) set by the Carbon Pricing Leadership Coalition (CPLC). The trend of implementation is also interesting and useful. Until 2010, the EU ETS was actually the only significant carbon pricing scheme in the world. Since then, a constant increase has been witnessed (Ibid, p. 20). Implementation is particularly increasing since 2016: ten ETS and eight carbon taxes have been implemented or announced for the years to come (Métivier et al., 2017). Asia and the Americas have all made progress. As mentioned before, the major improvement in Asia concerns the launch of the Chines ETS. Nevertheless, other Asian countries such as Singapore or Kazakhstan are also implementing carbon pricing. In Americas, Canada has set up a federal carbon pricing in all its provinces. Mexico, Chile and Columbia have also all moved towards carbon pricing initiatives.

Now, what is the effective carbon price used in those schemes? Since the price can be used as a proxy of carbon pricing ambition, the question really is: how many ambitious carbon pricing schemes have been implemented? Figure 5 provides a very clear answer to this question. Only five countries' carbon price matches the lowest threshold of 40 $ advised by Stiglitz and Stern: Sweden, Switzerland, Liechtenstein, Finland and France. Except for France, all those countries are relatively rich and small countries, which means their added emission levels is rather small. The distribution of the prices is particularly alarming, as all other jurisdictions price carbon under 35$ per ton. Half of all GHG emissions covered by carbon pricing are priced under 10$ per ton (Ibid, p. 27).

Nevertheless, data allow mitigating this finding. Indeed, carbon prices have increased in the last few years, and are expected to follow this trend. The World Bank reports that most initiatives have increased their prices from 2017 to 2018 (World Bank, 2018, p. 17). In 2017, 75% of pricing initiatives were priced under 10 $ per ton of CO_2, compared to 50% in 2018 (Ibid, p. 27). This testifies of an increased price from low-price jurisdictions. More advanced countries have also planned on increasing their effort. For instance, the tax rate in Canada will progressively go from 10 $ in 2018 to 50 $ in 2022. Some countries (or jurisdictions) have also increased the ambition of their carbon pricing instruments, without increasing the price. For instance, the EU ETS has set new rules for its fourth phase (2021-2030). “The overall number of emission allowances will decline at an annual rate of 2.2% from 2021 onwards, compared to 1.74% currently” (ec.europa.eu). Also, the number of allowances allocated for free will slowly be reduced to zero by 2030[21]. Those are steps that satisfy the definition of ambitious carbon pricing given in the previous chapter. An other interesting point reported by the World Bank is that not only does the public sector adopt carbon pricing. Firms are increasingly internally putting a price on their carbon emissions (Ibid, p. 55). This means that firms are starting to anticipate an additional cost of polluting, and should also invest in low-emission technologies more willingly. Even though this trend of an increase in carbon prices is encouraging, it will clearly not be sufficient to reach the goals of the Paris Agreement.

[21] This only concerns sectors that are not highly at risk of international competition.

Figure 5: Carbon prices and emissions coverage of implemented carbon pricing initiatives



Source: World Bank, 2018, p. 22

1.4. Why so few ambitious carbon pricing schemes? The role of acceptability

With all those elements, we are now able to ask an important question: Despite the clear evidence that carbon pricing is needed to reduce GHG emissions, why are so few ambitious carbon prices policies implemented? This is an important question of our thesis, and one that seems particularly important given the future environmental challenges imposed by climate change. We use this subchapter to introduce the concept of acceptability, which is our answer to this question. We will see that a growing part of the literature starts to emphasize the importance of acceptability in the implementation of environmental policies. First, we define acceptability (1.4.1) and explain why it matters for the implementation of environmental policies (1.4.2). By then, it will be clear that low acceptability might explain why so few ambitious carbon pricing are in place. Lastly, we go one step further and introduce the very central question of our thesis: What creates the lack of acceptability for carbon pricing (1.4.3)? This is our research question, and parts 2 and 3 of our work are entirely dedicated to answering this question. This chapter really allows us to introduce those two parts.

1.4.1. The notion of acceptability and its relevance

Why are so few ambitious carbon pricing policies implemented? Our answer to this question is acceptability. Klenert and Hepburn (2018) state that "political acceptability is the biggest challenge to implementing ambitious carbon pricing schemes". In the same idea, Bristow et al. (2010) mention that "the implementation of potentially uncomfortable but necessary policy measures is critically dependent upon public acceptability" (p. 1824). Acceptability refers to the notion of not being opposed to a particular policy. As we see it in both previous quotes, it includes both political acceptability, as well as acceptability from the citizens (public acceptability). We will discuss acceptability as a broad term reflecting both of those elements (public and political support), as it is done in multiple papers (for example in Klenert et al., 2018). In fact, public and political support are highly linked. Indeed, it is easier for politicians to support a policy, knowing that their citizens (and thus voters) also support it. Similarly, "policy makers may be reluctant to implement climate policies if they expect public opposition" (Drews and Van den Bergh, 2016, p. 855). We therefore follow Bicket and Vanner's (2016) definition of *public* as "all individuals who stand to be affected (directly or indirectly) by the given policies in question, as well as additional interested individuals who choose to express an opinion" (Bicket and Vanner, 2016, p. 2). In the literature, the terms acceptability, acceptance and support are often used interchangeably (Zverinova et al., 2013, p. 14). We will do the same in this thesis. Nevertheless, a slight difference exists between those terms. Acceptability and acceptance describe a more passive attitude, while support is an active behavior. Also, acceptability happens before the implementation of a policy, while acceptance happens after it (Ibid, p. 15).

The behavioral acceptability of environmental policies has been a vast subject of interest in social sciences. Already in 2000, Paul Stern was developing a theoretical framework in order to understand "environmental significant behaviors". He defined three types of significant environmental behavior (Stern, 2000, pp. 409-411). First, individuals can participate in environmental activism. This refers to active involvement in organizations or demonstrations. Secondly, citizens may act through "nonactivist behaviors in the public sphere". This second category consists of acceptability, acceptance and support towards environmental policies. This can be done by approving some regulations (vote), or by expressing a willingness to pay for environmental protection. It is this type of behavior that we will analyze in this thesis. Lastly, environmental behavior can also be done by "private sphere activism". This includes consumption choices ("green" consumption) or environmental-friendly behavior (waste disposal).

Why is it so important to understand the public support for climate policies, and more particularly for carbon pricing? Because a clear relationship seems to have been found between public opinion and actual measures being taken. Public opinion has been identified as "a key determinant of policy change in democratic countries" (Drews and Van den Bergh, 2016, p. 856). Regarding GHG emissions, Tjernström and Tietenberg (2008) have obtained an interesting empirical result. In two steps, they first identified which socio-demographic factors influence people's attitude towards the risks associated with climate change. In the second step, they ran a linear regression on the level of GHG emissions. Among the independent variable was the attitude measured in step 1, as well as press freedom, per capita income, and private rate of time preference. The results showed that individuals' attitudes towards environment significantly influenced the level of GHG emissions: "A one percentage-point increase of people in a country who think that climate change is an important issue is associated with a .49 percentage point reduction in greenhouse gas emissions" (Tjernström and Tietenberg, 2008, p. 321). Given their data, this represents a large reduction of GHG emissions. Lastly, "the lack of broad public support has been identified as a major barrier to realizing a transition to low-carbon economy" (Drews and Van den Bergh, 2016, p. 856). All those elements point to the fact that positive opinion (and thus acceptability) for environmental protection facilitates the implementation of climate policies.

We saw earlier that there was an important gap between current carbon prices and what was needed to reach the Paris agreement's targets. Increasing acceptability appears as a possible solution to reduce this gap. This is why Klenert and Hepburn (2018) emphasize that rather than efficiency, the question of acceptability should be the primary focus of policy makers' attention.

1.4.2. Which factors influence acceptability of climate policies?

Before to discuss the specific case of carbon pricing, let's briefly discuss which factors influence acceptability of general climate policies. Drews and Van den Bergh (2016) provide a detailed review of experimental and empirical studies on this subject. This literature is part of the field of behavioral economics. The authors identify four main types of factors impacting acceptability.

The first category is "general personal orientations". The literature agrees on the fact that left-wing political orientation and having strong self-transcendent values (ex: social justice) increase people's acceptability for climate policies (Drews and Van den Bergh, 2016, p. 857). Younger people, as well as ones with higher education also support more heavily climate policies (Zverinova et al., 2013, p. 17).

The second category is climate change perception (Drews and Van den Bergh, 2016, p. 858). Very intuitively, the more people believe that climate change is happening; the more they support climate policies. Also, larger future damages expectations increase people's acceptability.

Contextual factors are the third types of variables impacting acceptability. Economic context can particularly modifies people's support for climate policies. For instance, it was empirically found that people's support for climate policies significantly decreased during the economic downturn of 2007 to 2013 (Ibid, p. 864). Weather also plays a role, as acceptability usually increase after extreme weather occurrences. Lastly, the way the media cover those topics also determine public acceptability.

The last element impacting public support is the perception of the climate policy itself, and its design. We saw that different possible instruments exist. CAC regulations, economic instruments or voluntary approaches have different characteristics and will thus generate different public support. Perceived benefits and effectiveness of policy is one of the design characteristics that influences acceptability. It is intuitive that expected success from an instrument will increase its public support (Ibid, p. 860). This is an argument for gradually increasing the objectives of an instrument: once people have realized a policy is actually working, they accept more easily the development of this policy. The most important element is the perceived costs (Ibid, p. 861). Shwom et al (2008) asked American citizens what were the determinants of their support (or refusal) for climate policies. The cost was the most frequent answer (by 58% of the respondents). The actual level of costs is not the only important point; their distributions also highly matter. Distribution of costs can refer to both social distribution (who pays the costs in a country) and international one (which country bears the highest cost). Results tend to show that a progressive distribution of costs can gather more acceptability (Drews and Van den Bergh, 2016, p. 862). Also, acceptability increases when the polluters bear a highest cost (rather than the victims).

1.4.3. Acceptability of carbon pricing

We can now advance to discuss more specifically acceptability of carbon pricing, and thus finally set our research question: Which reasons create this lack of acceptability for carbon pricing, and how can this acceptability be improved?

First, we need to precise that we will focus on how does the design of carbon pricing affects acceptability. We saw in the previous parts how general personal orientations, climate change perception and contextual factors could also affect public support. Nevertheless, it is clear that those factors are "generally hard to change" (Drews and Van den Bergh, 2016, p. 868), particularly personal orientation and contextual factors. Indeed, policy makers have very little direct influence on those elements. Climate perception can be modified by a better communication and education on the effects of climate change. This is a policy advice mentioned in many papers (Carattini et al., 2017), and one that we will also introduce in our discussion[22]. Nevertheless, from the point of view of policy making, the design of carbon pricing clearly appears as the easiest option to increase acceptability. It is thus the on we investigate.

Carattini et al. (2017) provide an updated review of literature on the aversion of people regarding carbon tax. They have identified five main reasons as why people do not accept carbon pricing (pp. 8-9). The first concern of citizens is that personal costs are too high, but also unequally distributed (second issue). Mainly, people fear that low-income people will be strongly impacted. The third problem concerns negative effects on the economy, particularly in terms of competitiveness and employment. Another problem is that people are concerned about the use of tax revenues. They fear that carbon pricing will be used to increase

[22] Indeed, communication about carbon pricing can be seen as a true design parameter of the policy.

government revenues, instead of reducing GHG emissions. Lastly, they often do not believe that carbon pricing will effectively lead to a decrease of GHG emissions. We can observe that similarly to general climate policies, costs remain the main concern. Note that all those fears may have for a long time been instrumented by lobbying groups (for example oil groups). Indeed, there is evidence that "lobbying by energy-intensive industries contributed to prevent the implementation of carbon pricing in several countries, and may have influenced voters' perceptions about its potential drawbacks" (Baranzini et al., 2017, p. 8). Still, we will not discuss in much details the influence of lobbies for two reasons. First, their activities are exogenous for policy-makers (those have no way to stop lobbies' activities). Secondly, many energy-intensive lobbies[23] have recently increased their support for carbon pricing policies. Why? Simply because they have realized that carbon taxes would be much less costly than a strong ban on their activities. Indeed, "many businesses already realize that carbon pricing is not a bad option as it leaves them a free choice between paying for emitting or abatement" (Ibid, p. 8).

In the next two parts of the thesis, we discuss more in details what appeared to us as the two biggest limits to acceptability. We choose those elements based on their large occurrence in the literature, but also because they are often used in public debates against carbon pricing. The example of the Canadian climate policy perfectly allows us to introduce those two issues. In their paper (31 July 2018), Klement and Hepburn (2018) were mentioning the example of Canada and its provinces, where the government was able to reach "broad political acceptance for carbon pricing". Indeed, Justin Trudeau's government developed a plan for a federal carbon tax. Each province which would not have a carbon pricing scheme implemented by the end of 2018 would be forced to implement this federal carbon tax. Ironically, history bore Klement and Hepburn (2018) out the day after the release of their article. The very next day (August 1 2018), the Canadian government was announcing that it was softening its objective on carbon pricing (cbc.ca), bending to the growing protest led by Ontario's Premier Doug Ford. To be precise, the government increased the threshold level of emissions from which polluters are actually taxed. This means that all polluters will see their tax bills decrease. Some of them will even no longer be taxed. Political unacceptability has thus led to the softening of an initially ambitious carbon pricing scheme. The two main themes of Doug

[23] For instance, BP and ExxonMobil have both showed their support for carbon taxes in the last year.

Ford's argument perfectly introduce the two key issues we identified in the literature and in the ongoing international debate on the need for more climate policies.
Mister Ford first promised to "make life more affordable in Ontario" (cbc.ca). This perfectly matches with the two first concerns identified by Carattini et al (2017): the costs supported by individuals, and their distributions between the population. The first recurrent question and "fear" of the public is indeed that carbon pricing will translate into higher energy prices, ultimately hurting the citizens by increasing the tax burden. More importantly, will low-income households have to bear the highest burden? In economic terms, is carbon pricing a regressive tax? This is exactly the issue used by Ford when promising to make life more affordable for his citizens. This will be the issue we discuss in the second part of thesis. In addition, we will propose solutions by setting up better "recycling of revenues". In this way, we also treat the concern of people regarding the use of revenues (Carattini et al.)

The second issue we identified is the fact that carbon pricing could hurt competiveness of the country's firms, resulting in carbon leakage. This relates to the problem of collaboration among countries. Indeed, if all countries were equally and with certainty implementing carbon pricing, none of them would suffer from a lack of competitiveness. Carbon leakage would be impossible in perfect cooperation. But to this date, no legally binding international agreement exists. This gives the possibility to countries to free ride on others' efforts, creating the incentive structure of a prisoner's dilemma. Stiglitz perfectly emphasizes the importance of this question in terms of political acceptability: "Even if the quantitative effects (of carbon leakage) are limited, the political consequences of plants and jobs moving to another jurisdiction because of its lower carbon price can be significant, and undermine support for strong carbon policies" (Stiglitz, 2018, p. 23). This concern was perfectly visible in the case of Canada: conservatives (and Doug Ford) constantly emphasized that carbon prices would drive jobs and money out of Canada, before to relocate in regions without carbon prices. This was also exactly the third concern identified by Carattini et al., regarding the negative effects on the wider economy.

2. The distributional effects of carbon pricing

The first limit towards acceptability of carbon pricing is the distribution of its costs. As we have seen previously, the regressivity of carbon pricing is often used as an argument against its implementation. As Morris perfectly states: “A carbon tax that is perceived as unfair is less likely to pass and less likely to stay passed” (Morris and Matur, 2015, p. 98).

The timing for a discussion on the distributional effects of carbon pricing is particularly appropriate. Indeed, the current situation in France (The New York Times, 2018 and The Washington Post, 2018) is a perfect example of the relevance of this topic. On the 17th November 2018 broke out the first act of the “yellow vest” protest movement. It gathered 300’000 people, who organized the blocking of many roads. Even though the grievances of the movement have become a bit blur and unclear, protest has kept in 2019 and has led to the beginning of a “national debate” in France. The initial spark was clearly the programmed increase of taxes on fuels, which was a part of France environmental policy. The prices of diesel and gasoline were to be increased by respectively 24 and 12 cents per gallon. Low-income households have been particularly critic towards this measure, particularly in rural areas where people are dependent of car transportation on an every day basis. The extent and violence of the protests forced president Macron to back paddle on his ambition, delaying of six months the planned increase of prices. One of the key issues with France’s carbon pricing policy appeared to be the use of revenues (The Washington Post, 2018). Indeed, the French government was using most of the revenues for deficit reduction. Only a fourth of the revenues were used to support low-income households.

This example of France shows that higher negative effects on low-income households (i.e. regressivity) can clearly reduce acceptability for carbon prices. This can complicate their implementation. Thus, it clearly “illustrates how equity and fairness consideration have to be built into the design of such policies” (The New York Times, 2018). In this second part of this thesis, we address this issue more in detail. First, we question the actual level of regressivity of carbon pricing policies, both from theoretical and empirical points of view (2.1). As we just mentioned it in the case of France, low-income households were the ones who fought the increase of prices the harder. Indeed, those households felt that they were unfairly supporting the burden of carbon prices. It is thus important to understand how carbon prices affect households with different levels of income. After that, we discuss the possible solutions to this problem. Mainly, we investigate how tax revenues should be redistributed in order to generate public acceptability for carbon pricing policies (2.2). The idea of this second chapter will be to give advice on how to redistribute revenues in a way that avoids leading to public protest (like in the case of France).

2.1. Is carbon pricing regressive?

In this chapter, we attempt to look at who really supports the burden of carbon pricing. In the first part of this thesis, we showed how carbon pricing's efficiency represents its main advantage. Nevertheless, we also mentioned that there were other important criterions to evaluate environmental policies. Equity was one of those criterions, and it is at the center of this second part. We will focus on "end-results" equity, which asks "whether the outcomes of economic decisions or events are fair" (Tresch, 2008, p. 8). Currently, all countries have implemented some kind of redistribution between rich and poor (at different levels). This is proof that societies do care about inequalities and the costs they generate[24]. Fairness has been an important part of environmental policies, and "is actively pursued by policy makers" (Rivers, 2012, p. 200). For instance, the Canadian Government, in its framework for evaluation of environmental tax proposal, emphasizes the key role of fairness: "The assessment of distributional impact is an important part of the evaluation" (p. 325).

In order to fully understand who bears the cost of carbon pricing, we address three important points. First, we present the mechanisms through which a carbon price policy affects households (2.1.1). This comes down to understanding the real economic incidence of the carbon tax. The first mechanism is an increase of prices for households, resulting from the fact that firms are able to shift "forward" the burden of the tax. The second one results from a "backward" shifting of the tax, and leads to a modification of the revenues for households. Once we have understood those two mechanisms, we analyze how each of them (2.1.2 and 2.1.3) impacts households with different levels of income. Doing so allow us to give an answer to the question of the regressivity of carbon pricing policies. Along this chapter, we also emphasize on giving the intuition of how those mechanisms can be estimated in practice. Therefore, empirical methods will be discussed.

2.1.1. Incidence of carbon pricing on households: the key mechanisms of transmission

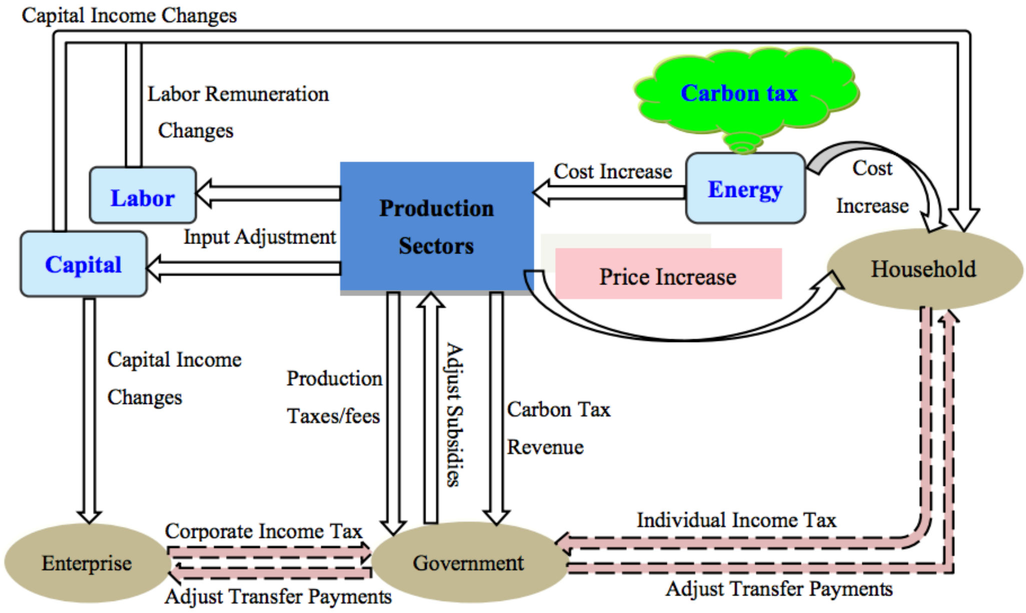
Distinguishing the statutory and economic incidence of the carbon tax is important, because "the economic incidence determines the distributional impacts of a tax" (Metcalf et al., 2008, p. 32). When a carbon pricing policy is implemented, various economic actors are impacted through different channels. Figure 6[25] perfectly illustrates this idea.

---

[24] For a detailed discussion of equality in public finance, see Tresch, 2008, pp. 79-99.

[25] "Solid lines represent the effects transmitted in the primary income distribution, while dotted lines represent those in the redistribution of income" (Wang et al., 2016, p. 1125)

Figure 6: Schematic diagram of the transmission mechanisms of a carbon tax in the short run



Source: Wang et al. (2016), p. 1125

Households, as well as enterprises and the government, are all affected differently by a carbon tax[26]. Let's focus on the effects on households, as they are our main concerns in terms of distributional effects. The distributional effect of a carbon tax is complex (Wang et al., 2016, p. 1125), but can ultimately be separated in two main categories. First, firms can shift the burden of the tax forward, meaning that they charge higher prices to the customers. Secondly, they can also pass this burden backward, by lowering capital and income remunerations. We now present both of those effects.

2.1.1.1 Variation of spending for households

Direct price effect

The first consequence of a carbon tax is obviously a direct increase of energy prices. Households then support a share of the tax burden by paying those higher prices (this is why we refer to those effects as the "spending-side"). It is relatively straightforward to calculate this increase of energy prices. For instance, Rivers (2012) calculated the effect of a carbon tax of 30 $ per ton of CO_2 on prices of gasoline, diesel, natural gas and coal. Given at-that-time delivery prices of those energies, this carbon tax is equivalent to a 5.8 % tax on the consumer price of gasoline (respectively 7% for diesel, 17.7 % for natural gas and 108 % for goal) (Rivers, 2012, pp. 901-902). This direct price effect is applied only on goods directly taxed by

[26] Carbon emission trading would here lead to the same transmission mechanisms than a carbon tax.

the carbon tax. Nevertheless, the carbon tax may also affect the price of goods not directly taxed, by an indirect price effect.

Indirect price effect

Could we now look at how much each class of income spends on those energies, and thus assess if this carbon tax is regressive or not? Unfortunately not directly. Indeed, two elements prevent us from doing so. To begin with, the introduction of the carbon tax also increases the cost of production for other economic sectors (not only the energy sector). Indeed, those sectors are also impacted by the increase of energy prices, which is one of their inputs. Firms active in those sectors have to make adjustments, in terms of both inputs and outputs. For outputs, firms have to decide if they will increase their prices (and thus pass the carbon tax burden onto consumers), or if they keep their price constant (and thus reduce their profit). If they decide to increase their prices, this will lead to an increase of prices for commodities consumed by households. This mechanism is therefore an indirect price effect. For instance, Rivers (2012) mention the example of food production. Its production naturally requires the use of fossil fuels inputs (for agricultural production or for food transport), and "increases in the price of these inputs will increase the end price of food products". Food is also a particular relevant topic in terms of fairness, as it is a vital commodity for individuals. An increase of food prices could then be more problematic for low-income households. If we refer again to a tax of 30 $ per ton of CO_2, Rivers (2012) statistically predicted that it would increase food prices by 1.2 % in Canada. More recently, Wu and Thomassin (2018) investigated in detail the impact of the Canadian carbon tax on food prices. The authors computed two scenarios (Ibid, p. 24). In the first one, they simulated the federal carbon tax[27] applied to all the sectors of the economy. In this scenario, food prices would increase by 4.6% (with a 50 $ tax per ton of CO_2). This increase is the combination of the direct and indirect price effects. In the second scenario, they computed the same tax, except that it is not directly enforced on the agricultural sector. This means that "on-farm fuel use for agricultural production is exempt from the tax system". By doing so, the authors can now assess only the indirect price effect of the carbon tax. With this scenario, the price would increase by 1.27 % by 2022. To compare with the results of Rivers, a tax of 30 $ per ton of CO_2 would lead to a price increase of around 0.8 %. The difference in results between those studies testify of the difficulty to estimate how much of price increase is computable to a carbon tax.

[27] As described earlier in the thesis, the Canadian federal tax consisted of an initial tax of 10 $ per ton of CO_2. It would then be increased yearly by 10 $, until reaching 50 $ in 2022.

This relates to the second measurement issue: The carbon tax "may or may not be fully passed on to final consumers" (Rivers, 2012, p. 901). In mainstream public sector economics, this refers to distinguishing the (economic) incidence of a tax and its impact (statutory incidence). The economic incidence can highly differ from the statutory incidence because participants in the supply chain can shift the burden forward (what we just discussed) or backward (see discussion below) (Mathur and Morris, 2014, p. 328). One well-known theoretical concept is that the incidence of the tax depends on the relative demand and supply elasticities: "The more inelastic demand is relative to supply, the more consumers bear the burden of the tax" (Tresch, 2008, p. 346). More simply explained, the side of the market that is less willing to respond to price will support the highest share of the tax burden (Ibid, p. 346). In the literature, it seems to be agreed that "fuel supply curves are generally fought to be flatter than demand curves, so the majority of the carbon tax is passed forward" (Morris and Mathur, 2015, p. 105). Empirically, there are only a few studies that have investigated how much of a carbon tax is passed onto consumers (Rivers, 2012). Both Bovenberg and Goulder (2001) and Metcalf et al. (2008) found that around 90 % of carbon tax is passed onto consumers. Although forward shifting seems not to be complete (100%), most of empirical papers on the distributional impact of carbon prices assume full forward shifting (for instance Rivers, 2012, p. 905).

2.1.1.2 Variation of revenues for households

Now let's go back to figure 6. It is evident that the carbon tax does not only impact households through higher prices. We mentioned that firms impacted by the carbon tax will also proceed to input adjustments. This means that enterprises might modify their input from capital and labor, resulting in a variation of both capital and labor (wages) remuneration. Thus, households are not only impacted through a change of commodity and energy prices (in other terms in the use of their revenues), but also by a variation from their sources of income. The intuition behind this so called "pass-back" of the tax burden is that firms might not be able to fully shift forward the burden of the carbon tax. Thus, in order to maintain their profits, they need to reduce wages and returns on capital.

The revenues of households are not only modified by the behavior of firms, but also by the action of the government. Why? Because in most developed countries, transfer to households are indexed to the Consumer Price Index (CPI). This is for instance the case in the United States, where Social Security payments and Supplementary Security Income are both indexed to the CPI. Thus, if overall prices increase because of the carbon pricing policy, the transfers to low-income households will increase in the same proportion. In the same idea, programs helping low-income households to buy food are also indexed on the prices of food (Dinan, 2015, p. 125). In the rest of the thesis, we will refer to those two effects as the revenue (or income) side of the distributional impact.

We now have a better idea of how carbon pricing affects households. The next step consists of understanding how those two effects (spending side and revenue side) differently impact poor and richer households. The income side effect has often been ignored in the literature, focusing only on the spending side. "Doing so biases distributional studies towards finding carbon pricing to be regressive" (Rausch et al., 2011, p. 25). It is thus important to discuss both of those effects. In fine, it will allow us to answer the question of this chapter: is carbon pricing regressive or not?

2.1.2. Regressivity from a spending-side perspective

The initial idea of a carbon pricing policy is to increase the price of energy-intensive goods. This increase of prices should give incentives to economic agents to change their behavior. Nevertheless, as we described previously, this increase of prices creates an additional cost for consumers (and thus households). The question is now to know if this distributional effect of a carbon price is regressive or not.

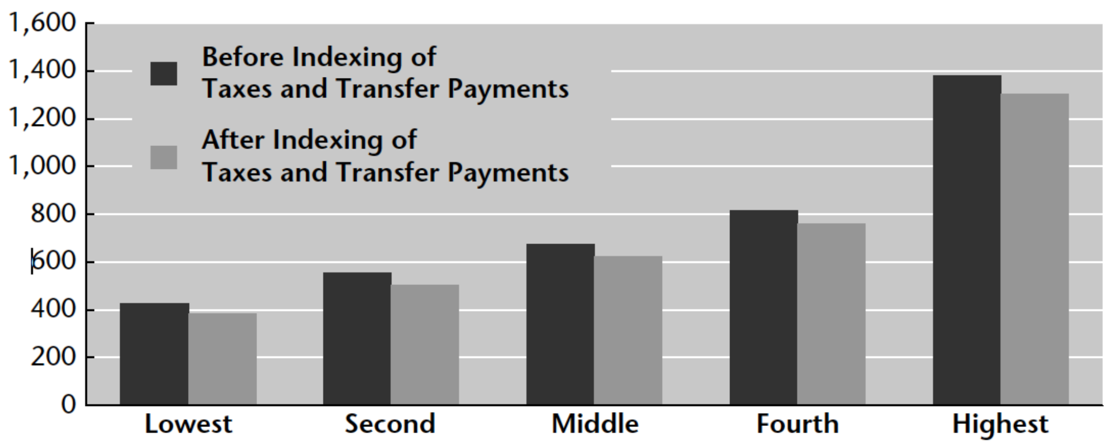
2.1.2.1 Spending patterns of households

In order to answer this question, we turn to the spending patterns of households. We want to see if low-income households spend more money on fuels (or on goods using fuels and whom price indirectly increases) than higher income households. In order to be able to compute those statistics, researchers need two elements. First, they need to know by how much the carbon tax increases the price of each goods. Mathur and Morris (2014) provide a good explanation of how this can be done, using "input-output" matrices. Those matrices combine "how much each industry uses of each commodity" (input) and "how much each industry makes of each commodity"(output). Combining those data, they can trace back the inputs used in the production of different types of goods. Since those inputs include energies taxed by the carbon tax (fuel, coal), they can link the initial carbon tax to the final price of commodities. Simply said, it is then possible to know which part of a final good's price is directly attributable to the carbon tax. The second element needed is to know how much each type of households spends on each goods. Those data can be furnished by national surveys about household's expenditures (Scott and Eakins, 2004, p. 2). Those surveys usually detail specifically the types of goods consumed by households, as well as the income levels of those households. By combining those two datasets, it is possible to compute "the carbon tax paid (via those higher prices) by each household" (Mathur and Morris, 2014, p. 328). Multiple empirical studies have followed this procedure. An important hypothesis of most of those studies is that the carbon tax is completely passed forward to consumers[28]. Also, those studies assume no (or little) behavioral response from the consumers. For instance, they do not change their consumption patterns because of the tax. As stated by Morris and Mathur (2015, p. 101), this is reasonable assumption when the carbon prices are modest and that we are interested in short-run effects of the tax.

Absolute incidence

First, when looking at absolute costs for households, it is intuitive that highest earners will support a larger share of the carbon tax. Indeed, people with higher income will spend more money on goods (and thus indirectly on energy). Figure 7 depicts the results of such calculations for a simulated carbon tax of 28 $ per ton of CO_2 in the USA. Households are divided into 5 quintiles, based on the income distribution. From this, we can see that households from the highest quintiles pay around 3.5 times more carbon tax than what households from the lowest quintile pay. This is not a surprising result, and has been found in studies analyzing other countries[29]. Nevertheless, absolute values are not so useful when assessing the regressivity of a policy. Indeed, remember the definition of regressivity that we gave in chapter 1.2.1. The important thing to observe is the *relative* burden of the carbon tax.

Figure 7: Estimated annual cost of a carbon tax of 28 $ per ton of CO_2



Source: Dinan (2015), p. 123

[28] We saw in part 2.1.1.1 that this was a relatively credible assumption.
[29] See for instance Callan et al. (2009) for the same kind of results in Ireland.

Relative incidence

Therefore, we must compare the burden of the tax relative "to a measure of household socioeconomic status" (Morris and Mathur, 2015, p. 101). The chosen measure is usually income[30]. The literature expects that low-income households will spend a larger share of their income on energy-intensive goods, and this for two main reasons (Ibid, p. 101). First, low-income households spend a higher share of their income than richer households (those tend to save more). Dynan et al. (2004) have for instance found a strong relationship between current income and saving rates. The second reason is that "poorer households spend proportionately more of their income directly on electricity and other fuels than higher-income households do" (Morris and Mathur, 2015, p. 102). The intuition behind this idea is that no matter the income of households, basic expenses on heating and transport have to be made; they are necessities. On the opposite, higher incomes have the resources to afford technologies that consume less energy. For instance, electric cars consume less CO_2, but are for now relatively expensive. This should result in the level of expenses on electricity being rather flat along the income distribution. Since by definition, the level of income of poorer households is much lower than for higher households, it should result in low-income households spending a larger share of their income on energy-intensive goods.

Table 1: Average annual household expenditures on energy-intensive items, by income quintile

Quintile	Utility expenditures	Gasoline expenditures	Total spending on energy-intensive items	Total as a percentage of income
Bottom	1'203	1'046	2'249	21.4
Second	1'596	1'768	3'364	12.2
Third	1'840	2'418	4'258	9.2
Fourth	2'181	2'988	5'169	7.1
Top	2'847	3'696	6’543	4.1

Source: Author's own representation, based on Dinan (2015), p. 124

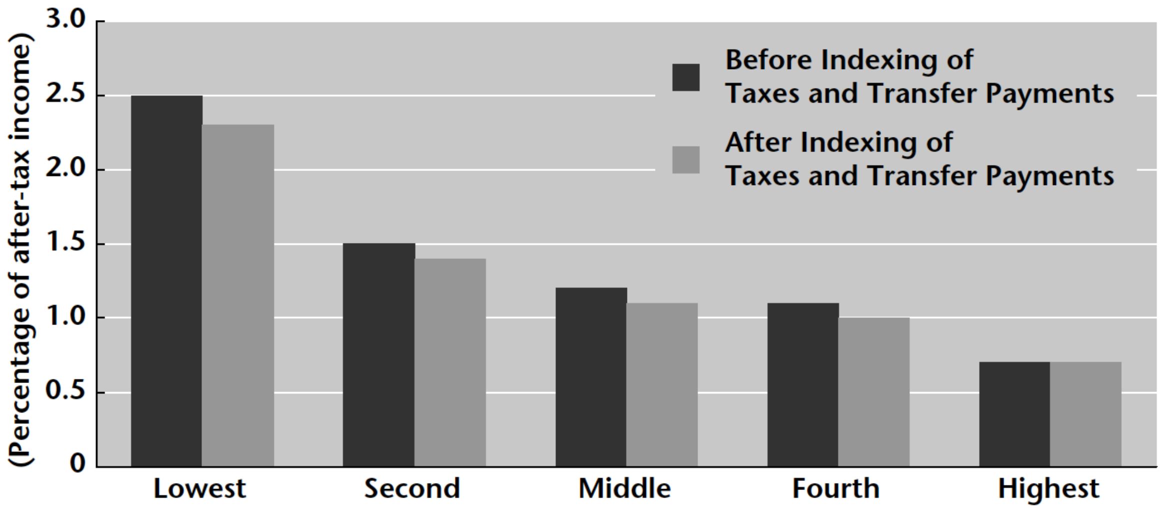
Data analyzed by Dinan (2015) in the American context verify those theoretical expectations. We can see that indeed, poorest households spend a larger share of their income (21.4 %) than the highest earners (6.8 %) on energy-intensive goods. Empirical data in Ireland also point to the same direction: the distribution of energy expenses is quite flat across the income distribution (Callan et al., 2009, p. 409). For instance, Irish households in the highest decile spend only 8 % more on home heating than households in the lowest decile. Meanwhile in

[30] We will discuss later what would be the effect of choosing an other measure, paricularly consumption.

Ireland, the disposable income of the richest households is eight times larger than those of the poorest households. All empirical articles assessing this spending pattern of household show the same types of data and conclusions[31].

The next step is now to look at the impact of the carbon tax relative to the income of households. Based on the elements that we have just introduced, it seems like the burden of the carbon tax represents a larger part of income for poor households than for richer ones. Empirically, this intuition is verified and commonly agreed in the literature. Let's go back to the study of Dinan (2015) who simulated the distributional effects of a carbon tax in the USA (28 $ per ton of CO_2).

Figure 8: Estimated cost of a carbon tax of 28 $ per ton of CO_2, relative to income



Source: Dinan (2015), p. 124

From figure 8, we see that the cost of the carbon tax represents a larger share of income for poorer households than for richer ones. Indeed, the "increased cost due to the carbon tax would account for 2.5 percent of annual after-tax income for the average household in the lowest income quintile, compared with less than 1 percent of annual after-tax income for the average household in the highest quintile" (Dinan, 2015, p. 124). Those results clearly indicate that a carbon tax is regressive, when looking only at the increase of prices that households face. Those results from Dinan are similar to results obtained by other empirical analyzes done on the same subject. For instance, Callan (2009) has showed that because of this spending side, a carbon tax in Ireland would be regressive. The same conclusion was also reached in an analysis of British Columbia (Canada)'s carbon tax (Beck et al., 2015).

[31] For a good review of the empirical literature, see Callan et al. (2009), pp. 407-409.

Distinguishing the direct and indirect price effects

Using the same kind of input-output methodology, Mathur and Morris (2014) have also distinguished the direct and indirect price effects. Empirically, this is quite easy to do. Indeed, it only requires separating the commodities directly taxed by the carbon tax, and goods that are not directly taxed.

Table 2: Distribution of burden by annual income

Table reports the within-decile average ratio of carbon tax burdens to income (Mathur and Morris, p. 328)

Decile	Direct	Indirect	Total
Bottom	2.38	1.16	3.54
Second	1.83	0.9	2.73
Third	1.27	0.75	2.02
Fourth	1.06	0.61	1.67
Fifth	0.94	0.55	1.49
Sixth	0.78	0.48	1.26
Seventh	0.68	0.44	1.12
Eighth	0.54	0.41	0.95
Ninth	0.48	0.37	0.85
Top	0.31	0.31	0.62

Source: Mathur and Morris (2014), p. 328

Results show that the direct price effect is more regressive than the indirect one. This makes perfect sense from a theoretical point of view. Indeed, the direct effect measures the impact on heating, electricity, gasoline, etc… As we saw it earlier, those goods are necessities for poor households and represent a large share of their expenses. It is then logic that the direct cost is higher than the indirect one. In terms of policymaking, it only confirms that putting a price on energies that are vital to low-income households will be regressive. Therefore, we see that redistribution seems to be needed.

2.1.2.2 Brief discussion of those results

Even though all studies agree on the fact that this spending side is regressive, the results differ on by how much it is regressive. We can see it easily by looking at the results from Dinan (Figure 8) and Mathur and Morris (Table 2). Even though those studies apply the same method to the same country (United States), Dinan finds that the poorest unit of observation (quintile) supports a relative burden 3.5 times higher than the one supported by the richest households. In Mathur and Morris, this ratio is almost of 6. This is thus a reminder that those results must be taken with precaution. Yes, the carbon tax is regressive (at least when looking at the spending side), but by how much remains to be better assessed empirically.

An important point of discussion in the empirical literature is the choice of the measure of socioeconomic status. We have presented results that use the level of income as a proxy for wellbeing. Nevertheless, many researchers point out the fact that income might not be the better proxy (Morris and Mathur, 2015). Indeed, basing themselves on the Permanent Income Hypothesis developed by Friedman in the end of the 50's, they claim that level of consumption might be a better proxy (than current income) for the well-being of households.

Empirically, assessing the relative distributional effect of the tax with regards to consumption levels reduces dramatically the regressivity of the tax (Mathur and Morris, 2014, p. 329). We can observe this by comparing the results of table 2 and 3. Why is it so? First, because consumption expenses are more evenly distributed than income (Ibid). Indeed, there is a smaller difference between rich and poor in terms of consumption than for income. Mathematically, this automatically reduces the level of regressivity of the carbon tax. Secondly, poor households tend to consume more than their income (they use their savings or loan). Thus, their carbon tax to consumption ratio is smaller than their carbon tax to income ratio. For higher households, the mechanism is the opposite: their revenue are higher than their consumption (they are able to save money). Thus, their carbon tax to consumption ratio is higher than their carbon tax to income ratio. Once again, this mathematically leads to a less regressive carbon tax.

Table 3: Distribution of burden by current household consumption

Table reports within decile ratio of carbon tax burdens to current consumptions (Mathur and Morris, p. 330)

Decile	Direct	Indirect	Total
Bottom	1.52	0.62	2.14
Second	1.42	0.62	2.04
Third	1.46	0.6	2.06
Fourth	1.28	0.61	1.89
Fifth	1.22	0.61	1.83
Sixth	1.06	0.63	1.69
Seventh	1	0.65	1.65
Eighth	0.9	0.66	1.56
Ninth	0.8	0.68	1.48
Top	0.6	0.69	1.29

Source: Mathur and Morris (2014), p. 330

To conclude, it appears very clearly that this spending side effect is regressive. Nevertheless, we have seen that the measurement of this regressivity is subject to a few complications. Because of that, it is hard to present a consensus on the exact level of regressivity. We now move to discussing the impact of the second transmission mechanism of the carbon tax on the level of regressivity. As introduced a bit earlier, this second mechanism is the so-called revenue side effect.

2.1.3. Regressivity from a revenue-side perspective

As we have described it at the beginning of this chapter, the carbon tax is also expected to impact the revenues of households. We just saw that poor and richer households have heterogeneous patterns of consumption, which tends to make carbon pricing policies regressive. The reasoning behind the following chapter is very similar. This time, we analyze how the sources of households' revenue differ along the revenue distribution. We focus on the three revenue sources analyzed in the literature: labor remuneration (wages), return on capital and transfer from the government.

This revenue side assumes that a portion of the carbon tax' burden is shifted backward. Therefore, empirical assessment requires relaxing the assumption seen in the previous chapter (full burden of the tax was passed forward to consumers). Empirically, we will see that this is not an easy task. This might explain why only a minority of papers on the distributional effects of carbon pricing policies does incorporate this revenue side. Lastly, it is important to precise that we will present empirical studies that combine the spending-side and the revenue-side effects. Why do no empirical studies focus only on the revenue side? The reason is simple and can be found in chapter 2.1.1.1: it has been proven that a large part of the carbon tax' burden is actually shifted towards consumers. Therefore, it would make absolutely no sense to completely delete the spending side effect. For this thesis, presenting studies that combine the two effects will allow us to see which of this effect is the largest, and what is the total distributional effect of a carbon price policy.

2.1.3.1 Structure of revenues for households

Just as a reminder, we saw that a carbon price policy may have an impact on the sources of revenues for two reasons[32]. First, "rather than being fully passed forward into higher consumer prices, some of the burden of the tax may be "passed back" to producers in the form of lower producer prices" (Morris and Mathur, 2015, p. 104). This reduction of production

[32] See chapter 2.1.1.

prices could then lower the returns on capital, as well as wages. Secondly, governmental transfers are usually indexed to overall price level. By increasing those prices, carbon pricing policy can then lead to higher transfers.

An appropriate point to start this discussion is to look at the sources of revenues along the whole population: Do poor households gather a higher share of their revenues from transfers compared to richer households? Do returns on capital and wages represent a larger share of high-income revenues than for low-income households? The usual expectation is that this revenue side effect can make the tax less regressive. Why? It seems intuitive that low-income households receive relatively more transfers than higher income households (1). If it is the case, the carbon tax will indirectly increase the revenues of low-income households. Also, richer households should receive a majority of their revenues from wages and returns on capital (which are expected to decrease) (2). Therefore, those two effects could mitigate the regressivity of carbon pricing policies.

Table 4: Household income sources in the case of British Columbia (Canada)

Decile	Income	Labor income share	Investment income share	Transfer income share
Bottom	17'000	0.224	0.025	0.751
Second	26'000	0.392	0.026	0.581
Third	35'000	0.511	0.03	0.458
Fourth	45'000	0.643	0.05	0.306
Fifth	55'000	0.758	0.021	0.221
Sixth	68'000	0.831	0.025	0.144
Seventh	82'000	0.837	0.031	0.132
Eighth	100'000	0.884	0.023	0.093
Ninth	130'000	0.921	0.025	0.054
Top	(+)	0.933	0.046	0.021

Source: Beck et al. (2015), p. 51

Table 4 for example provides a detailed analysis of the sources of income in the province of British Columbia. This example verifies the assumptions (1) and (2) mentioned earlier. Low income households receive a vast majority of their income from transfers (75 %), while it represents only 2 % of the highest decile's income. The share of labour income follows the opposite trend. For the lowest decile, labor income constitutes only 22% of total income, while it is 93 % of the richest households' total income. Even though investment income are only a low share of households' income, it is almost twice larger for richest households (4.6

%) than for the poorest ones (2.5%). Morris and Mathur (2015) find similar trend for sources of income in the USA[33].

2.1.3.2 Estimating the impact of the carbon tax on sources of income

The next step is now to estimate how the carbon tax really impacts those different sources of households. As said by Morris and Mathur (2015), the effects of the carbon tax on the sources of income are hard to estimate concretely. Indeed, a precise estimation would require knowing how much of the carbon tax burden is passed forward to consumers, and how much is passed backwards to workers and shareholders. Unfortunately, we have already said earlier that very precise estimation of this was still needed. Nevertheless, it is still possible to approximate the effects of the carbon tax on the sources of income. In the literature, we have found two options to do this.

Partial Equilibria

In section 2.1.2. , we described the methodology used by Mathur and Morris (2014) to assess the spending side of the carbon tax. They relied on so called input output matrices. The key assumption behind their analysis was that the full burden of the carbon tax was shifted forward to consumers. Nevertheless, in their sensitivity analysis, they introduce *the possibility* that a share of the burden could actually be passed onto factors of production. Introducing this possibility is the first way to assess the effect of a carbon tax on the sources of income. Of course, the question of how much of the carbon tax is shifted backwards remains an issue: "the true distribution of the burden between consumers, capital-owners and labor is uncertain" (Mathur and Morris, 2014, p. 332). Nevertheless, the authors explore the consequences of the following distribution of the tax burden: 80 % on consumers, 20 % on capital and labor. Again, the argument here is not that 20 % of the burden is shifted backwards: the authors do not precisely know if it is the case or not. Rather, their goal is only to show what would be the distributional consequences *if* some share of the cost were actually shifted backwards. We can see the results of this sensitivity analysis in the table below.

[33] To our knowledge, no study has investigated this income side for a European country yet. This would be interesting, as redistribution is usually larger in Europe.

Table 5: Distribution of burden by annual household income decile, with burden split between consumers (80 %) and factors of production (20 %).

The table reports the within-decile average ratio of carbon tax burdens to income.

Decile	50% labor- 50% capital	90% labor- 10% capital
Bottom	2.99	3.08
Second	2.32	2.36
Third	1.69	1.67
Fourth	1.57	1.61
Fifth	1.39	1.42
Sixth	1.19	1.17
Seventh	1.06	1.02
Eighth	0.94	0.91
Ninth	0.89	0.87
Top	0.78	0.81

Source: Mathur and Morris (2014), p. 332

By comparing it with table 2 [34], it is clear that the regressivity of the carbon tax is reduced. Indeed, the burden on the lowest decile is decreased (from 3.54 % of income to 3.08 %), while it increases for the top decile (from 0.63 % to 0.81 %). Keep in mind that those results must be taken with caution. They do not intend to depict the true distributional impact of a carbon tax. Again, this would require a clear knowledge of how much of the carbon tax is passed backward and forward. Nevertheless, those results confirm that in reality, a carbon tax might be less regressive than the predictions of studies focusing only on the spending-side effect. The intuition behind this result is that richer households receive more wages and returns on capital than low-income households. Those latter receive a majority of their income from transfers. Therefore, when a share of the burden is passed backwards, richest households are hurt relatively more than low-income households. Still, general equilibrium analysis will be more precise at estimating those distributional effects.

General Equilibrium analysis

The second way to assess the distributional effect of a carbon pricing policy is by using General Equilibrium responses. Thanks to a very recent and growing body of literature, it appears that the "incidence of energy and carbon taxes is dictated by general equilibrium responses" (Beck et al., 2015, p. 41). What is interesting is that this part of the literature tends to find that carbon pricing policies can be progressive even before the redistribution of

[34] As a reminder, table 2 showed the results of the same study, but with the assumption that the full burden of the carbon tax is shifted on consumers.

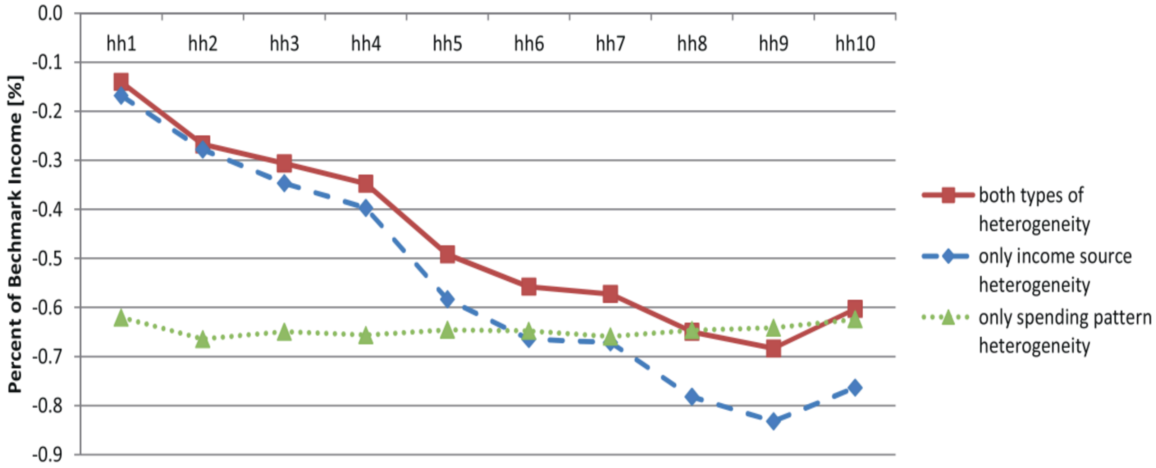
revenues (Rausch et al., 2010, Beck et al., 2015). This progressivity is the result of introducing the revenue side effect.

We will here present the intuition behind the study of Beck et al., who have used a computable general equilibrium (CGE) in order to assess the distributional implication of a carbon tax in British Columbia (BC). We use this study in particular because it clearly differentiates the spending side and revenue side effect. In order to do so, the authors use a "static, multi-sector, multi-region, multi-household CGE model of the Canadian economy" (Beck et al., 2015, p. 43). This analysis is interesting because it includes characteristics of energy spending and income sources for different household income classes (ten deciles). This allows assessing precisely the distributional effect of the carbon tax. Each household is endowed with three factors (labor, capital and natural resources), and also receives transfers from the government. Other elements of their model are rather usual for a CGE model[35]. Labor is mobile between sectors in each region, but immobile between regions. Half of capital is fixed to region and sectors, while the other half is mobile between regions and sectors. Producers maximize profits by substituting different inputs factors. For households, their welfare is a function of consumption, leisure and investment.

In order to model the incidence of the carbon tax, the authors simulate two scenarios: one without any revenue recycling, and another that includes the redistribution of revenues generated by the tax. For now, we will use only the first one. Indeed, redistribution will be discussed in the next chapter of the thesis. Furthermore, we are interested in the distributional effects of the carbon tax, no matter how the revenues are then redistributed. Let's now look at the results they obtain.

[35] A more detailed presentation of their model can be found in Beck et al., 2015, pp. 43-52.

Figure 9: Welfare impacts of household heterogeneity

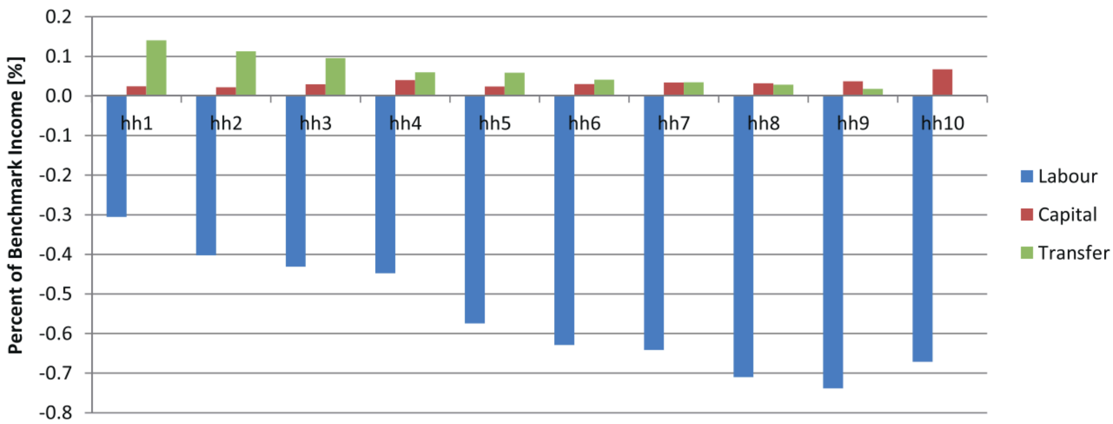


Source: Beck et al. (2015), p. 55

Their model shows that a carbon tax of 30 $ per ton of CO_2 would be a progressive policy. This can be seen in figure 9. The downward slope of the "both types of heterogeneity" line indicates that higher income households support a larger relative share of the burden. Even more interestingly, they distinguish the revenue side effect and the spending one. This is done by running two extra scenarios. In the first one, they "suppress all heterogeneity between households on the income side, but retain heterogeneity on the expenditure side". This allows measuring only the spending side effect (green line in figure 9). In the second scenario, they do the exact opposite (suppress all heterogeneity on the spending side) in order to assess the revenue side effect (blue line in figure 9).

Results are only partly matching theoretical expectation. First, we see that the spending side heterogeneity does not create any regressive scheme, but is instead distributionally proportional. This is contrary to the results we presented in the last chapter. Indeed, we had seen that heterogeneity of spending created regressivity. Why do Beck et al. arrive to a different result? By looking at the initial data of their study, it appears that the heterogeneity of spending between income deciles is very weak in the context of British Columbia (Beck et al., 2015, p. 51). Indeed, higher income households almost use the same share of their income for natural gas expenditures, petroleum and transportation services. The only difference is in consumption of electricity. Nevertheless, "the carbon tax does not increase the electricity price because the electricity in BC is mostly generated with hydro" (Ibid, p. 55). Therefore, it is clear why the "distributional impact of the spending-side effect is proportional" (Ibid, p. 55). Now, the income source heterogeneity verifies theoretical expectations, as it creates progressivity. Since the spending side is distributionally neutral, this income source heterogeneity is the reason why this carbon tax is progressive. It is then interesting to go one step further, and analyze which income source (labor, capital or transfer) has the largest effect.

Figure 10: Welfare impacts from each income source



Source: Beck et al. (2015), p. 56

We see very clearly that the largest driver is the reduction of wages. Capital income slightly increases. Those results are driven by the assumption of the model. Indeed, we mentioned that capital is assumed to be mobile across provinces, while labor is not. Automatically, capital can then move out of British Columbia when the carbon tax is implemented. Since labor cannot do the same, it has to bear the burden of the carbon tax. In a sensitivity analysis, Beck et al. suppress capital mobility across provinces. In this case, capital income also decreases (Beck et al., 2015, p. 59). This would make the policy even more progressive, since high-income households receive a larger share of their income from returns on capital. As predicted by the theory, lower income households also benefit from higher transfers, since they are indexed to the price index.

We just explained how each income source is affected by the carbon tax. But in order to truly understand the economic incidence of the tax on this revenue side effect[36], we need to look at the sources of income from each household decile. Why? Let's explain it with a very simple example. Imagine the richest household receives 100 % of their income from returns on capital, while low-income households would receive 100 % of their income from wages. Then the carbon tax would be strongly regressive: rich households would benefit from it (since returns on capital slightly increase in this model); while low-income households would see

[36] Or in other words, in order to understand figure 10.

their revenues go down. Now if we change the initial assumption, the distributional effects are modified. Indeed, now assume that low-income households receive 50 % of their income from wages, while the other 50 % comes from transfers. The regressivity of the carbon tax would be strongly reduced. We therefore see with this very simple example that the economic incidence depends on the sources of income of each types of household. In the case of BC, the source of revenues per deciles had already been presented in table 4. We saw that returns on investments represent only a very small and constant share (around 2 % for the first nine deciles, and 4 % for the top one) of household's revenues. Therefore, returns on investments do not strongly impact the final incidence of the carbon tax. The important difference is between transfers and wages. Poor households receive a large share of transfers (75%), while the remaining of their revenues is generated by wages (22 %). On the opposite, 93 % of the top decile revenues come from wages, while they receive only 2 % of transfers. Therefore, it should now be clear why Beck et al. find this revenue side effect to be progressive: rich households' main source of income (wages) is reduced by the carbon tax, while low income' main source of income (transfers) are increased. Therefore, low-income households are relatively less affected by the carbon tax than high-income households.

Now how can we conclude the question of the regressivity of carbon pricing policies? First, we have to admit that there is no clear empirical answer to this question. It is clear that households are affected through two channels; the source of income and the use of income. According to the empirical literature that we have introduced in this thesis, heterogeneity of spending tends to make carbon pricing policies regressive. This is supported by all partial equilibrium analyses. Nevertheless, we have seen that in some contexts (for example the carbon tax in BC), CGE found this spending side to be distributionally neutral.

Regarding the revenue side, the few studies that integrate this element have found that it makes the policy more progressive. This points out to an important bias of the literature, since the majority of distributional studies do not include this effect. Therefore, we agree with the conclusion of Rausch et al. (2011), which stated that this problem "biases distributional studies towards finding carbon pricing to be regressive" (p. 25).

As to which of those two effects is larger, this remains to our opinion a very opened empirical question. We showed that CGE analysis provided a powerful tool for future researches. For instance, Beck et al. found that the overall effect of a carbon tax was progressive in British Columbia (Canada). Rausch et al. (2011) have conducted the same analysis with American data. Their results indicated that a carbon tax in the USA would be distributionally neutral (Rausch et al., 2011, p. 24). In their results, the progressive characteristic of the income side is balanced by the regressive characteristic of the spending side. The difference between those two results perfectly emphasize that empirical results are highly influenced by contextual factors and assumptions of CGE model. As an example of contextual factor, the case of BC showed us that a detail in the production of energy had a big impact on the distributional effect of the carbon tax. Indeed, the fact that electricity was produced mainly by hydro (and was thus not taxed) was a big reason of why the carbon tax was in fine progressive. Regarding the assumptions of CGE model, multiple examples can be found on how they impact the results. For instance, we have discussed earlier how the results of Beck et al. (2015) changed when assumptions on capital and labor mobility were modified. These are only two examples that testify of the extreme difficulty to correctly estimate the distributional impact of carbon pricing policies. Nevertheless, it is clear that "advances in computing power and numerical techniques make solving CGE models with large numbers of households quite tractable" (Rausch et al., 2011, p. 25). Therefore, this method might bring a better empirical answer to this question in the future.

If we go back to the notion of acceptability, we saw that people against carbon pricing schemes often pointed out the regressivity of carbon prices. Unfortunately, we have been unable to clearly deny this critic. Until the literature finds clear evidence that carbon pricing is progressive, this argument will remain important. Furthermore, opposing people can even rely on studies which study only the spending side effect. As we saw it, those are almost guaranteed to find evidence of regressivity. Therefore, we now need to discuss possible solutions to this issue of regressivity. Those solutions will have to satisfy two conditions. First, they will have to make carbon-pricing schemes more progressive. Secondly, they will have to also increase acceptability for carbon pricing. The most intuitive way to solve this issue is to discuss the use of tax revenues. Indeed, a carbon tax imposes a cost on citizens, but also allow the government to use those revenues in the best possible way. The next part then investigates how revenues should be redistributed in order to satisfy the two conditions that we have just mentioned.

2.2. How should revenues be redistributed?

Up to now, we have left aside the question of the use of carbon tax revenues. This made sense, since our first goal was to see if carbon taxes were regressive or not, no matter how revenues would later be used. We just saw that the empirical answer to this question remains unclear and depends on the context. Therefore, the possibility that a carbon tax might be regressive remains strong. It is then imperative to discuss solutions available to reduce this potential regressivity. Indeed, we saw that regressivity was one of the main arguments against carbon pricing policies, and therefore limited the implementation of ambitious carbon policies. One of the most direct way to address the regressivity of a carbon pricing policy is simply to use the revenues for this objective. As stated by Mathur and Morris (2014), "the final incidence of a carbon tax depends heavily on what happens to the revenue".

This chapter will be divided in three sections. In the first one, we discuss the possible options to use revenues. We will discuss the three main possibilities to redistribute revenues: reducing existing distortionary taxes, supporting low-income households through lump-sum transfers or earmarking the revenues for investment in environmental innovation. We will see that there is a clear trade-off between equity and efficiency. This complicates the task of policy makers, and may point out to a redistribution that combines lump-sum transfers and reduction of taxes. The second section will allow us to link the possible solutions to the notion of acceptability. Indeed, we analyze which redistribution method generates the highest level of acceptability. This is an important point from the point of view of policy making. The case of France[37] perfectly illustrates this. Indeed, the fact that France used the revenues of carbon taxes to reduce its deficit was a big reason why people were unhappy with the policy. Using quantitative surveys and choice experiments will allow us to analyze which method is better accepted by citizens, and why it is so. In the last section, we will formulate policy suggestions on the use of revenues, based on the findings of the two preceding sections.

2.2.1. Available options

As we just said it, this first part of the chapter is dedicated to presenting the main options to redistribute revenues. Since the theme of this chapter was regressivity, we will particularly be interested in the distributional effects of those options. Nevertheless, efficiency and environmental objectives also have to be taken in consideration and will be included in our analysis. First, we present the two main ways to redistribute revenues: lumps-sum transfers

[37] Discussed a bit earlier, in the introduction to chapter 2.

and cuts in existing taxes. Discussing those two options together makes sense, since we will see that they have opposite effects in terms of efficiency and equity. Therefore, we will be able to show the existing trade-off between those two options. Secondly, we will present other possible strategies to redistribute revenues, mainly reducing public deficits or promoting green spending. After having presented all those options, it will be clear that none of the redistribution method is an optimal choice. Therefore, we will use the example of the carbon tax in British Columbia to show how those different options can be combined in a positive way.

2.2.1.1 Lump-sum transfers versus cuts in existing distortionary taxes

The intuitive way to make a carbon tax progressive is by returning an equal amount of money to all households. This is what the literature refers as lumps-sum transfers. Since the amount of money is the same for rich and poor households, the transfer represents a larger share of income for poorer households. It would therefore clearly be a progressive way to redistribute revenues[38]. This is for instance the redistribution method chosen by Switzerland. Each Swiss citizen receives a deduction from its health insurance bill, no matter his yearly consumption of CO_2 or his income. This way to use carbon tax revenues clearly focuses on equity concerns.

On the other side, carbon tax revenues could be used in order to reduce existing distortionary taxes. Distortionary effects of taxes are a huge part of the field of public economics. One well-known effect is that by increasing labor taxes, labor supply tends to decrease (substitution effect). Since the marginal benefit of working is reduced, some individuals decide to substitute leisure against work. This creates a deadweight loss, which in economic terms is seen as inefficient. By using carbon tax revenues to reduce those distortionary taxes, it would increase incentives to work, invest, etc… As a consequence, "the best recycling scheme is not to redistribute revenues through lump-sum transfers, but to reduce other pre-existing taxes that distort employment choices" (Combet and Méjean, 2017, p. 5). This process is called "revenue recycling" or "tax swap" in the literature. It is exactly the idea of the double dividend. The carbon tax allows reducing pollution (first dividend), but also to increase economic activity by reducing other distortionary taxes (second dividend). In order to be as efficient as possible, policymakers would need to cut down the most distortionary existing taxes. Most economists tend to agree on the fact that taxes on capital (corporate taxes) are the most distortionary ones (Metcalf, 2015, p. 6). Therefore, in order to optimize

[38] Mathematical proof of this intuition can be found in Klenert and Mattauch (2015).

allocative efficiency, carbon taxes revenues should be used to reduce corporate taxes. What about the distributional effects of such redistribution? Since corporate taxes are usually paid more by the richest households, reducing those taxes would benefit relatively more to rich households. This clearly creates an implicit trade-off between equity and efficiency criterions: “the most efficient tax swap may be the most regressive” (Morris and Mathur, 2015, p. 109).

In summary, lump-sum transfers allow for a progressive distribution. Unfortunately, since they do not reduce any distortionary taxes, they do not generate any productive activity. On the contrary, revenue recycling is optimal in terms of efficiency, particularly if corporate taxes are reduced. Unfortunately, a “uniform reduction of distortionary taxes has undesirable consequences in terms of redistribution” (Combet and Méjean, 2017, p. 6).

This clear trade-off between equity and efficiency has also been found empirically, for instance in the analysis of Dinan and Rogers (2002). They have tried to analyze how government decisions determine winners and losers in the implementation of a cap-and-trade scheme in the United States. More precisely, they look at the consequences of three different redistribution methods on both efficiency and equity. We present their results because it is one of the rare empirical study that compares multiple different options of revenue redistribution in the same context. The first option is to redistribute revenues through equal lump-sum transfers. The two other options are revenue recycling ones, once by cutting down corporate taxes, once by reducing payroll taxes. Similarly to previous analyzes presented in this thesis, they use input-output matrices: This allows estimating the effect of the carbon price on each household. The authors also rely on partial equilibrium in order to estimate the deadweight loss created by the carbon price policy[39]. This deadweight loss is separated in two effects. The first effect is the modification of consumption patterns, resulting from higher energy prices. The second effect is the impact on factor supplies. Indeed, since returns on capital and labor are reduced, it will reduce factor supply. It is important to emphasize that the first effect should be the same no matter how redistribution of revenues is organized: redistribution has no effect on the demand and supply of energy-intensive goods. On the contrary, the redistribution method can partially offset the effect on factor supplies. Indeed, by reducing other distortionary taxes, revenue recycling could increase factor supply (for instance labor).

[39] For more details on the empirical methodology, see Dinan and Rogers (2002), pp. 208-211

Table 6: Change in annual after-tax average household income under various redistribution strategies

Allocation /Revenue recycling strategy	Income groups 0-20	21-40	41-60	61-80	81-100	All households: Deadweight loss in carbon markets	Deadweight loss in factor markets
Auction/Decrease Corporate Tax rate							
In dollars	-495	-479	-595	-754	1505	-104	-43
As a percent of income	-5.9	-2.4	-1.9	-1.6	1.5	-0.3	-0.1
Auction/ Decrease Payroll Tax							
In dollars	-451	-342	-258	-42	277	-104	-43
As a percent of income	-5.3	-1.7	-0.8	-0.1	0.3	-0.3	-0.1
Auction/ Lumps-sum rebate							
In dollars	294	101	-211	-589	-1661	-104	-291
As a percent of income	3.5	0.5	-0.7	-1.3	-1.6	-0.3	-0.7

Source: Dinan and Rogers (2002), p. 213

Their results (Table 6) perfectly testify of this trade-off between efficiency and equity. Let's first look at the distributional effects. We see that allocating the revenues through lump-sum transfer is the only way to have a progressive policy. In this case, households in the lowest decile would see their after-tax revenue increase by 3.5 %. Households from the richest decile would bear a reduction of their income of 1.6 %. Also, we see that reducing corporate tax rates is more regressive than cutting payroll tax rates. This verifies the theoretical expectation we had just discussed. Now in terms of efficiency, it is clear that the deadweight loss in the factor market can be strongly reduced by decreasing distortionary taxes. In fact, doing so reduces this size of the deadweight loss by nearly 7 times, compared to a situation where revenues are distributed through lump-sum transfers. Mathur and Morris (2014) have also found that reducing corporate or payroll tax rates would make a carbon tax more regressive, as it would benefit richer households more than low-income ones.

2.2.1.2 Other available options

Even though the literature focuses a lot on the two previously mentioned options (lump-sum transfers and tax cuts), in practice other options are also used (Carl and Fedor, 2016). We here briefly discuss three additional types of revenue's use.

Green spending

Green spending by definition includes "any form of government spending on or subsidy toward (primarily) energy efficiency and renewable energy research, development, and deployment, as well as other efforts intended to reduce greenhouse gas emissions related to agriculture and forestry, landfill management, alternative vehicles, and mass transit or transit-oriented development, as well as measures to adapt to climate change" (Ibid, p. 51). This definition however remains vague on how this can actually be done in reality. A first possibility could be to give incentives for energy-saving investment. In practice, this can for instance mean allowing subsides or tax credits for any citizens buying solar panels or electric cars. From an environmental point of view, this would be positive. Indeed, it further reduces CO_2 emissions. Unfortunately, this would be a regressive way to redistribute revenues (Dinan, 2015, p. 132). Why? Those investments in new technology remain expensive and would be done mostly be richer households. Therefore, they would be the ones receiving the higher share of the revenues. Lastly, this solution could also create distortions in investment choices. Indeed, it could lead to investments that are in reality not cost-efficient, in fine increasing the total cost to reduce CO_2 emissions (Ibid, p. 132). A second option for green spending is to earmark a share of the revenues for investments in R&D and innovation in clean energy technologies. Bowen (2015) emphasizes the need for such investments: "Even in the major international companies which manufacture solar and wind equipment, the ratio of R&D to sales is under 2 per cent, compared with over 5 per cent in consumer electronics and 15 per cent in pharmaceuticals" (Bowen, 2015, p. 7). Ironically, public governments may be one of the reasons of this underinvestment. Indeed, some parts of the energy supply market are generally seen as public goods, and therefore provided by the state. This might reduce incentives for private firms to invest in new energies technologies, as they might fear not being able to reach high returns on their investments (Ibid, p. 6). Nevertheless, from an allocative efficiency point of view, the state should not blindly foster those investments in clean energy technologies. Rather, "the costs and benefits of these interventions would need to be carefully assessed, including relative to other potential investments in R&D" (Morris and Mathur, 2015, p. 111).

Reducing public debt (or public deficits)

Another possibility would be to allocate the revenues of carbon pricing to reduce the public debt (or deficits). In this case, those revenues become a part of general public budget, and there is no obligation anymore to use them for a predefined task. We already mentioned a few times that this was the case in France, and that it was a big reason why people were unhappy with the policy. In terms of allocative efficiency, Morris and Mathur (2015) state that it might produce "even larger benefits than using it to cut current taxes"[40] (Ibid, p. 111). The main reason behind this conclusion is that it reduces the need for a future increase in taxes. Governments may agree more easily on implementing carbon policies, knowing that it "has the potential to relax the financial constraints on government, giving them a wide range of options for extra spending at the margin" (Bowen, 2015, p. 15). Regarding its distributional implications, it is impossible to discuss it for this option, given the uncertainty on what those revenues will in fine be used for (Morris and Mathur, 2015, p. 111).

Reduce households' energy costs

This last option is a bit different: it is a perfect example of how revenues should not be redistributed. In some practical cases, it has been proposed that revenues should be used to reduce households' energy costs. This was for example the case in the American Clean Energy and Security Act (2009)[41], where part of the revenues of a cap-and-trade scheme in the USA should have been used to subsidize households' energy bills. Why does this proposition make no sense? Remember that the main goal of a carbon pricing policy is to reduce CO_2 emissions. It should now be clear to our readers that this is done by increasing the prices of energy-intensive goods. This creates strong incentives for economic agents to change their behavior, by consuming less energy-intensive goods. Now, with this proposition of revenue use, this price signal would be strongly weakened. Indeed, the increase of price induced by the carbon price would be balanced by those subsidies. By subsidizing household's energy bills, households might not see an actual increase of prices for their use of energy. They have no longer interests to reduce their use of energy, or to switch to less emission-intensive energies. Therefore, such a proposition would reduce the environmental effect of carbon pricing policies.

[40] We here only refer to the allocative efficiency. It is clear that the revenues generated by the carbon tax remain small with regards to the public budget, and therefore are clearly not meant to totally reduce the public deficit…

[41] This act was an energy bill which wanted to implement a cap-and-trade program in the United States. The House of Representatives approved it on June 26, 2009. It was then never passed on the American Senate for further discussion.

We have now presented and discussed all the main options found in the literature to use carbon tax revenues. In the table below, we have summarized those policies and their effects on the three important objectives of environmental policies: Cost effectiveness, equity and environmental efficiency. This table immediately shows an important conclusion: no single option performs well in all of the three objectives. Unfortunately, there is therefore no clear answer on how revenues should be used. The solution chosen by a particular country should depend on which criterion he values the most. In the next section, we use the example of British Columbia to show that in practice, countries rarely use only one of those options. Rather, different methods of redistribution are combined.

Table 7: Summary of possible options to use carbon-pricing revenues

	Cost efficiency	Equity	Environmental efficiency
Lump-sum transfers	(−)	(+)	/
Cuts in distortionary taxes			
• Payroll taxes	(+)	(−)	/
• Corporate taxes	(+)(+)	(−)(−)	/
Green spending			
• Incentives for energy saving investment	(−)	(−)	(+)
• Earmarking for R&D	(−)	/	(+)
Reducing deficits	(+)	Unclear	/
Reducing households' energy costs	(−)	(+)	(−)

For cost efficiency: (−) stands for a reduction of cost efficiency, (+) means that cost-efficiency is improved.
For equity, (+) implies a progressive redistribution, while (−) a regressive one.
For environmental efficiency, / stands for no effect (either positive or negative), compared to a situation without any revenue recycling.

Source: Author's own representation, based on discussions in subsections 2.2.1.1 and 2.2.1.2.

2.2.1.3 A combination of different redistribution: the case of British Columbia

We have now presented the main options to use carbon tax revenues. According to data from Carl and Fedor (2016), use of carbon pricing revenues in the world is actually split between three main options. First, 36 % of total revenues are redistributed to citizens or firms, either by lump-sum transfers or tax cuts. Secondly, 27 % of total revenues are directed towards green spending. Lastly, 26 % of revenues are allocated to general public budget. The discussion that we just had on those methods was rather theoretical. In order to see if those theoretical elements hold in practice, we now focus on the case of British Columbia (BC). We had already discussed the case of BC when assessing the distributional effects of a carbon tax prior to revenue recycling. We now focus on the effects of the redistribution method chosen by the government of BC. We have not chosen this case randomly. Rather, it is particularly useful to our discussion, and it is important to explain why. First, since the carbon tax applied in BC was the "first comprehensive and substantial carbon tax in North America" (Murray and Rivers, 2015, p. 674), it has been the subject of a few empirical analyzes. These provide recent estimations of the effects of a carbon tax, and of its revenues redistribution. Secondly, in British Columbia, revenues have been used by combining both lump-sum transfers and tax cuts. We saw in the previous section that there was a trade-off between equity and cost-efficiency when choosing between those two options. Therefore, the natural experiment of BC allows discussing an important question: Is it possible to combine lump-sum transfers and tax cuts, so that both progressivity and cost-efficiency are increased (compared to a situation without revenue recycling)? This leads to an other reason why this natural experiment is particularly useful. Since some studies analyzing the case of BC use CGE simulation, we are able to precisely discuss the effects of the revenue use for both equity and efficiency criterions.

Before to start discussing the consequences of this redistribution method on equity and efficiency, we need to mention one last reason why we choose the case of BC. To our opinion, it was key to discuss a practical case of carbon pricing which was proven to be effectively reducing GHG emissions. Indeed, it would have made no sense to discuss a carbon tax which does not fulfill its main goal: reduce GHG emissions. Since the policy in BC has been in place for a few years already, some studies have assessed its environmental effects. In their CGE analysis, Beck et al. (2015) find that GHG emissions would be reduced by around 9 % by the carbon tax. This is the same result obtained by Elgie and McClay when applying difference-in-difference (DiD) to the case of BC. Up to now, all existing empirical analyzes agree on the fact that the carbon tax in BC is effective at reducing emissions (Murray and Rivers, 2015, p. 678). Therefore, we are confident that this case study provides a good opportunity to discuss an environmental effective carbon pricing policy.

We will first briefly explain how revenues are being used in British Columbia's carbon tax, before to focus on its consequences on equity and efficiency.

The redistribution method in BC

The most interesting characteristic of the BC carbon tax is that it was designed to be revenue neutral. It means that all revenues perceived are returned to residents in other forms. Therefore, rather than being an additional tax, it can truly be described as a "tax shift".

First, revenues are used to cut existing taxes (Rivers and Schaufele, 2015, p. 25). The following table summarizes the different adjustments made to the fiscal system of BC. First, the "BC government lowered the tax rate on the bottom two personal income tax brackets" (Ibid, p. 25). As it can be seen in table 8, the income tax rate for an income of 100'000 $ has dropped from 8.74 % to 7.72 %. Further revenue recycling was targeted at businesses. In BC, two different tax rates exist. Firms earning more than 400'000 $ are subject to the "provincial corporate tax rate" (12 %), while small businesses (the ones earning less than the provincial business limit of 400'000 $) are charged with the "small business tax rate" (4.5 %). The second measure taken was to increase the provincial business limit to 500'000 $. As a consequences, businesses earning between 400'000 to 500'000 $ would now move from the provincial corporate tax (12 %) to the small business tax rate (4.5 %). The third measure was to progressively reduce both of those corporate tax rates by 2 %.

Table 8: Key characteristic of the revenue neutrality of the BC carbon tax design

	Carbon tax ($/tonnes)	Carbon tax (cents/ litre)	Average provincial personal income tax rate on $100,000 (%)	Provincial business limit	Provincial corporate income tax rate (high income) (%)	Provincial small business tax rate (low income) (%)
July 1, 2007	0	0	8.74	$400,000	12.0	4.5
July 1, 2008	10	2.34	8.02	$400,000	11.0	3.5
July 1, 2009	15	3.33	7.89	$400,000	11.0	2.5
July 1, 2010	20	4.45	7.86	$500,000	10.5	2.5
July 1, 2011	25	5.56	7.83	$500,000	10.0	2.5
July 1, 2012	30	6.67	7.72	$500,000	10.0	2.5

In column 2, $/tonne refers to the price in Canadian dollars per carbon dioxide equivalent tonne. Column 3 displays the tax in cents per litre of unleaded liquid gasoline as calculated by the BC Ministry of finance. The Personal Income Tax rates displayed in Column 4 are the average provincial tax rate for a household earning a nominal income of $100'000 per year up to the point of the tax change (i.e., the tax rate is calculated such that all income is assumed to be earned instantaneously on July 1st). The provincial business limit in Column 5 is the level at which the high income corporate becomes effective. Column 6 presents the corporate tax rate for business profits that are greater than the provincial business limit, which is displayed in column 5. The Small business tax rate as shown in column 7 applies to net income that is less than the small business limit.

Source: Rivers and Schaufele (2015), p. 26

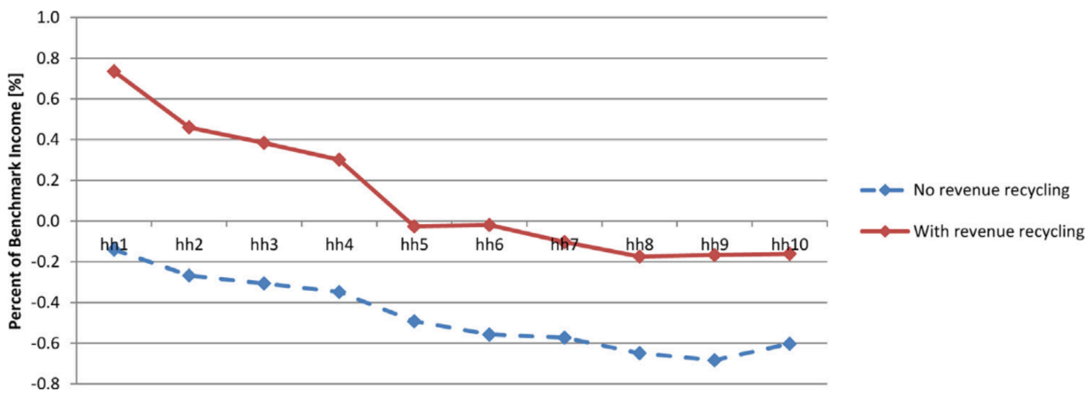
Secondly, and to relief low-income households of a share of the burden, two lump-sum transfers were implemented: "Low income households receive quarterly rebates, which, for a family of four, equal approximately $300 per year" (Ibid, p. 25). The second transfer was targeting specifically rural households, because those were fought to have fewer possibilities to use public transports. Indeed, there were concerns that those households would bear a very large burden of the carbon tax. Therefore, “northern and rural homeowners received a further benefit of up to $200” (Ibid, p. 25).

The official website of British Columbia mentions that carbon revenues will also be used to encourage green initiatives. Nevertheless, it is not mentioned in any of the existing empirical analysis. This is because it is an aspect still under development from the government of British Columbia. Indeed, they are currently developing a program called “Clean BC” (or Clean Growth Incentive Program), which aims at giving incentives to businesses and citizens to invest in new technologies. For instance, a share of BC’s carbon tax revenues may in the future be directed to businesses that become energy-efficient in their production process.

Distributional effects

The analysis of Beck et al. (2015) provides a good starting point to discuss the distributional effects of revenue recycling in the case of BC. We had already used this paper for the previous chapter. Therefore, its basic methodology can be found in chapter 2.1.3. We here focus on the second part of their analysis, which we had not treated earlier. The authors model a scenario, in which they “represent the existing BC revenue recycling scheme as closely as possible” (Beck et al., 2015, p. 52). They compare it to the scenario in which no revenue recycling was modeled. Therefore, the difference between the two scenarios allows to clearly estimating the effects of the redistribution scheme. Table 9 shows the results obtained by Beck et al. (2015).

Table 9: Welfare impacts: No revenue recycling vs. with revenue recycling



Source: Beck et al. (2015), p. 57

The blue line represents the burden of the tax relative to income, without the revenue recycling. The red line represents the same thing, but with revenue recycling. As we just explained, the difference between the two scenarios is then only the result of the redistribution. What does it tell us? First, the redistribution benefits to all households. Indeed, each household decile is better off after the redistribution. Nevertheless, it benefits relatively more to low-income households. Indeed, we can see that the improvement induced by the redistribution is higher for the lowest decile (around 0.9) than for the highest one (0.4). Therefore, in this particular case, the government of BC has been able to design a clearly progressive redistribution of revenues.

Then the authors tried to distinguish the effects of each redistribution method (Ibid, pp. 57-58). Their results are interesting, as they confirm the theoretical intuitions seen previously. First, lump sum transfers play a large role in making this redistribution progressive. Indeed, once the direct transfers have been done, they amount to 0.7 % of the lowest decile's average income. On the contrary, they are an insignificant part of the top decile's income. This is an intuitive result, and one that confirms that lump-sum transfers are an effective way to redistribute revenues progressively. Secondly, and also as we could have expected, reducing income taxes is slightly regressive. Indeed, it benefits high-income households more than low income ones, because labor income represents a larger share of their total revenues.

"However, in total the existing revenue recycling scheme enhances the progressive nature of the tax, and renders it welfare-improving for low-income households" (Ibid, p. 58). For us, this is an interesting result. Indeed, it testifies that it is clearly possible to design a redistribution mechanism that protects low-income households, without using only lump-sum transfers. Therefore, even tax cuts can be introduced in a progressive redistribution, as long as they are correctly balanced with lumps-sum transfers. Of course, how much of each method has to be used will depend on the context. Empirically, it would be easy to find the required level of lump-sum transfers needed to protect a chosen share of the population. For instance (let's briefly move away from the specific case of BC), Mathur and Morris (2014) have estimated this when simulating a carbon tax of 15 $ per ton of CO_2 in the USA. They found that "if policymakers direct about 11 % of the tax revenues towards the poorest two deciles, … then those households would on average be no worse off after the carbon tax than they were before" (Mathur and Morris, 2014, p. 333). Of course, we saw earlier that using revenues to provide relief for the lowest earners also meant sacrificing some efficiency[42]. But in this case, this would still leave almost 90 % of the revenues for other possible uses (for instance reducing existing taxes or green spending).

[42] This is the trade-off between efficiency and equity which we have discussed earlier.

Macro-economic effects

Now that we have seen that this policy and its redistribution are progressive, let's see how much cost it generates. We saw in chapter 1 that a carbon pricing policy is a cost-effective method to reduce CO_2 emissions. Nevertheless, it is clear that some costs are still generated. The redistribution method used in BC is supposed to reduce some of those costs, by reducing existing distortionary taxes. The question we have to answer in this section is then how large are the effects of this policy on the economy of BC. If the economic consequences are large and negative, this could complicate the implementation of further similar carbon pricing policy. Indeed, in our initial discussion on acceptability of carbon pricing (1.4.3), we saw that the absolute level of the costs generated by the policy (and not only their distribution) was also a big reason why people did not favor carbon pricing policies (Carattini et al., 2017).

Still referring to Beck et al. (2015) CGE model, they report a modest negative impact: aggregate welfare[43] in BC is reduced by 0.08 % (Beck et al., 2015, p. 54). Without revenue recycling, aggregate welfare would drop by 0.13 %. Therefore, they have empirically proven the existence of a weak double dividend ("revenue recycling improves welfare relative to no revenue recycling", (Ibid, p. 54)), but not of a strong double dividend. Indeed, "welfare is still negatively affected" (Ibid, p. 54). Regarding this particular study, it is also important to mention that they "ignore the welfare gains of reduced greenhouse gazes in this calculation" (Ibid, p. 54). This is one of the limit of this kind of study, as most articles proceed in the same way. The reason behind this is that is it difficult to monetary value this reduction of CO_2 emissions.

The approach chosen by Beck et al. (2015) is to estimate the impact of the carbon tax with simulations. Another type of approach could be to "compare observed economic outcomes against counterfactual statistical estimates of the outcomes without this policy" (Murray and Rivers, 2015, p. 679). Since those approaches have different assumptions, they might lead to different results. It is therefore interesting to present an example of a study that uses this second approach.

Metcalf (2015) conducts a difference-in-difference (DiD) analysis, comparing GDP growth in BC and in the other Canadian provinces (first difference), before and after the implementation of the carbon tax (second difference). Since BC is the only province having established a carbon tax in 2007, all the other Canadian provinces provide a perfect control group. Their

[43] Aggregate welfare is defined as a function of final consumption, leisure and investment in this particular study.

analysis points out to an interesting result: the coefficient of the interaction between *BC* and *after 2007* gives a small positive coefficient (0.4 percentage points). This means that the carbon tax has very slightly increased economic growth in British Columbia. Nevertheless, this coefficient is statistically insignificant. Therefore, the only conclusion which can be drawn is that this DiD fails to show any negative effect of the carbon tax on BC's growth.

Using the same method of DiD (estimating the effects of the tax in BC by using the other Canadian provinces as a control group), Yamazaki (2017) has assessed the impact of BC's carbon tax on employment. Theoretically, it is not clear if a carbon tax combined with a tax swap should reduce or increase employment (Yamazaki, 2017, p. 198). Indeed, on one side, the tax increases the marginal cost of production (Ibid, p. 200). This should lead to a decrease of economic output, and in fine to reduction of labor demand. This "output effect" is expected to be even larger in energy-intensive industries. On the other side ("redistribution effect"), redistribution of revenues could lead to an increase of both labor demand and labor supply (Ibid, p. 201) First, redistributing the revenues increases the revenues of households, which they can use for consumption. This can increase output, and therefore increase the demand for labor. Secondly, if taxes are redistributed through a reduction of income tax rates, workers receive incentives to reduce consumption of leisure, and increase labor supply[44]. Therefore, knowing the true effect of a carbon tax on employment is an empirical question. Yamazaki's results of the DiD show that the carbon tax in British Columbia has led to the creation of 63'000 jobs between 2007 and 2013. This represents a yearly increase of 0.74 %. By distinguishing the effects across industries, the authors find that "the most carbon-intensive and trade sensitive industries see employment fall with the tax while clean service industries see employment rise" (Ibid, p. 198). One important channel in this result is the "output effect". Emission intensity negatively affects employment, after the introduction of the carbon tax. Simply said, the carbon tax logically increases the cost of production relatively more for very energy-intensive industries (because the increase of marginal cost is proportional to their use of energies). On one side, this is a good result from the point of view of environmental objectives: energy-intensive activities are replaced by less-intensive ones. But this can also lead to concerns of competitiveness for trade-exposed industries[45]. We will deal with this concern in the third part of this thesis.

[44] This could also be countered by the revenue effect, which leads to a decrease of labor supply.
[45] This issue will be discussed in the third part of this thesis.

The goal of this section was to present the different options to offset the regressivity of a carbon tax. We saw that different options were available, each of them having different effects on redistribution and cost-efficiency. Since no single option outperforms the others in all objective criterions, it appears that combining multiple options can be useful, as it has been done in the case of British Columbia. Now, an important point for sound policy-making is to know how citizens accept these different redistribution options. Indeed, we saw that some parts of the revenues can easily be used to protect the lowest deciles of the population. But what should be done with the rest of the revenues, so that public acceptability is maximized? This is the topic of the next section.

2.2.2. Public acceptability for those redistribution options

As we just said, this section will link our current discussion on regressivity to the broader notion of acceptability. It is important to remember that we have two major objectives in this thesis. The first one was to identify limits to the acceptability of carbon prices, and understand whether they are justified or not (1). The second goal is to identify the best solutions available, in order to formulate clear policy suggestions (2). Regarding the question of regressivity, we have so far treated objective (1). On the contrary, our discussion on the solutions is not completed yet. We now need to discuss whether some of the solutions presented in the previous section generate higher level of acceptability. This will then allow us to formulate policy suggestions in the next and last section of this chapter.

We claim that this is an important task. Indeed, some focus group studies have showed that the preoccupations of policy-makers were not in line with the ones of the general public. This was for instance shown by Beuermnn and Santarius (2006) in the case of Germany. Policy-makers were mostly concerned with small details of the German Ecological Tax Reform (ETR) design[46]. On the contrary, citizens (the "general public")' interviews revealed that they were highly concerned by the lack of environmental effects of the ETR. Even tough most of them (79%) agreed on the basic principle of the environmental taxation, they did not understand well the idea of the double dividend. Or rather than not understanding the concept, they were not convinced by the fact that both environmental and economic issues could be solved by an environmental tax reform. As a result, "the majority was clearly in favor of using revenue for environmental purposes" (Beuermann and Santarius, 2006, p. 923). In addition, they also favored two separate policies (one for the environment and one for the economy), rather than combining both under a tax swap. This very brief example is only an example that

[46] For instance, they criticized the fact that renewable energies produced by households was also taxed.

in some cases, policy-makers are clearly unaware of citizens' concerns. Therefore, this section should give useful advises on how to design revenue recycling in a way that will be accepted by citizens.

To do so, we will now use another and more recent part of the literature. Lately, multiple surveys (quantitative and qualitative) and choice experiments have been conducted in order to see which redistribution option is the most accepted. Qualitative surveys will allow us to go further than simply showing which option is more accepted. Rather, we will also be able to discuss the reason behind individual's preferences. We will often refer to the paper from Carattini et al. (2018), which provides a great discussion on this question, as well as a detailed and recent literature review. This section is separated in four small sub-sections. First, we briefly present the general order of preferences for the three main redistribution options. Then, we focus on each of those redistribution methods, and attempt to understand why each is (or not) popular among citizens.

2.2.2.1 The overall order of preferences

We saw that in terms of cost-efficiency, reducing existing taxes was the option favored by economists, rather than lump-sum transfers or environmental earmarking. Looking at studies, which have used focus groups to evaluate people's opinion, a clear pattern of preferences seems to appear. Those qualitative studies conducted in Denmark, France, Germany, Ireland and the UK all showed that "earmarking energy tax revenue to support further emissions reductions was the most preferred option for their participants, followed by social cushioning measures to help vulnerable groups"(Carattini et al., 2018, p. 6). Lastly, reducing existing taxes is always the least favorite option of citizens. It is clear that findings from qualitative surveys should in no case be interpreted as results applying to the entire population (they are not statistically representative). Nevertheless, the fact that multiple qualitative studies conducted in various locations witness the same appeal of individuals for green spending is striking.

2.2.2.2 Preference for environmental earmarking

Baranzini and Carattini (2017) have conducted a survey on 300 random individuals in the streets of Geneva (Switzerland). Their goal was to test a few hypotheses on which characteristics of a carbon tax would affect individual's acceptability for this policy. One of their hypothesis is particularly relevant to our discussion: "Earmarking revenues increases acceptability, especially for environmental purposes" (Ibid, p. 200). First, after a brief discussion on the effects of a carbon tax (120 CHF per ton of CO_2), respondents were asked about their acceptability for such a policy. It is important to precise that up to this point, the policy had been presented without any revenue-recycling plan: revenues were simply added to the public budget. At this stage, 49 % of respondents reported to be in favor of this policy. In a second step, the authors asked individuals how revenues should, based on their opinion, be redistributed. In line with the results obtained by the qualitative survey presented earlier, 60 % of respondents favored the option of earmarking revenues for environmental purposes. Reducing the regressive effects of the policy ("social cushioning") comes second in the order of preferences, while only a small minority supports tax cuts for firms and individuals (Ibid, p. 205). In the last step, the authors asked respondents who reported to be against the policy in step 1, whether they would change their mind if their favorite revenue recycling option was implemented. According to the results, 23 % of individuals who had chosen environmental earmarking as their favorite redistribution method have reconsidered and now agree to the policy. This change is statistically significant. By using environmental earmarking as a redistribution method, the overall acceptability for the policy is raised from 49 % to 64 %. Even though the authors claim that their results can be extrapolated to the Swiss population, we remain careful with those results. The main reason why is that in reality, it is very unlikely that all revenues would be used for environmental earmarking. As we saw it earlier, revenue recycling often combines multiple methods. Therefore, such a large effect would to our opinion not be observed in reality. Nevertheless, it clearly shows that by using revenue recycling to increase environmental investments, acceptability for the carbon tax can be increased. Our second concern regarding those results is a more general one: the fact that biased may occur when conducting surveys. Mainly, individuals may be less critic about the costs of a policy in a survey than in real votations or other behavior. Indeed, they perfectly know that reporting to be in favor of the policy will not lead to the direct implementation of the carbon tax discussed, and therefore not lead to any real costs. Other case studies have found a similar effect of earmarking on acceptability, for instance in the case of Norway (Saelen and Kallbekken, 2011).

A truly interesting question is to understand why people tend to be in favor of environmental earmarking. In the literature, we have found two reasons, which may explain this preference (Carattini et al., 2018, pp. 6-7). The first, and maybe more important reason, is the fact that people doubt the environmental effectiveness of carbon taxes. In the choice experiment conducted in Norway, Saelen and Kallbekken (2011) find that 80 % of the respondents agree to the following sentence: “In order for fuel taxes to have an environmental effect, it is crucial that the tax revenues are earmarked for environmental purposes”. Therefore, according to this explanation, earmarking the revenues is a tool to convince people that environmental improvement will be achieved[47]. Once they are convinced of this, they are more willing to contribute to this improvement. The second issue is the so-called “issue-linkage” concern: people do not understand why revenues from an environmental tax should be used to promote economic activity (which is the case when taxes are being cut down). In other words, they do not understand (or trust) the principle of the double dividend. The third possible explanation provided by the literature is a sense of distrust towards the government. If the use of tax revenues are not clearly specified, people which do not trust their government may believe that this money will be used for spending which they do not support. We argue that based on people clear preferences for environmental preferences compared to other clearly defined uses, this explanation is not valid. Why? Because if the concern of people was simply that the government does not respect its promises, “any specific use of the revenues should work equally well in terms of garnering public support” (Saelen and Kallbekken, 2011, p. 2182). In their choice experiments, those authors do not find any impact of distrust towards the government on the preference for environmental earmarking. When we later formulate policy suggestions, it will be important to take into account those elements.

2.2.2.3 Desire to compensate low-income households

Here the question is the following: Will a progressive redistribution of revenues increase acceptability for a carbon tax? The discussion in this chapter was motivated by the fact that the regressivity of the carbon tax was one of the main concerns of citizens. Therefore, redistributing revenues in a more progressive way should increase acceptability. As a brief reminder, we saw that lump sum transfers and transfers targeted at low-income households were two options for a progressive redistribution.

The findings of the literature tend to show that discussing regressivity as a limit for acceptability was justified. Indeed, a positive relationship has been found between progressivity and acceptability: “People seem to value tax schemes that are perceived to be fair and that creates a lighter burden for low-income households” (Carattini et al., 2018, p. 7). This result has been found in both qualitative and quantitative surveys (Ibid, p. 7). In the first type, distributional concerns are always mentioned by respondents. Choice experiments have also been useful at showing people’s appreciation for a progressive distribution of the costs.

[47] The reader can find more empirical findings supporting this explanation in Saelen and Kallbekken, 2011, p. 2182.

For instance, in a choice experiment conducted in Turkey, Gevrek et al. (2015) were able to show that people clearly favored progressive environmental taxation. This choice experiment is also interesting, because in addition to the distributional structure of a carbon tax, respondents were also asked how revenues should be redistributed. In addition to favoring a progressive carbon tax, people also want revenues to be earmarked for environmental purposes. Unfortunately, this creates a clear trade-off for a policy-maker who wants to maximize acceptability for a carbon tax. Indeed, environmental earmarking is by no means a progressive way to redistribute revenues. Even though the main concern of citizens seems to be the environmental effectiveness of the carbon tax, "concerns over the distribution of impacts are likely to persist, and at the margin may make the difference between a successful policy and one that is rejected" (Carattini et al., 2018, p. 8). In our policy suggestion, we will provide a proposition to partially go around this trade-off.

2.2.2.4 Unpopularity of cutting other taxes

It may be complicated for policy makers to choose between earmarking revenues for environmental purposes and compensating low-income households, because both seem to increase support for carbon taxes. This problem does not really exist for the option to reduce existing distortionary taxes. Indeed, it is clearly a redistribution method which is not favored by citizens. This is a constant result among all surveys and choice experiments conducted until now. We admit that we were surprised by this result. Indeed, prior to writing this thesis, we were not aware of this preference of individuals. Rather, we expected at least a share of citizens to be in favor of a reduction of existing taxes. This expectation was probably driven by our training in environmental economics. Indeed, after having understood the logic behind the double dividend, it was (and still is) for us clear that a tax swap is a great policy tool.

The reasons behind this surprising result are the same than the reasons which lead individuals to favor environmental earmarking. The first reason we had identified was the "issue-linkage" concern: people do not really understand (or agree to) the logic of the double dividend. Rather, they would prefer to see revenues from environmental taxes being used for environmental spending, and not for economic purposes. The second reason was this idea of distrust towards the government. This issue could be even stronger in the case of reducing existing taxes. Indeed, for someone without very deep knowledge of the fiscal system, it would be extremely complicated to actually check whether taxes have been reduced or not. Therefore, trust in the government's promises becomes even more crucial.

2.2.3. Policy suggestions

This last chapter will conclude our discussion on the redistribution of carbon pricing revenues and regressivity. We use the most relevant findings from our discussion to present some interesting policy suggestions found in the literature. Those suggestions are interesting because they match with one of this thesis' goal: increasing acceptability for carbon pricing.

The reason behind this last section is the difference between people's preferences (2.2.2) and the advices of economic theory (2.2.1). We argue that up to now, policy makers have not taken people's preferences into enough consideration. Once again, the example of France is striking. The government chose to allocate most of the revenues to the reduction of the deficit. According to the results presented in the previous section, this redistribution option is not well accepted by the citizens. Policy makers may have been able to increase acceptability if revenues had been used in another way, for instance with green investments.

Before to present those suggestions, some clarifications must be done. First, we are aware that the empirical results discussed so far have been obtained in various countries. Our goal was not to focus on one specific case study, but rather present global trends concerning carbon taxes acceptability. Therefore, those policy suggestions remain general ones, and any country interested in those ideas will have to adapt it to their national context. Secondly, we must remind to our readers the initial purpose of this thesis. Our research question is to discuss solutions to increase acceptability of carbon pricing policies. Therefore, those suggestions will clearly be directed towards this objective. As a result, some of those ideas are likely to diverge from a "first-best" policy which would be advised by an economist without the objective of being really passed in legislation. To this regard, we agree with and follow Carattini et al. (2018) on the fact that "an imperfect carbon tax may still be better than no carbon tax at all" (p. 8). Of course, minimizing the costs for the society remains an important goal. Still, it is sometimes worth relaxing this objective if it allows implementing ambitious carbon pricing policies. Lastly, we base our suggestion policy on existing but very recent ideas proposed in a few research articles.

2.2.3.1 Following citizens' preferences for redistribution

The first policy suggestion in order to increase carbon-pricing acceptability is intuitive: follow citizens' preferences when choosing how to redistribute the revenues. Indeed, we saw in results from choice experiments that following people's preferences could significantly increase acceptability. Of course, people's preferences will likely differ across countries and times. Therefore, we suggest that an analysis should be conducted prior to the implementation of a carbon pricing policy. Randomized qualitative surveys and choice experiments would allow having a better understanding of people's main concerns. Even though preferences will likely vary across countries, we have seen that there is a clear trend witnessed in choice experiments and choice surveys.

Using revenues for environmental earmarking (or green spending)

First, it is clear that some substantial share of the revenues should be allocated to green spending or environmental earmarking (Carattini et al., 2018, p. 9). The reason behind this is that citizens doubt the environmental effectiveness of carbon pricing. By making real investments in green spending, the government can testify of his true commitment to reducing greenhouse gas emissions. We mentioned that preferences across countries are heterogeneous. Carattini et al. (2018) mention two cases (Sweden and Edinburgh) in which people did not favor environmental earmarking. Why? Residents believed that the carbon taxes were already successful at reducing emissions. This is in line with our theory: once people become to be convinced of the environmental effectiveness of a carbon tax, the need for environmental earmarking may progressively decrease.

Here, we would like to mention an element of the current political discussion that we see as an issue (and is related to green spending). In an article published on the blog of the ETH Zürich, Patt and Lilliestam (2019) make the case that "Climate policy is most effective when it helps people use alternative energy sources, rather than when it makes fossil energy more expensive". Their article critics carbon taxes for being only able to reduce CO_2 emissions, and not completely eliminating them: "To push technologies like solar power or electric cars, we need neither carbon taxes nor new subsidies, but rather new and updated regulatory frameworks and infrastructure networks" (Ibid, 2019). We find their argument against carbon pricing unfair. They argue that carbon pricing doesn't lead to an energy transition process. The core of their argument is that even though carbon taxes are effective at inducing people to use less fossil energies, "carbon taxes do little to stimulate investment in alternative sources of energy". This is where in our opinion; the suggestion of Carattini et al. should be useful. By using revenues of the carbon tax for green spending, the government has the opportunity to be an important driver of this energy transition.

Also, the carbon tax, in our opinion, has an important role in the energy transition process mentioned by Patt and Lilliestam. This energy transition requires making clean energy affordable. One important point is that customers will assess this affordability by comparing it to the costs of other alternative energies (which include “dirty” energies). Therefore, when the carbon tax increases the prices of dirty energies, it automatically increases the relative affordability of clean energies. To conclude this brief discussion, we claim that helping people use renewable energies should not be seen as an “alternative” of carbon pricing (like it is the case in the article of Patt and Lilliestam (2019)), but rather as two very complementary policies: a share of carbon pricing revenues should be addressed to finance the energy transition, as it is suggested by Carattini et al. (2018). In light of the different results presented in this chapter, this would very likely be supported by citizens, and therefore increase acceptability for carbon pricing policies.

Reducing carbon taxes' regressivity

The second important way to use the revenues is to protect low-income households, i.e. making the carbon tax less regressive (Carattini et al, 2018, p. 10). This was the initial concern of this part of thesis, and it appears very clearly that citizens do not favor regressive carbon pricing policies. Lump-sum transfers are an easy and low-cost way to improve progressivity. More targeted transfers can also be used. Even though the initial goal of a carbon tax is not to address inequalities issues, it seems to be important that a carbon tax is at least distributionally neutral: Regressive effects may highly reduce support for carbon taxes. This share allocated to social cushioning could increase as environmental earmarking may progressively be reduced, as well as when the tax rates are increased (Ibid, p. 10).

2.2.3.2 Improving communication about the carbon pricing policy

We have seen that very often, people do not understand, neither trust the concept of carbon pricing. Therefore, we agree with Carattini et al. (2018) on the need to better communicate with the citizens about those topics. Particularly, policy-makers should clearly communicate about the estimated reduction of emissions which would be achieved with a carbon tax. This is a proposition that has been supported by many policy-makers specialists, as well as by the Carbon Pricing Leadership Coalition: “The process of stakeholders engagement is not an addition, it is a fundamental part of the policy design” (Carbon Pricing Leadership Coalition). For us, this is a very intuitive, but yet under estimated element of the policy design. Going back to our presentation of carbon pricing policies in the first part of this thesis, communication was never discussed as an important design aspect of the policies[48].

[48] Because the relevant literature only very rarely discusses the need to better communicate about the carbon policies.

In addition to increasing general acceptability towards carbon pricing, better communication may also allow to modify how revenues have to be used. Indeed, we saw that citizens preferred environmental earmarking because they feared that CO_2 emissions would not truly be reduced. If better communication manages to reduce this fear, policy-makers would then have the possibility to use revenues in a more cost-efficient manner.

To this extent, the study conducted by Carattini et al. (2017b) bring very useful insights. Their set-up is interesting, as they conduct a choice experiment, while at the same time providing very good information to respondents. Their goal was to see if providing better information about carbon pricing policies would affect the acceptability of citizens. In order, to do so, they use Switzerland as a laboratory. On march 8 2015, Swiss citizens had to vote on an initiative wanting to replace the Value Added Tax (VAT) by a tax on non-renewable energies. This initiative was rejected by 92 % of the 2.2 millions of voters. The first part of their paper is to analyze the mains reasons behind this actual voting behavior[49]. The results are very similar to what we have presented so far (Ibid, pp. 107-113). People are highly concerned about distributional and competitiveness effects (those will be discussed in the third part of this thesis). Also, they do not believe that a carbon tax would change individuals' incentives, and thus do not trust its environmental effects. Lastly, 60 % of respondents would have preferred revenues to be used for green spending, rather than reducing the VAT. The second part of their analysis is a randomized survey of the Swiss population, designed as a choice experiment. People were asked to choose between three possibilities: two different carbon taxes (in terms of tax rates and option for redistribution), and the status quo (thus refusing the two other propositions). Prior to answering the survey, respondents were given clear explanations on the mechanism of carbon pricing, and on the estimated effects of each proposition. Their results are very interesting. First, they find that redistributing revenues through a decrease of the VAT reduces acceptability. This is an expected issue, as we have clearly showed that reducing existing taxes is an unpopular approach. Also as expected since they address distributional concerns, redistributions through lump-sum transfers and social cushioning positively affect acceptability. Lastly, and this time surprisingly, environmental recycling reduces acceptability. This is the complete opposite result of all results previously discussed. It shows that "providing information on the expected environmental effectiveness of carbon taxes reduces the demand for environmental earmarking" (Ibid, p. 98). Therefore, better communication about environmental effectiveness of carbon taxes "may contribute to

[49] To do so, the authors use the VOX survey database.

close the gap between economists' prescriptions and the preferences of the general public" (Ibid, p. 98). We find this result interesting because it clearly shows that communicating the true environmental effects of a carbon tax can reduce people's concerns. Therefore, policymakers would need to allocate a smaller share of the revenues for green spending, and could use revenues in a more cost-effective manner.

Even though we believe that this result deserves better attention when designing carbon taxes, we also have concerns about its potential effects in a true voting process. Why? Because in their choice experiment, the authors present scientific and credible information to respondents. In real life, those evidence would be strongly contested by opposing parties. As advocates of carbon taxes would try to reduce the fear of voters by providing those information, opposite parties would very likely to the exact opposite. For instance, in the vote conducted in Switzerland, opposing parties emphasized on the potential negative effects on competitiveness, as well as the lack of environmental effectiveness.

In practice, communicating about carbon pricing can be complicated (Carattini et al., 2018, p. 11). For instance, imagine a situation in which GHG emissions have actually increased (but have increased less than what it would have increased without the carbon tax). The credibility of such a result may be difficult to explain to people without any knowledge of empirical estimation. Communication strategies must also be adapted to the context in which they are used (Ibid, p. 11). Even though the role of communication seems to have been ignored for a long period in the literature, organizations are catching up and developing tools to handle carbon-pricing communication. For example, the Carbon Pricing Leadership Coalition has published in 2018 a detailed "Guide to communicating carbon pricing". We will not go more in details in the communication process, but readers interested in this topic will find in this guide "step-by-step guidance on how to develop communications strategies for carbon pricing, and how to integrate communications into the policymaking process".

This second part of the thesis has allowed us to discuss in detail the use of carbon taxes revenues. We must admit that prior to writing this thesis, we expected a different conclusion to this topic. Indeed, we expected that people would prefer revenues to be used to reduce the regressivity of carbon taxes. Even though this is also an important desire of citizens, people far much prefer revenues to be used for green spending. This is a key insight of this thesis, and one we really would like policy-makers to be aware of.

The initial goal of this part was to present the distributional consequences of carbon taxes. We saw that the empirical literature has not yet reached a consensus on this question. Still, many results seem to indicate that carbon taxes have regressive effects. Therefore, we turned to the possible solutions to make it more progressive. The simple answer would have been to proceed to social cushioning or lump-sum transfers. But once we introduced the notion of acceptability in this discussion, the conclusions became different: people favor green spending. This is a very clear and unanimous result in the most recent literature. This difference of results between traditional theory and the true preferences of citizens perfectly justify the relevance of our research question. Indeed, we argue that those preferences are often ignored (or simply unknown) by policy-makers, as it has been the case in France. Therefore, a better use of those conclusions could help implementing more ambitious carbon price policies. Even though France has been the most spectacular example of this problem, we also showed that it has been a problem in the Swiss initiative in 2015. Indeed, this latter also had not taken those findings into account. In fact, the proposed redistribution of revenues by this initiative (i.e reducing an existing tax) is systematically the least favored one by citizens in the literature.

3. The cost of carbon leakage

In order to properly introduce this third and final part of our thesis, let's refer back to the analysis of Carattini et al. (2017). In subsection 1.4.3, we mentioned that these authors had identified five main reasons behind people's aversion for carbon pricing policies. The previous part of our thesis has allowed us to address four of those five concerns: people's concerns about the personal costs of carbon taxes and the distribution of those costs (regressivity), their concerns about the use of tax revenues and their fear of carbon pricing policies not really reducing GHG emissions. For our analysis to be complete, we need to address the last concern of citizens and politicians: the negative effects of carbon taxes on their national economy, because of competiveness issue.

Given the importance of competitiveness in political discussion, it seems clear that this issue could play a large role in the implementation of ambitious carbon pricing policies: "Concern for industrial competitiveness is often put forward as a key barrier to more ambitious carbon pricing policies" (OECD discussion paper, 2015, p. 9). Competitiveness issue, in the case of carbon pricing, is the result of the application of uneven carbon prices across countries. This can lead to a loss of competiveness for countries that apply more stringent climate policies, and ultimately to carbon leakage. We will define carbon leakage in details, but it simply relates to the potential relocation of businesses in countries with laxer climate policies. Therefore, carbon leakage will be at the center of this third part, since it is the visible consequence of competiveness issues and may have important consequences for acceptability towards carbon pricing policies: "Even if the quantitative effects of carbon leakage are limited, the political consequences of plants and jobs moving to another jurisdiction because of its lower carbon price can be significant, and undermine support for strong carbon policies" (Stiglitz, 2018, p. 23).

This third part of this thesis will be split in two major chapters. The first one will present and define the mechanism of carbon leakage. It will also introduce empirical results on the existence (or not) of carbon leakage. The second chapter will be dedicated to discussing the main possible solutions to tackle competitiveness issues.

3.1. The concept of carbon leakage

Carbon leakage is a term that often comes up in the political discussion on environmental policies, and more particularly with carbon pricing. The first goal of this chapter is to familiarize our readers with this mechanism (3.1.1). Then, we will turn to empirical estimation in order to check if carbon leakage really takes place (3.1.2). It will therefore help us understanding whether policy-makers should introduce (or not) solutions to counter carbon leakage.

3.1.1. Definition, origin and channels

3.1.1.1 Definition

Carbon leakage is defined as "the increase in emissions in the rest of the world when a region implements a climate policy, compared to a situation where no policy is implemented" (Branger and Quirion, 2014, p. 54). It is therefore measured as the following ratio (Barker et al., 2007, p. 6284):

$\mathbf{CL = -\,\Delta\, CO_{2\,N} \,/\, \Delta\, CO_{2\,M}}$, with : $CO_{2\,N}$ being the level of emissions in non mitigating countries, and $CO_{2\,M}$ being the level of emissions in mitigating countries.

Therefore, a CL ratio of 20 % would mean that 20 % of the mitigation of CO_2 emissions achieved in mitigating countries is undermined by an increase of emissions in non abating countries. It is important to realize that any ratio under 100 % still means that the policy has globally been able to reduce CO_2 emissions.

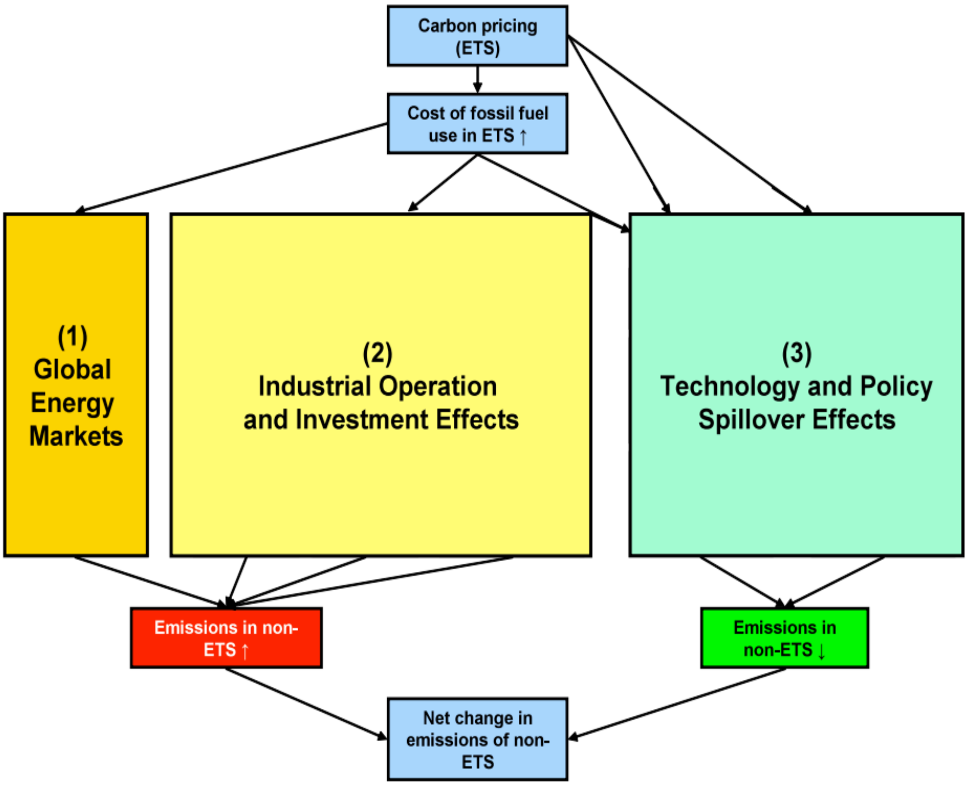
From this definition, we can derive the two main effects of carbon leakage on the criterions used to evaluate carbon pricing policies. The first effect is on environmental efficiency. Very intuitively, carbon leakage implies that the reduction of CO_2 emissions achieved in abating countries is undermined by the increase in other regions. The main objective of carbon pricing policies is therefore complicated. Secondly, carbon leakage will also increase the cost of reaching a certain reduction of emissions. Indeed, it requires more effort to reach a level of abatement, since a share of this effort is undermined by the carbon leakage. Therefore, carbon leakage also affects the cost-efficiency of a carbon pricing scheme.

3.1.1.2 Channels

The next question is to understand through which channels this carbon leakage may happen. We use the contribution from Dröge S. (2009), which summarizes these theoretical mechanisms.

The implementation of a unilateral carbon pricing policy can have three different effects on emissions in the other countries. Those three channels are summarized in the figure below.

Figure 11: Carbon pricing and the channels for carbon leakage



Source : Dröge S. (2009), p. 16

The first channel is the effect of carbon pricing policies on the global energy market. The intuition behind this mechanism is the following: when a country (or group of countries, i.e the European Union) implements a carbon pricing policy, firms in those countries reduce their demand for CO_2 intensive energies (for instance fuel). This lower demand drives down the price of those energies in the global market. Therefore, firms located in countries who do not impose a price on emissions can benefit of lower prices. Theoretically, those latter are thus expected to increase consumption energies and increase output in non-abating countries.

The second channel concerns the effects of carbon pricing on both industrial operations[50] (i) and investments (ii). It is also commonly called the competitiveness mechanism. The key idea behind this channel is that "the cost of compliance gives a comparative disadvantage for regulated firms vis-à-vis their competitors" (Branger and Quirion, 2014, p. 55). In other words, firms located in countries with strong carbon pricing policies automatically face higher

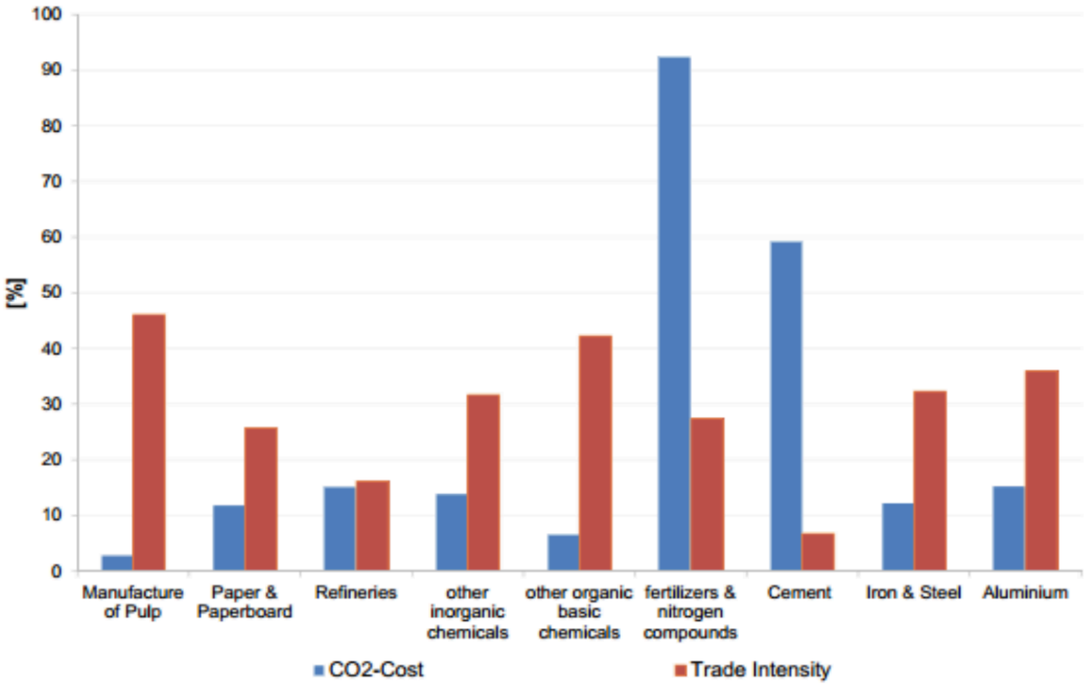
[50] Industrial operations simply mean « production ».

costs of production than firms in other countries. This creates a change in relative prices. A change in relative prices can then theoretically produce two effects. First, it leads to "a change in the trade balance" (Ibid, p. 55): countries with stricter carbon policies will export less and import more. The direct (short-term) modification of the trade balance is what Dröge defines as the "operational leakage". In other words, this operational leakage simply refers to "domestic firms losing market shares to unregulated foreign competitors" (Naegele and Zaklan, 2019, p. 126). Secondly, in the medium or long run horizons, the change of relative prices leads to a relocation of investments in non-abating countries[51]. Indeed, investments are driven by profitability, and high carbon prices reduce profitability. This element is called the "investment leakage". Both of those first channels theoretically lead to an increase of CO_2 emissions in non-abating countries. This competitiveness channel is the center of attention of all studies investigating carbon leakage. Why? Because both of those leakages (operational and investments) directly affect trade flows (Ibid, p. 126). Therefore, trade flows provide a way to estimate carbon leakage.

This competitiveness[52] channel is also by far the most debated in current debates, and was in fact at the heart of the policy process of the EU ETS (Dröge, 2009, p. 6). Therefore, it is worth making an important precision about it. It does not concern all economic sectors, but only those which are actually facing the risk of carbon leakage. Sectors at risk meet the following two characteristics. First, "the carbon cost must be high" (Branger and Quirion, 2014, p. 55), meaning that a large share of their activities releases CO_2. Therefore, carbon policies increase the costs of production of those sectors. Secondly, "international competition in this sector must be fierce" (Ibid, p. 55). Indeed, without international competition, there can be no relocation of industries in other countries (and therefore no carbon leakage). Figure 12 shows the major sectors at risk in the European Union, based on those two criterions. This matches with what Branger and Quirion mention as the most vulnerable sectors: iron and steel, cement, refineries and aluminum (2014, p. 55).

[51] This is in line with the economic theory of the pllution haven hypothesis.
[52] Our readers will find a definition of competitivness in the following pages (3.1.2.1).

Figure 12: Quantitative assesment of the main sectors at risk of carbon leakage



Column on the left (blue) denotes CO_2 cost, while column on the right (red) measures trade intensity

Source: Marcu et al., 2013, p. 12

The third channel of carbon leakage actually has the opposite effect: the implementation of unilateral carbon policies can also reduce emissions in non-abating countries through innovation spillover effects. This dynamic effect originates from the capability of cabon pricing to induce innovation[53]. By increasing innovation and deployment of energy-friendly technologies, carbon pricing can help to reduce the costs of those technologies (for instance solar panel in Europe). Those technologies are then available at a lower cost for non-abating countries as well. Therefore, innovation in abating countries (induced by carbon policies) can lead to more efficient production (in terms of energy) in non-abating countries. However, Dröge (2009, p. 20) mentions high difficulties to measure this innovation spillover effect. Why? Because it is difficult to isolate the effect of carbon pricing policies on innovation. Indeed, all abating countries have additional policies which try to foster energy-friendly technologies (ex : feed-in tariffs or public spending for R&D).

As we just saw it, the three channels of carbon leakage have different effects. The effect on energy market as well as on competitiveness can lead to an increase of emissions in the rest of the world, while diffusion of new technologies can reduce emissions in the rest of the world.

[53] We have presented this property of carbon pricing policies in the first part of this thesis.

Theoretically, the overall net effect of carbon pricing on leakage is then unknown (Dröge S., 2009, p. 21). The uncertainty about this net effect of asymmetric carbon policies (or more generally of environmental policies) on competitiveness is shown by the existence of two opposing views in the literature (Dechezleprêtre and Sata, 2017, p. 183). The well-known Pollution Haven hypothesis argues that firms active in energy-intensive sectors will attempt to avoid the cost of stringent environmental policies by relocating in laxer countries. Therefore, we see that the Pollution Haven hypothesis assumes that the competitiveness channel is stronger than the technology and spillover effects. On the contrary, the Porter hypothesis argues that "environmental regulations can actually trigger innovation that may more than fully offset the costs of complying with them" (Ibid, p. 187). According to this view, technology spillover effects would be the strongest mechanism; allowing environmental regulations to even increase competitiveness. If this Porter hypothesis happens to be correct, we should see no evidence of carbon leakage in real cases.

3.1.1.3 The true origin of carbon leakage

Before to see empirically whether carbon leakage is significant or not, we wish to say a few words about the starting point of carbon leakage: the fact that asymmetric carbon prices are being applied around the world (Marcu et al., 2013, p. 5). Indeed, the presentation of the various channels of carbon leakage has showed that leakage mainly occurs because of a difference of relative prices. In a hypothetical world with a uniform global carbon tax, carbon leakage would by definition not happen[54]. We showed in chapter 1.3 that the current situation is very far from this latter hypothetical case. Indeed, very strong differences in carbon prices exist across countries. This *failure to coordinate* is therefore the true origin of carbon leakage, and then leads to an other key question: Why do countries fail to cooperate in the fight of climate change? This question is very relevant to this part of the thesis. Indeed, if countries were able to perfectly cooperate (for example with a uniform global carbon tax), no distortions of competitiveness (and therefore no carbon leakage) would happen. Let's briefly discuss this issue through the lenses of game theory.

The main issue behind the global failure at coordinating to fight climate is the characteristics of mitigating climate change. Indeed, it can clearly be defined as a global public good. A public good must meet the two following characteristics: be non-excludable and non-rivalrous. Climate protection fills those two criterions. Since the geographical location of the pollution impact is independent of the location of the emission source (Perman et al., 2003, p.

[54] Because we would not observe difference of relative carbon prices.

321), one country action will impact all the other countries of the world (no matter how distant they are from the emissions). Therefore, if one country reduces his emission, all other countries will benefit from it. Secondly, it is non-rival in the sense that if someone enjoys the benefits of a more stable climate, other people can enjoy it in the same way. The "consumption" of the public good by one agent does not prevent other agents to also "consume" it. The nature of public goods creates strong incentives to free ride. Indeed, since agents cannot be excluded from its consumption once it has been produced, they can simply wait for other agents to provide it, and then free ride on them. In game theory, public good games model those kinds of issues. The theoretical prediction from those models is that all agents have a dominant strategy to not contribute in the public good. As a result, there is a Nash equilibrium at the point where nobody contributes, and therefore the public good is not provided.

Still, our societies provide plenty of public goods examples that have successfully being provided: National security is a perfect example of that. So to what regard does reduction of CO_2 emissions differ from provision of national security? The answer is simple, but has enormous implications: climate protection is a *global* public good. National security is by definition, a national issue. Each country organizes its own security system within its borders. Those borders prevent people from other countries to free ride on national security, because by definition, national security is organized only within the particular country. When consequences of a public good are limited to one particular country, this latter has the sovereignty over this issue, and can organize provision of this good according to its political system. Therefore, he can design mechanisms so that everybody is forced to contribute (in this case usually by taxation). On the contrary, *global* public goods impact every country in the world, not only one. Therefore, mitigation of climate change would require action from all countries. This is the true issue, because worldwide governance faces the Westphalian dilemma[55]:

"First, nations are sovereign and have the fundamental right of political self-determination; second, states are legally equal; and third, states are free to manage their internal affairs without the intervention of other states. The current Westphalian system requires that countries consent to joining international agreements, and all agreements are therefore essentially voluntary" (Nordhaus, 2015, p. 1340).

[55] The treaty of Westphalia (or Peace of Westphalia) was signed in 1648, and formulates the core pricinciples of modern international law.

In other words, there is no "supra state" which has the authority to regulate global public goods. Rather, all countries must voluntarily agree to cooperate on this issue. As incentives of countries are theoretically to free ride on others' efforts, it is extremely hard to reach effective agreements. In the case of climate change mitigation, this is even complicated by the fact that climate change has different effects on various regions. Indeed, we saw in the first part of the thesis that some countries could even benefit from climate change in the future. Therefore, interests of all countries are not automatically aligned. We will discuss later how researches in the field of game theory offer solutions to move away from the payoff structure of a public good game[56].

3.1.2. Empirical evidence of carbon leakage

Even though the definition of carbon leakage is rather simple, empirical assessment will be challenging. Indeed, it requires accurately "differentiating the shift in emissions and the changes in production and investment patterns caused by climate policy, from what is attributable to other drivers" (Marcu et al., 2013, p. 3). We will first make a few general remarks on carbon leakage measurement. Then we will present results from both ex-ante and ex-post studies. The goal of this second section is to analyze whether empirical studies have found proof of carbon leakage or not.

3.1.2.1 General remarks

In order to measure carbon leakage, the vast majority of existing studies adopt the strategy of analyzing trade flows between abating countries and non-abating countries. More precisely, the analysis focuses on energy-intensive sectors, since it is their competitiveness that carbon policies are supposed to affect the most.

The measurement of carbon leakage is interlinked with the notion of competitiveness, which we should briefly define. Even though this notion is at the core of policy debates, it is often not clearly defined in the literature. Rather, it is "used as a catch-all term that reflects a combination of concerns related to trade, profitability, employment, and welfare" (Carbone and Rivers, 2017, p. 26). As a starting point, we could use the definition given by the U.S. committee on finance: "A firm is competitive if it can produce products or services of superior quality or lower costs than its domestic and international competitors. Competitiveness is then synonymous with a firm's long-run profit performance" (Ibid, p. 26). This definition of competitiveness at the firm level is rather clear. The problem with

[56] Climate change mitigation is also often depicted as a prisomner's dilemna, as it has the same consequences than a public good game. See for instance Barrett, 2016, pp. 14515-14516

competitiveness is that it is commonly used for different levels (firm, sectorial, regional, and national), even though "a concept that makes sense at the firm level may not have the same meaning at the country level" (Ibid, p. 26). Still, this basic definition allows understanding what should be the outcomes of competitiveness: market share, employment, and productivity. We therefore see that competitiveness is linked with trade flows, which will be our variable of interest in this section.

3.1.2.2 Ex-ante estimations

There are two possibilities in order to empirically assess carbon leakage. The first one is to use ex-ante CGE modeling. The second option is to run ex-post econometric studies, based on actually implemented carbon policies. The latter would allow estimating policies that are currently implemented and would therefore be useful for policy evaluation. Unfortunately, those empirical set ups are limited by three key issues (Carbone and Rivers, 2017, p. 29). First, there are only a few examples of ambitious carbon policies, and those are relatively recent. Therefore, there is only limited evidence on real-world cases. Secondly, data are often hard to gather, especially for "environmental policies and economic performances in less developed countries" (Ibid, p. 29). Lastly, estimating the effect of carbon policies on competitiveness requires treating those policies as exogenous. This is a questionable assumption, since economic conditions at least partly affect the adoption of climate policies. Those issues are not impossible to solve, and we will present in the next section some ex-post empirical analysis, which have been conducted. But still, those issues explain why a majority of analyses have used ex-ante CGE modeling.

We will here present the study of Elliott et al. (2010). This study aims at analyzing the performance of unilateral carbon pricing policies, given international trade. To do so, the authors use the CIM-EARTH model[57]; an open source CGE model which is often used in the literature to assess the effects of carbon policies. Indeed, it allows estimating the effects of hypothetical carbon policies on global emissions and trade flows. In this paper, countries are split between Annex B countries (USA and Other Annex B countries, i.e. OAB) and Non-Annex B countries (NAB). Annex B countries are the ones required to limit emissions by the Kyoto Protocol (developed countries), while NAB refer to all other countries. The authors run three different scenarios[58] (Ibid, p. 468). The first one is a business-as-usual scenario (1), and simulates a situation without any carbon pricing. This scenario will be used as a point of

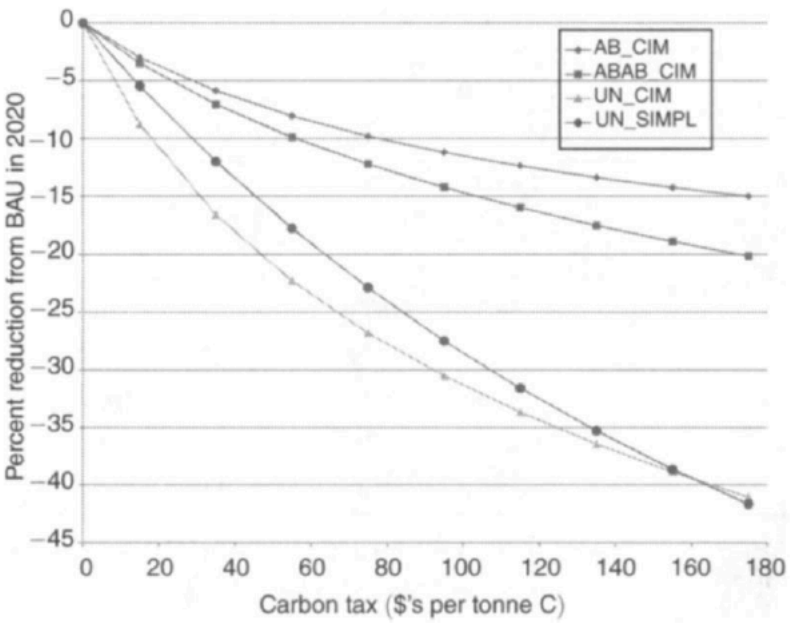
[57] See http://www.rdcep.org/research-projects/cimearth

[58] There is a fourth scenario, estimating the effect of Border Carbon Adjustments, but we do not present it here, as this issue will be discussed in the next section.

comparisons for scenarios simulating carbon taxes. The second one is a global uniform carbon tax, applied by all countries (2). The third one is the more interesting, because it allows estimating possible carbon leakage through trade flows. Indeed, it simulates the implementation of a carbon tax only in Annex B countries (3).

Figure 13 provides the effects of those scenarios on global emissions. On the X-axis, we have the different potential levels of carbon prices. On the Y-axis is presented the reduction of emissions induced by scenarios 2 and 3, compared to the business-as-usual scenario.

Figure 13: Reduction in global emissions in the different scenarios



Source: Elliott et al. (2010), p. 468

The UN_CIM line gives us the estimations of scenario 2. For instance, a global carbon tax of 80 $/ per ton of CO_2 would reduce global emissions by 27 %. Lines AB_CIM and ABAB_CIM are the results for the third scenario, and therefore allow discussing carbon leakage. The upper-line AB_CIM is the variation of global emissions after a tax imposed by only Annex B countries. Intuitively, the reduction of emissions is much lower than when all countries implement the carbon tax. But is it because Non-Annex B countries increase their emissions, and therefore create carbon leakage? Line ABAB_CIM shows us the contribution of *only* Annex B countries in scenario 2. We clearly see that *the reduction of global emissions generated by Annex B countries is larger than the total reduction of emissions*. This tells us that carbon leakage does happen: Non-Annex B countries seem to increase their emissions when annex B unilaterally apply a carbon tax. Let's show a numerical example to simplify the comprehension. When a carbon tax of 180 $ per tons of CO_2 is unilaterally implemented by Annex B countries, global emissions decrease by 15 %. But Annex B countries alone have generated a reduction of global emissions of 20 %. This means that Non-Annex B countries emissions have increased, and have precisely increased global emissions by 5 % (20 – 15). If we use the definition of carbon leakage presented previously, this creates a carbon leakage of 25 % (= 5 % / 20 %).

In terms of trade flows, their results also match with the theoretical predictions of carbon leakage, which we discussed in chapter 3.1.1. In the case of the unilateral carbon price implemented by Annex B countries, Annex B countries reduce their exports towards Non-Annex B countries. On the contrary, Annex B countries increase their imports from Non-Annex B countries. Therefore, this CGE analysis verifies the theoretical explanation of the competitiveness channel.

Of course, conclusions from CGE models must be analyzed carefully. They depend on the parameters of the model, as well as the scenarios that they simulate. For example, in the study of Elliott et al. (2010), the authors show evidence of carbon leakage in a situation where all Annex B countries agree on implementing a uniform carbon pricing policy. As we saw it in the first part of the thesis, this is far from the current situation. Indeed, even Annex B countries struggle to cooperate in climate change mitigation. However, multiple reviews[59] of the empirical literature on ex-ante estimations of carbon leakage seem to reach the same types of conclusion.

In their systematic review of literature, Carbone and Rivers (2017) analyze the results from 54 empirical studies, which had assessed the effects of unilateral carbon pricing policy on competitiveness outcomes. Pooling those analyzes together allow to have some variation in the underlying features (assumptions) of the CGE models. First, the authors find that "the estimated leakage rates are consistently positive across the studies in the sample – typically in the range 10 to 30 percent" (Carbone and Rivers, 2017, p. 36). They also witness a slightly positive correlation between abatement effort and leakage rate[60]. This is line with the conclusion of the third assessment report of the Intergovernmental Panel on Climate Change, which also emphasized that carbon leakage is an "increasing function of the stringency of the abatement strategy" (IPCC, 2001, p. 59).

[59] See Carbone and Rivers (2017) and Branger and Quirion (2014), pp.58-59

[60] Similar conclusion is stated by Branger and Quirion (2014, p. 58)

Regarding trade flows, Carbone and Rivers (2017) report an average reduction of exports by 7 % in trade-exposed energy intensive sectors (after the abatement of 20 % of GHG emissions). Nevertheless, the authors also report a large variance among the results of all CGE studies [61]. Concerning imports, the authors find that in average, carbon pricing policies have no effect on the imports of the country.

3.1.2.3 Ex-post estimation

We just saw that ex-ante analysis tend to show that carbon leakage does occur. But their results remain theoretical ones, in the sense that they do not estimate any "real" application of carbon pricing policies. Also, their results are affected by the assumptions of CGE models. This is why we want to check if ex-post estimations also find significant evidence of carbon leakage. First, we will present one very recent study published by Naegele and Zaklan (2019), which analyzes carbon leakage in the case of the EU ETS. This will allow us to show how ex-post analysis can be conducted empirically. Then we will briefly review the ex-post literature on carbon leakage.

Carbon leakage in EU ETS (Naegele and Zaklan, 2019)

We have chosen to present this particular study for two reasons. First, it explains clearly how the stringency of a carbon pricing policy can be measured. Secondly, it performs numerous sensitivity analysis, which all confirm their initial conclusion. Their goal is to analyze carbon leakage in the manufacturing sector[62], after the introduction of the EU ETS. They focus on the competitiveness channel, since they analyze trade flows between countries. Precisely, they test if "parts of the evolution of sectoral trade intensities can be explained by the stringency of environmental policy" (Ibid, p. 126). Their methodology is to regress a measure of trade (dependent variable) on the stringency of carbon pricing policies and other control regressors. The first empirical question is how to construct their main regressor: **policies' stringency**. They measure it with the following equation (Ibid, p. 130):

$$\theta_{ist}^{tot} = \theta_{ist}^{d} + \theta_{ist}^{i} - \theta_{ist}^{a},$$

The first term (θ^{d}_{ist}) is the direct cost of the ETS, basically the allowance price multiplied by the emissions covered by the EU ETS. The second one (θ^{i}_{ist}) is the indirect cost of the ETS,

---

[61] This variance seems to be caused by different assumptions.

[62] This term refers to production activities in which raw resources are transformed into finished goods. Those activities are often energy intensive and exposed to trade, therefore matching the definition of sectors at risk of carbon leakage.

measured by the increased price of electricity which all sectors face[63]. The last term ($\square^{a}_{ist}$) is the level of free allowances offered to some sectors, which reduce the total cost. Therefore, this equation measures the total cost of the cap-and-trade for a particular sector[64].

Two possible indicators measure **bilateral trade**. When they are available, Naegele and Zaklan (2019) use the trade flows in "embodied carbon". This is simply the amount of CO_2 emissions that were used to produce a traded product. When those data are not available, they simply use trade flows in US dollars. Therefore, the equation estimated is the following:

$$y_{xmst} = \alpha^m \theta_{mst} + \alpha^x \theta_{xst} + \beta \tau_{mst} + \gamma F_{mst} + \delta t_{mst} + \nu_{mt} + \nu_{xt} + \nu_{st} + \nu_{mxs} + \epsilon_{mxst}$$

, where :

- Y_{xmst} is the trade flow (= exports of country x – imports of country x) from country x to country m, in year t and sector s.
- θ_{mst} is the stringency of the carbon pricing policy in the country m (importer). θ_{xst} is the same, but for country x (exporter).
- τ_{mst} (tariffs on imports) in the importer's countries, as well as transportation costs (t_{mst}) automatically protect some sectors from carbon leakage. Therefore, they are also included.
- The other elements are control variables (year-fixed effects, as well as sector-country and sector-country fixed effects).

Concerns of endogeneity (as well as omitted variable bias) are addressed in further details by the authors (pp. 130-131), but the details presented here should be sufficient to understand the intuition of their regression.

Now, what should be the results of the equation if the EU ETS caused carbon leakage? In this case, θ_{xst} should have a negative effect on Y_{xmst}: If the stringency of the policy is increased in country x, then his exports towards country m will go down (therefore Y_{xmst} also goes down). On the contrary, θ_{mst} should have a positive effect on Y_{xmst}: If the stringency of the policy is increased in country m, then the imports of country x from country m will go down (therefore Y_{xmst} will increase).

[63] For further definition of direct and indirect price effect, our readers can go back to chapter 2.1.1.2, in which those notions were initially defined.

[64] Therefore, the authors use the total cost of a carbon pricing polivy as a proxy for its stringency.

The period analyzed by the authors goes from 2004 to 2011. Since the EU ETS was implemented in 2005, this also allows having data for one year prior to the implementation. Their data on trade is drawn from the Global Trade Analysis Project (GTAP), while measure of stringency comes from the EU Transaction Log (EUTL).

The authors conduct this estimation for both measures of trade ("embodied carbon" and value in US dollars). In both cases, their results show no evidence of carbon leakage (Ibid, pp. 136). In the estimation with embodied carbon, neither $\square_{xst}$ nor $\square_{mst}$ are statistically significant. With US dollars, $\square_{mst}$ is significant at the 10 % level, but has the wrong sign (it is negative, while it should be positive in the case of carbon pricing). The authors conduct multiple robustness checks (pp. 138-146), as well as a second estimation with a simplified version of the initial equation (pp. 134-136). The results remain the same: "The EU ETS did not have a systematic impact on trade flows" (Ibid, p. 137).

Review of ex-post estimation of carbon leakage

This result is in line with other ex-post estimations of carbon leakage in the EU ETS. For instance, Branger et al. (2013) analyze consequences of the EU ETS on the competitiveness of cement and steel industries. They also find the price of the allowances does not affect carbon leakage.

After having carefully gone though the literature, we are able to say that no convincing evidence of carbon leakage has so far been found in ex-post estimation empirical studies. Branger and Quirion (2014) had already reached this conclusion. Lately, Dechezleprêtre and Sato (2017) conducted a review of all the most recent ex-post estimations. They were also unable to find any concrete evidence of any carbon leakage, and conclude that other factors than stringency play a larger role in trade flows: "The effect of relative stringency on trade flows is overwhelmed by other determinants of trade" (Ibid, 2017, p. 191).

This leads to the question of why carbon leakage does not seem to happen, even when some countries unilaterally impose stricter regulations? The existence of other determinants of trade may be one powerful explanation. To our opinion, one other strong explanation is the low-ambition of carbon pricing policies. In the study that we have presented in the previous section, Naegele and Zaklan (2019) have estimated the cost generated by the ETS for manufacturing sectors. In average, the total cost[65] generated by the ETS amounts to only 0.10 % of firms' material cost. Is it thus really surprising to find no evidence of carbon leakage,

[65] See the equation of the cost (or stringency) of a policy presented earlier.

with such a low cost imposed to polluters? This means that if producing abroad generates any additional costs of the same amount than the abatement costs (here 0.10 % of total production costs), abating countries will not face any loss of competitiveness in comparison with non-abating countries. Those additional costs could be transportation costs, or also a fixed relocation costs (Naegele and Zaklan, 2019). Another explanation comes from the fact that empirical studies do not account for the technology spillover channel of carbon leakage. As a reminder, we presented this mechanism in subsection 3.1.1.3. It basically states that stricter environmental policies may induce innovation in energy-friendly technologies. Many evidence of such a dynamic effect have been found in the literature (Dechezleprêtre and Sato, 2017, pp. 198-199). Whether this effect is sufficient to compensate the increased costs of abatement remains an open empirical question, but it might at least partly explain why evidence of carbon leakage are so rare. The exact answer is probably a combination of those different mechanisms.

Therefore, we can conclude this section by saying that at the current level of ambition of carbon pricing policies, there is no evidence of competitiveness issue generated by carbon pricing schemes. It then clearly appears that “concerns about carbon leakage are not unfounded, but may have been largely overplayed” (Sata and Dechezleprêtre, 2015, p. 5). This is an important conclusion in order to address people’s concerns about potential adverse competitiveness effects. Still, we also saw that the current low level of abatement costs may explain this. This may also explain the strong difference of results between ex ante and ex post estimations.

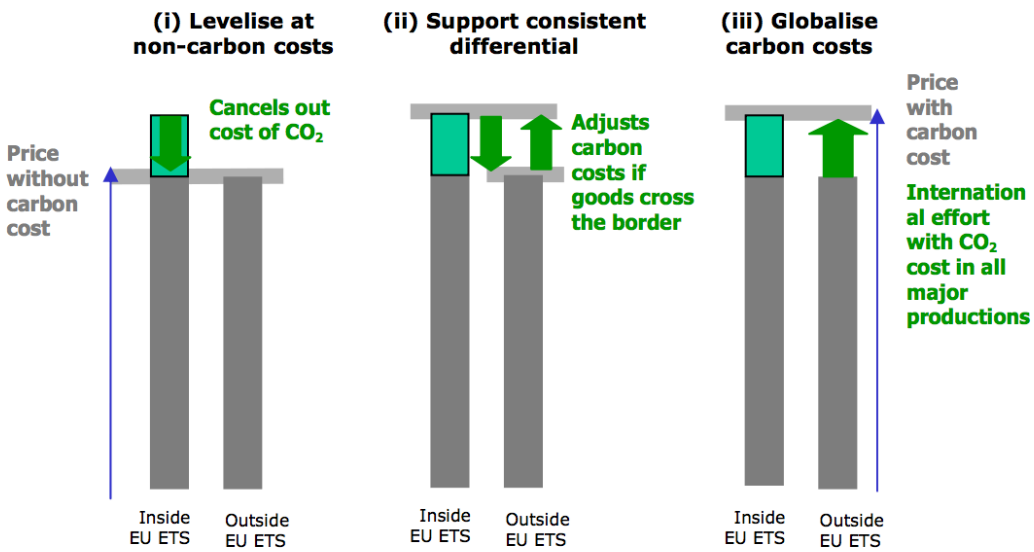
Nevertheless, the goal of any carbon pricing policy is to increase stringency over time. This can be done by many manners: increasing the price on carbon emissions (raising the tax in a carbon tax), limiting the number of free allowances in a cap-and-trade system, etc... As carbon pricing policies become more costly for local energy intensive sectors, the issue of competitiveness may become stronger[66]. Therefore, it is useful to discuss possible solutions that are available. Even though those solutions may not yet be required today, their existence may reduce people’s concerns about negative effects on competitiveness. Therefore, they may help increasing acceptability for carbon pricing.

[66] And thus coming closer from the predictions of ex-ante models. Still, this theoretical intuition is challenged by the analysis of Sata and Dechezleprêtre (2015), which conlcuded that an increase of energy price in abating countries explain only an extremely small share of variation in trade flows (0.01 %).

3.2. Solutions to avoid (future) carbon leakage

Our readers should now have understood how unilateral carbon pricing policies can create some issues in terms of competitiveness. Even though we also saw that carbon leakage is not a major issue in the current situation, it may become one as carbon prices increase in the future. Indeed, if the gap in carbon prices between abating countries and non-abating countries increases, it will become more and more difficult for firms in the abating countries to keep a comparative advantage over firms in the non-abating countries. The literature proposes three different solutions in order to avoid carbon leakage (Dröge, 2009, pp. 40-61). Those solutions all try to "level the playfield" of carbon prices, meaning that producers at home or abroad should face the same carbon costs. Those three options are perfectly summarized by the following simple figure.

Figure 14: Options to adjust carbon costs



Source: Dröge, 2009, p. 40

The first option (i) is to level the costs downwards. This implies that energy-intensive firms facing international competition should be "protected" by lowering their tax burden. The second option (ii) is to proceed to Border Carbon Adjustement (BCA). The idea is to adjust the carbon costs of goods crossing the border (both exports and imports), based on the costs which is imposed in their country of destination (for exports) or provenance (for imports). Finally, the last option (iii) is to increase cooperation from non-abating countries, such that they also start imposing a price on CO_2 emissions. This would automatically prevent carbon leakage. This last chapter of this thesis presents and discusses each of theses options.

3.2.1. Downward adjustment of carbon costs

Downward adjustment of carbon costs implies protecting sectors at risk of carbon leakage, by reducing the price of emissions abatement which they face. The most important (and often used) method is "grandfathering". Grandfathering simply consists of freely allocating emission permits to those firms at risk of carbon leakage. Nevertheless, it is clear that this method creates a very important trade-off (Dröge, 2009, p. 46). On one side, free allowance preserves local firms' competitiveness compared to international competitors, and thus should reduce incentives for carbon leakage. But on the other side, it strongly undermines polluters' incentives to reduce GHG emissions[67]. Indeed, they no longer pay the direct cost of abatement (since they receive the emission permits for free), which is the key idea of carbon pricing. This automatically reduces cost-efficiency of carbon pricing. Indeed, in order to reach the same level of abatement, "more abatement must take place in the other sectors, including less cost-effective options" (Branger and Quirion, 2014, p. 61). If we go back to our definition of *ambitious* carbon prices, we had showed that the carbon price itself was the main signal of the ambition of a particular carbon pricing scheme. Since free allocation of permits (in a cap-and-trade) basically equals to not imposing a carbon tax on certain sectors, it is clear that grandfathering does not lead to the implementation of ambitious carbon pricing policies. Therefore, it is clearly not an appropriate solution to our research question.

Box 2: Free allocation of emission permits in the EU ETS

The EU ETS has set up large free allowances mechanism in order to protect firms at risk of carbon leakage, following this definition (ETS directive, article 10a)[68]:

I. A sector or sub-sector is deemed to be exposed to a significant risk of carbon leakage if:

- *Direct and indirect costs induced by the implementation of the directive would increase production cost, calculated as a proportion of the gross value added, by at least 5%;* ***and***

- *The sector's trade intensity with non-EU countries (imports and exports) is above 10%.*

II. A sector or sub-sector is also deemed to be exposed if:

- *The sum of direct and indirect additional costs is at least 30%;* ***or***

[67] It is important to note that free allowance does not completely delete polluters' incentives to reduce GHG emissions. Indeed, they still have the opportunity to sell those emissions permits. Since reducing GHG emissions automatically increase the nmber of permits which they can sell, some incentives are preserved.

[68] Source : https://ec.europa.eu/clima/policies/ets/allowances/leakage_en

• *The non-EU trade intensity is above 30%.*

The first part of the definition matches with the definition of sectors at risk seen previously. Those sectors must be both energy-intensive and trade-exposed. The second part is, to our opinion, more questionable. Indeed, what would be the justification to freely allocate heavily energy-intensive industries, when these latter are active in a sector that is not trade-exposed? Similarly, why allocating free allocation of permits for firms for which the direct and indirect costs of carbon pricing are extremely low (even is it highly exposed to trade, above 30 %)? We have not find any satisfying answers to these questions in the economic literature.

On the contrary, we have found multiple papers mentioning over-allocation of free allowance as one issue of the EU ETS (Joltreau and Sommelfeld, 2017). Economists are concerned about the level of free allocation, because it undermines the price signal of carbon pricing policies.

To our opinion, a very concerning result, particularly in terms of acceptability from the citizens, is that energy-intensive industries have actually freely received more emissions permits than what they needed. In other terms, it means that they are over-subsidized. Over the period 2008-2015, this has allowed heavy industries (in the EU ETS) to earn 25 billions of euros (Carbon Market Watch, Nov. 2016). How is that possible? Heavy industries are able to generate windfall profits because of two mechanisms (Ibid, pp. 3-4). The first one is a "windfall profit from surplus": firms who receive too many emissions permits can sell those latter on the market, and thus make a profit. Secondly, "industries have generated profits by letting their customers pay the price for freely obtained emission allowances" (Ibid, p. 4). This is called windfall profits from cost-pass through.

Our point here is not to say that grandfathering should never be used. In some cases (when industries truly face risks of carbon leakage), it may be a useful *short-term* solution. But over time and because of the trade-off it creates with the environmental objectives, it should only concern a marginal share of emission permits. Particularly, over-distribution of free emission permits (as we have presented it in Box 2) should be stopped. Indeed, it has multiple negative consequences. First, since we saw that it is similar to granting a subsidy to polluters, it reduces the resources available to invest in green technologies. Secondly, and more relevant to our thesis, it is very likely that citizens would be even more suspicious against carbon pricing after hearing of those windfall profits made by polluters.

3.2.2. Border Carbon Adjustment

A second option to address concerns of leakage is the concept of Border Carbon Adjustments (BCA). BCA is a way to balance carbon costs at the border for exchanged goods. In its initial form, a BCA was to be applied only on imports, but it has also been proposed for exports. First, we will define explain how BCA work and what their advantages are. Secondly, we will present the two limits to the implementation of BCA.

3.2.2.1 Definition and advantages of BCA

Let's explain the concept with a small example. Imagine a situation with 2 countries A and B. A has implemented an ambitious carbon pricing policy, for instance a carbon tax. Country B, on the contrary, is not taxing GHG emissions. As we saw it earlier, such a situation would create the risk for carbon leakage (from A to B), such that a part of the improvement in A would be undermined by an increase of emissions in B. First, how would a BCA on imports of country A work? The idea would be that exporters (located in country B) would be asked to pay an amount at the border equivalent to the carbon cost applied within country A (Dröge, 2009, p. 55). Basically, in order to have access to the market of country A, exporters first need to pay the same carbon price faced by producers in country A. In even simpler words, BCA applied on imports is simply a way to extend a carbon tax on imports. Regarding BCA on exports, we will not discuss it more in details. Why? Because it is nothing more than leveling carbon costs downwards (cf 3.2.1) for exports of country A. Indeed, it requires reducing the carbon costs for exporters of A, such that they do not face a competitiveness disadvantage. We have already explained why this instrument is not optimal, and therefore will here focus on BCA applied to imports.

The first advantage of BCA is that by equalizing the costs of carbon on both sides of the border, it "levels the playfield" in international trade. Therefore, it should be able to reduce carbon leakage. Using CGE models, multiple analyses have been able to show the theoretical quantitative effects of BCA. Böhringer et al. (2012) showed that BCA allows to effectively reduce carbon leakage, and particularly for emissions-intensive sectors. Branger and Quirion (2014b) also find that everything else being constant, BCA reduces carbon leakage by 6% (results from a meta-analysis)[69].

In the long term, BCA is supposed to create "political leverage for more climate action across countries" (Mehling et al., 2017, p. 24). Indeed, non-abating countries would have incentives

[69] Those studies also show that BCA have negative effects on equity between countries, because it imposes a large cost on non-abating countries (which are often less developped countries). See Böhringer et al. (2012b) for a better discussion of this issue.

to implement a carbon pricing policy. Why? Because as we saw it with our initial example, exporters from country B are required to pay the carbon price before to access the market of country A. The revenues from this tariff on imports therefore increase the revenues of country A. If B were to implement a carbon pricing policy, those revenues would no longer be perceived by a foreign state (A), but would directly increases their own revenues. However, this argument is also balanced by a potential negative effect of BCA: it may "also trigger a trade war because of green protectionism suspicions" (Branger and Quirion, 2014, p. 62). Since BCA have so far never been implemented in practice, there is yet no clear possibility to evaluate those arguments empirically.

Also, the introduction of BCA "substantially changes the outcome of climate cooperation game" (Helm and Schmidt, 2014, p. 2). Indeed, BCA (both on exports and imports) reduce the costs to impose a carbon pricing policy, while BCA on imports increase the costs of not having implemented a carbon-pricing scheme. Those two effects increase the incentives to implement a carbon pricing policy, and thus should allow increasing cooperation between countries. We do not go any further on this topic, as it will be discussed more in the next subsection.

3.2.2.2 Limits of BCA

The idea of BCA has gathered more and more support over the years, both among researchers and policy makers. For instance, Emmanuel Macron has repeatedly said that this instrument is "indispensable to an effective and equitable ecological transition for Europe" (Mehling et al., 2017, p. 9). Therefore, why has it never been implemented yet?

The first limit to the implementation of BCA is its actual feasibility. First, in order to calculate the right level of BCA, countries need to know the level of "embodied carbon" of their imports. The difficulty of gathering such data is often put forward as a limit to BCA. Nevertheless, we have already presented in this thesis many papers that rely on such data (input-output tables). Therefore, we believe that this is a solvable issue. Melhing et al. (2017) also reached the same conclusion: "availability of such data has greatly improved in recent years… and provide continuously improving datasets for the determinants of carbon embedded in international trade" (pp. 46-47). The second measurement problem is to accurately assess the net difference of carbon prices between two countries. In the case where the other country has no carbon pricing policy in place, then this calculation is rather simple. But when the two countries have uneven carbon prices, calculating the net difference can be tricky and costly.

But by far, the most debated limit of BCA is its legality under international trade law. Indeed, BCA could be used as some form of protectionism against foreign competitors, and thus may come as illegal under the GATT and WTO laws. Since this is a legal question, we will only present the main elements of this debate. Regarding a BCA on imports, the GATT imposes two particularly important elements. First, a BCA should not violate the clause of the *Most Favored Nation Treatment* (art I). As stated by Dröge (2009), a "general border adjustment applied to all imports would be in compliance with the clause" (p. 62). On the contrary, a BCA that varies based on the origin of the product would be questionable under art I. Secondly, a BCA on imports should also not violate the clause of the *National Treatment* (art. III). This clause basically forbids the implementation of any "internal taxes and other internal charges… which would afford protection to domestic production" (art. III, 1). More precisely, any imports from contracting parties "shall not be subject, directly or indirectly, to internal taxes or other internal charges of any kind ***in excess*** of those applied, directly or indirectly, to like domestic product." (art. III, 2). We insist on the "in excess", because it implies that "the charging of the imported good as such is not forbidden" (Dröge, 2009, p. 61). Rather, it only stipulates that imported goods should not be charged of a higher tax than the local products. Since the core principle of BCA is to equalize the cost across the border, it should not violate this second condition. Even if BCA was found to violate one of those two important articles[70], it could still be legal if it can be proven to fill one of the ten possible reasons for exceptions (art. XX). In the case of the fight against climate change, it can be argued that BCA match with the two following exceptions: measures "relating to protect human, animal or plant life or health" (art. XX, b) or "relating to the conservation of exhaustible natural resources…" (art. XX, g). In the end, the legality of a BCA will highly depend on the design and motives of this particular BCA: "for an environment-related trade measure to be justified, it needs to be drafted and applied in a way that does not unjustifiably or arbitrarily discriminate between domestic and foreign products and among foreign products from different origins" (Tamiotti, 2011, p. 1208).

Without going in further legal debate, it seems clear that BCA would not necessarily violate international trade laws. Furthermore, some exceptions (art. XX) could allow the application of BCA.

[70] It is still a debated question in the literature.

3.2.3. Increasing global cooperation

The last way to reduce carbon leakage is simply to increase global cooperation. Indeed, we saw that the starting point of carbon leakage is the application of uneven carbon pricing policies across countries. Therefore, discussing how to foster cooperation is important.

3.2.3.1 Working in smaller groups

Working in smaller coalitions may first be seen as counterproductive for increasing global cooperation. But this suggestion results from the extreme difficulty to negotiate between all countries. This is for instance one of the major limits to reach agreements within the UNFCC: agreements are based on consensus, thus offering the power of veto to each of the member (175 countries). This requirement is even more problematic given the huge heterogeneity among states' interests. Particularly, the difference between developed and developing countries has led to failures on agreeing on treaties (for instance the Copenhagen agreement). On one side, developed countries have heavily used emission-intensive activities to reach their current level of development. Their high level of income also allows them to react better to consequences of climate change, and to recover from them. On the other side, developing countries have so far produced way less emissions. But their current desire to develop economically creates an increasing production of emissions. Those countries lack the capabilities and resources to protect themselves from the effects of climate change. This creates a situation where the countries who have so far not contributed much to the global warming will be the one suffering the most from its effect. Meanwhile, the economic growth they are witnessing is requiring a large increase of energy (Paavola, 2012, p. 420). This divergence between developed and developing countries' interests reached a peaking point at the COPs of Copenhagen (2009) and Cancun (2010), testifying from this "insoluble conflict of interests" (Brünnengräber, p. 71).

Therefore, authors propose to work in smaller groups to find solutions (Paavola, 2012, p. 423 and Wong, 2015, p. 273): "Enabling negotiation among a reduced number of parties appears vital to resolve current stand-offs, or at least to minimize disagreement". In addition to regrouping more homogeneous countries, this would also have the advantage of reducing free riding within those smaller groups. This is based on Olson's idea that smaller groups face smaller free-riding incentives. This relates to the "small coalitions paradox" (Nordhaus, 2015): coalitions can either be small or shallow[71]. The intuition behind this paradox is that a large and ambitious (with high carbon prices) coalition will not be stable. Indeed, imposing

[71] But on the contrary, those coalitions can not be at the same time large and amitious.

high carbon prices automatically increases the incentives for participants to free ride. Thus, large and ambitious voluntary coalitions will not be stable.

3.2.3.2 Making every actor pivotal

The two next propositions are based on Barrett's conclusion that cooperation requires a "pull" and a "push" (Barrett, 2016, p. 14521). A pull means that "Countries must understand that they will be better off if they coordinate". On the other side, a push describes the need for countries to understand that "If most other countries cooperate, those that do not will be worse off" (Ibid).

Barrett (2014) discusses the current failure to coordinate. One of his ideas is to try to reach a "coordination game", and not be in a prisoner's dilemma anymore. To do so, we would need to think of climate change as a "dangerous" game. Assume that if the increase of global temperature goes over a certain threshold, the consequences will be disastrous. This is an assumption that is very close to reality. It is agreed that global warming should be kept well below two degrees. In this situation, a treaty should be written this way: "It should assign to every country an emission limit, with each country's limit chosen to ensure that when all the limits are added up, concentrations stay within the "safe" zone. The agreement should only enter into force if ratified by every country" (Barrett, 2014, p. 263). This would automatically make every country pivotal, and creates this "push" incentive. If one country slightly emits more than what he should, the catastrophe happens.

Unfortunately, this solution is almost impossible to implement. Why? First because there is a huge scientific uncertainty about how much each country can actually emit, so that climate stays under the two degrees[72]. The second would lead to back to the issue of multilateralism. As Barrett state it, driving emissions close to zero would require participation of nearly all countries. Getting all countries to sign a treaty like the one we mentioned would be infeasible. If this treaty was implemented only by a small number of countries, this opens up the door to carbon leakage, and makes it impossible to calculate with certainty how much each country should abate.

3.2.3.3 Introducing sanctions to non-participants through climate club

An other way to create this "push" is to introduce some form of sanctions to non-participants. Graduated sanctions were one of the important characteristics found by Elinor Ostrom's well-known research on Common Pool resources' governance. Here we introduce the idea of

[72] This is mainly due to uncertainty in the carbon cycle.

implementing sanctions in order to change the incentives structure of countries. This is a key component of any stable solution. In the Kyoto protocol (and also the Paris agreement), "the emissions targets and timetables were chosen in the expectation that they would be met. No consideration was given to whether the treaty created incentives for them to be met" (Barrett, 2014, p. 273). On the last idea we discussed, changing incentives (by making every country pivotal) was also the core idea. But we have seen that it would be very hard to implement it. Here we will consider the idea of Nordhaus (2015) to set up a climate club.

The climate club as fought by Nordhaus would be an "agreement by participating countries to undertake harmonized emissions reductions" (Nordhaus, 2015, p. 1341). This harmonization would be done by a common carbon price. Countries would be free to choose the mechanism to reach this price (carbon tax or cap-and-trade). The key difference with other proposals is that non-participants would be penalized, through a uniform percentage tariffs on the imports of nonparticipants into the club region. The structure of this sanction is important for two reasons. First, it is an "external[73]" sanction. Since benefits of free trade are usually large for countries, this allows creating strong incentives to enter the club. The second element is that incentives for participants to sanction non-participants are high, as they gain revenues from imposing tariffs. The idea is very close from BCA, but slightly different and easier to implement. Here, the tariffs imposed would be the same for all non-participating countries, and would not necessarily represent the difference of carbon prices.

Nordhaus (2015) has modeled this approach empirically. He was able to show that participation and carbon prices increase with tariffs. Importantly, full cooperation towards a 25$/ton carbon price requires only a 2% tariff. For a carbon price of 50$/ton (which would respect what Stiglitz and Stern advice as a necessary price to stay under the two degrees), a tariff of 4% would be required. An interesting finding is also that when no sanction (tariff) is in place, results always lead to no cooperation (even for a very low price of carbon). This statistically shows why the Kyoto protocol has failed.

One of the key issues we see is how to start such a coalition. Is it possible to start with a small number of countries only, or would it require a certain threshold of the world's economy to create incentives to join? If only a few countries are a part of the agreement, then the consequences to non-participate might create only a small cost to the non-participants (because only a few countries impose tariffs on them). Also, participants would suffer of competitiveness issue when exporting to non-participants. Even though neither Barrett (2016)

[73] This means that those sanctions are part of a different game, here trade relations.

or Nordhaus (2015) mathematically show how many countries should be required to launch an effective climate club, they both mention the question of a certain threshold needing to be met. With regard to this aspect, having either China or the United States (by far the two largest polluters in the world) on board seems like an important requirement. Both countries have repeated that they would not engage in binding agreements, which complicated the Paris agreement. The implication of the United States is now extremely weak, with Trump's decision to back-out of the Paris agreement. On the contrary, China seems to be more and more concerned with the possible effects of global warming. A strong climate club including China and the EU would cover more than 40% of the world's GHG emissions. More importantly, they are two economic powers who could create strong incentives to join the effort by imposing tariffs.

This subchapter has allowed us to briefly discuss one of the most frustrating failures of international cooperation: Despite a consensus on the negative effects of climate change, countries have yet refused to set up any kind of binding agreement. Even more problematic: none of the currently enforced treaties on climate change include sanctions. According to the literature, this lack of sanctions appears to be the key explanation for the failure of cooperation in this matter (Barrett, 2014). We limit ourselves to a basic presentation of a few possible solutions[74]. Nevertheless, it was important to at least mention it, because it is clear that a better cooperation by countries could increase acceptability for environmental policies.

Furthermore, we have found reasons for optimism. Mainly, interesting suggestions in order to reach a cooperative equilibrium are suggested by Nordhaus and Barrett. The core idea is to use trade relations to apply sanctions towards non-participants. Those sanctions should then change the incentives of countries, so that the cost of not cooperating would be too high. Since it was shown mathematically that a small tariff on imports (2%) could lead to cooperation in carbon pricing, this policy could truly be effective. Also, the fact that such a mechanism has already been applied and been successful in the Montréal Protocol shows that this should not remain only a theoretical proposition in the future, but rather be implemented.

[74] Cooperation in climate change is a vast issue, which could easilly be the topic of an entire thesis.

Conclusion

This thesis was an opportunity to dive into the vast topic of environmental policies, focusing on carbon pricing initiatives. Carbon pricing is often discussed from the point of view of efficiency. We have chosen to present an other side of the debate, which is very important for policy-making: acceptability. As a conclusion, we would like to briefly restate the main conclusions of this thesis.

First, acceptability is important because it affects the actual implementation of environmental measures. Unfortunately, carbon pricing creates many fears and concerns, which all undermine carbon pricing implementation. To our opinion, two concerns were extremely important: potential regressive effects and carbon leakage.

Secondly, we addressed in details the issue of regressivity. So far, empirical results tend to show that carbon pricing policies are regressive. We also showed that most of those studies suffer from a bias, requiring further empirical analysis in this field. One very surprising result was people's preferences for the redistribution of carbon tax revenues. We expected acceptability for carbon pricing to increase when revenues are used in a progressive manner. Results show that rather, acceptability strongly increases when revenues are used to finance green investments. This is an important result in terms of policy making.

Lastly, we have discussed the issue of carbon leakage. This was a way to introduce concerns for national competitiveness, particularly when a carbon pricing policy is unilaterally implemented. This concern is probably the most often used argument against carbon pricing. We have been able to show that so far, no empirical study has been able to find any significant evidence of carbon leakage. Even if it was to become the case in the future, measures such as BCA should be able to mitigate this issue at a relatively low cost. This is a positive result for the future of carbon pricing; one that deserves more attention in the public discussions.

For further researches, we would like to emphasize three points. First, it is very important to improve the estimation of carbon pricing distributional effects. Indeed, we saw in our review of literature that most studies forget the so-called revenue side effect. Very recent studies have used CGE analysis to estimate both revenue side and spending side effects. We hope that this type of studies will be applied to more countries and data.

Linked with this issue, we also hope that analyzes of carbon pricing will in the future be able to include the potential benefits of reducing GHG. Unfortunately, empirical analyzes focus only on the costs of carbon pricing. We argue that in order to judge the true effectiveness of carbon pricing policies (and more generally of other environmental policies), some measure of potential benefits should be introduced. "The difficulties in measuring the monetary benefits of emission reductions have been discussed extensively in the literature" (Boyce, 2018, p. 55). Of course, it is an extremely difficult element to estimate. Yet, being able to give a monetary measure of carbon pricing's benefits would very likely increase acceptability. To this date, no satisfying solution to these difficulties has been found.

Lastly, it is important to better understand the true reasons behind people's aversion for carbon pricing. We have tried to answer this question by doing a detailed review of literature. Nevertheless, we also hope that more randomized surveys will be conducted in various countries. To our opinion, those surveys give valuable information on how to design carbon pricing policies, such that they are then accepted by the population. It would also be interesting to see whether those surveys find differences among countries, particularly between developed and developing countries. This is something that has not been done so far.

References

Andersson J. (2017), “Cars, carbon taxes and CO_2 emissions”, Centre for Climate Change Economics and Policy: working paper No. 238

Baranzini A., Van der Bergh J., Carattini S., Howarth R., Padilla E. and Roca J., (2017), “Carbon pricing in climate policy: seven reasons, complementary instruments, and political economy considerations”, *WIREs Clim Change*, 2017, 8:e462. doi: 10.1002/wcc.462

Baranzini A. and Carattini S. (2017), “Effectiveness, earmarking and labeling: testing the acceptability of carbon taxes with survey data”, *Environmental Economics and Policy Studies*, January 2017, Vol. 19, Issue 1, pp. 197-227

Barrett (2014), “Why have climate negotiations proved so disappointing”, Pontifical Academy of Sciences, Extra Series 41, Vatican City 2014, pp. 261-276

Barrett (2016), “Coordination vs. voluntarism and enforcement in sustaining international environmental cooperation”, *PNAS,* December 2016, Vol. 113, No. 51, pp. 14515-14522

Beck M., Rivers N., Wigle R. (2015), “Carbon tax and revenue recycling: Impacts on households in British Columbia”, *Resource and Energy Economics*, Vol. 41, August 2015, pp. 40-69

Best R., Burke P. (2018), “Adoption of solar and wind energy: The roles of carbon pricing and aggregate policy support”, *Energy policy,* July 2018, Vol. 118, pp. 404-417

Bicket M. and Vanner R. (2016), “Designing Policy Mixes for Resource Efficiency: The role of Public Acceptability”, *Sustainability*, Vol. 8, Issue 4, 366

Böhringer M., Balistreri E. and Rutherford T. (2012), “The role of border carbon adjustement in unilateral climate policy: Overview of an energy modeling forum study”, *Energy Economics*, Vol. 34, Supplement 2, pp. S97-S110

Böhringer C., Carbone J. and Rutherford T. (2012b), “Unilateral climate policy design: Efficiency and equity implications of alternative instruments to reduce carbon leakage”, *Energy Economics*, 34 (2012), pp. 97-110

Bovenberg A. (1999) “Green tax reforms and the double dividend: an updated reader’s guide”, *International Tax and Public Finance*, 6, pp. 421–443

Bovenberg A. and Goulder L. (2001), “Neutralizing the Adverse Industry Impacts of CO_2 Abatement Policies: What does it cost?”, pp. 45-89. In Carraro C. and Metcalf G. (2001), *Distributional and Behavioral Impacts of Environmental Policy*, Chicago University Press, Chicago

Bowen (2015), “Carbon Pricing: How best to use the revenues”, Policy Brief, Grantham Research Institute on Climate Change and the Environment, available at: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2015/11/Bowen-policy-brief-2015.pdf

Boyce J. (2018), "Carbon pricing : Effectiveness and Equity", *Ecological economics*, August 2018, Vol. 150, pp. 52-61

Branger F., Quirion P. and Chevalier J. (2013), "Carbon leakage and competitivness of cement and steel industries under the EU ETS: much ado about nothing", 2013, hal-00945186

Branger F. and Quirion F. (2014), "Climate policy and the carbon haven effect", *Wiley Interdisciplinary Reviews: Climate Change*, 2014, 5 (1), pp. 53-71

Branger F. and Quirion F. (2014b), "Would border carbon adjustments prevent carbon leakage and heavy industry competitiveness losses? Insights from a meta-analysis of recent economic studies", *Ecological Economics*, March 2014, Vol. 99, pp. 29-39

Bristow A., Wardman M., Zanni A., and Chintakalaya P. (2010), "Public acceptability of personal carbon trading and carbon tax", *Ecological Economics*, Vol. 69, pp. 1824-1837

Brünnengräber A. (2012), "Multi-level climate governance: strategic selectivities in international politics". In: Knieling J. and Filho W. (2012), *Climate change management*, Springer, pp. 67-83

Burniaux J-M., Chateau J. and Duval R. (2013), "Is there a case for carbon-based border tax adjustment? An applied general equilibrium analysis", *Applied Economics*, June 2013, Vol. 45, Issue 16, pp. 2231-2240

Callan T., Lyons S., Scott S., Tol R. and Verde S. (2009), "The distributional implications of a carbon tax in Ireland", *Energy policy*, Vol. 37, issue 2, February 2009, pp. 407-412

Carattini S., Carvalho M. and Fankhauser S. (2017), "How to make carbon taxes more acceptable", Policy Report, December 2017, Grantham Research Institute on Climate Change and the Environment

Carattini S., Baranzini A., Thalmann P., Varone P. and Vöhringer F. (2017b) "Green taxes in a post-Paris world: Are millions of nays inevitable?", *Environmental and Resource Economics*, pp. 1–32

Carattini S., Carvalho M. and Fankhauser S. (2018), "Overcoming public resistance to carbon taxes", *WIREs Climate Change*, October 2018, Vol. 9, Issue 5, pp. 1-26

Carbon Market Watch, "Industry's windall profits from Europe Carbon Market 2008-2015", Policy briefing, Nov. 2016. Availabe at: https://carbonmarketwatch.org/wp/wp-content/uploads/2016/11/CMW-Industry-windfall-profits-from-EUs-carbon-market-2008_2015.pdf

Carbone J. and Rivers N. (2017), "The impacts of unilateral climate policy on competitiveness: Evidence from Computable General Equilibrium models", *Review of Environmental Economics and Policy*, Janaury 2017, Vol. 11, Issue 1, pp. 24-42

Carl J. and Fedor D. (2016), "Tracking global carbon revenues: A survey of carbon taxes versus cap-and-trade in the real world", Energy Policy, Vol. 96, September 2016, pp. 50-77

Carmin J. and Darnall N. (2005), "Greener and cleaner? The signaling accuracy of U.S. voluntary environmental programs", *Policy sciences*, Vol. 38 (2005), pp. 71-90

Carraro C. and Sinsiscalco D. (1997), *New directions in the economic theory of the environment*, Cambridge University Press

Ciscar et al. (2011), "Physical and economic consequences of climate change in Europe", *PNAS*, February 15, 2011, Vol. 108, No. 7, pp. 2678-2683

Climate Action Network Europe (2018), "Off target: ranking of EU countries' ambition and progress in fighting climate change", available at: http://www.caneurope.org/docman/climate-energy-targets/3357-off-target-ranking-of-eu-countries-ambition-and-progress-in-fighting-climate-change/file

Cook J. et al. (2016), "Consensus on consensus: a synthesis of consensus estimates on human-caused global warming", *Environmental Research letters*, 2016, 11, pp. 1-7

Cole M. and Elliott R., (2005), "FDI and the capital intensity of "Dirty"sectors: A missing piece of the pollution haven puzzle", *Review of Development Economics*, 9(4), 530–548, 2005

Combet E. and Méjean A. (2017), "The equity and efficiency trade-off of carbon tax revenue recycling: A reexamination", http://www2.centre-cired.fr/IMG/pdf/main-3.pdf

Confédération Suisse, National Centre for Climate Services (2018), "CH2018 – Climate Scenarios for Switzerland", available at: https://www.nccs.admin.ch/nccs/fr/home/changement-climatique-et-impacts/scenarios-climatiques-suisses/rapport-technique.html

Cramton P. and Kerr S. (2002), "Tradable carbon permit auctions. How and why to auction not to grandfather", *Energy Policy*, March 2002, Vol. 30, Issue 4, pp. 333-345

Darnall N. and Sides S. (2008), "Assessing the performance of Voluntary Environmental Programs: Does certification matter?", *The policy studies journal*, Vol. 36, No. 1, 2008

Dechezleprêtre A. and Misato S. (2017), "The impact of environmental regulations on competitiveness", *Review of Environmental Economics and Policy*, Volume 11, Issue 2, 1 July 2017, Pages 183–206

Dinan T. and Rogers D. (2002), "Distributional Effects of Carbon Allowance Trading: How Government Decisions Determine Winners and Losers", *National Tax Journal*, Vol. LV, No 2, June 2002, pp. 199-221

Dinan T. (2015),"Off-setting a carbon tax's burden on low-income households". In: *Implementing a US carbon tax: challenges and debates* (2015), Parry, Morris and Williams, Routledge

Dinda S. (2004), "Environmnental Kuznets Curve hypothesis: A Survey", *Ecological Economics*, 2004, Vol. 49, pp. 431-455

Drews S. and Van den Bergh (2015), "What explains public support for climate policies? A review of empirical and experimental studies", *Climate policy*, Vol. 16, No. 7, pp. 855-876

Dröge S. (2009), "Tackling leakage in a world of unequal carbon prices", Climate Strategies working paper, July 2009, available at: http://www2.centre-cired.fr/IMG/pdf/cs_tackling_leakage_report_final.pdf

Dynan K., Skinner J., Zeldes S. (2004), "Do the rich save more?", *Journal of Political Economy*, 2004, Vol. 112, No. 2

Elliott J., Foster I., Kortum S., Munson T., Cervantes F. and Weisbach D. (2010), "Carbon taxes and trade", *The American Economic Review*, Vol. 100, No. 2, pp. 465-469

Fontagné et Fouré (2017), "La politique commerciale au service de la politique climatique", lettre du CEPII

Gevrek Z. and Uyduranoglu A. (2015), "Public preference for carbon tax attributes", *Ecological Economics,* Vol. 118, October 2015, pp. 186-197

Grainger C. and Kolstad C. (2009), "Who pays a price on carbon?", NBER working paper series, August 2009

Grubb M. (2009), "Tackling carbon leakage", Presentation at the British Institute of Energy Economics (BIEE), Climate Change and competitiveness

Haites E. (2006), "Allowance banking in emissions trading schemes: Theory and practice", Margaree Consultants Inc., available at : http://www.margaree.ca/papers/Allowance%20Banking.pdf

Helm C. and Schmidt R. (2014), "Climate cooperation with technology investments and border carbon adjustements", Harvard Project on Climate Agreements, Discussion Paper 2014-65

Hille E. (2018), "Pollution havens: International empirical evidence using a shadow price measure of climate policy stringency", *Empirical Economics*, May 2018, Vol. 54, Issue 3, pp. 1137-1171

IPCC (2001), *"Climate change: Mitigation. Contribution of Working group III to the Assesment Report of the IPCC"*, Cambridge University Press, 2001

IPCC (2007), "AR4 Climate Change: Synthesis Report", available at: https://www.ipcc.ch/report/ar4/syr

IPCC (2014), "AR5 Climate Change Report: Synthesis Report", available at: https://www.ipcc.ch/report/ar5/syr/

IPCC (2018), "Special Report: Global Warming of 1.5° C", available at: https://www.ipcc.ch/sr15/

Jenkins J. (2014), "Political economy constraints on carbon pricing policies: What are the implications for economic efficiency, environmental efficacy, and climate policy design?", *Energy policy*, Vol. 69, June 2014, pp. 467-477

Joltreau E. and Sommerfeld E. (2018), "Why does Emission Trading under the European Emissions Trading System not affect firms' competitivness? Empirical findings from the literature", Climate Policy, 2019, Vol. 19, Issue 4, pp. 453-471

Kellenberg D. (2009), "An empirical investigation of the pollution haven effect with strategic environment and trade policy", *Journal of International Economics*, Vol. 78, issue 2, July 2009, pp. 242-255

Klenert D. and Mattauch L. (2015), "How to make a carbon tax reform progressive: the role of subsistence consumption", MPRA paper No. 84290, available at: https://mpra.ub.uni-muenchen.de/84290/1/MPRA_paper_84290.pdf

Klenert D., Mattauch L., Combet E., Edenhofer O., Hepburn C., Rafaty and Stern N. (2018), "Making Carbon Pricing Work for Citizens", *Nature Climate Change* 8(8).

Koch N. and Mama H. (2016), "European Climate Policy and Industrial Relocation: Evidence from German Multinational Firms", SSRN working paper, available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2868283

Lawrence P. and Wong D. (2017), "Soft law in the Paris Climate Agreement: Strength or Weakness", *Review of European Comparative & International Environmental Law*, November 2017, Vol. 26, Issue 3, pp. 276-286

Marcu A., Egenhofer C., Roth S. and Stoefs W. (2013), "Carbon leakage: an overview", CEPS special report, No. 79, December 2013

Mathur A. and Morris A. (2014), "Distributional effects of a carbon tax in broader US fiscal reform", *Energy Policy*, 2014, Vol. 66, pp. 326-334

Mehling M., Van Hasselt H., Das K., Droege S. and Verkuijl C. (2017), "Designing Border Carbon Adjustments for enhanced climate action", Climate strategies, available at: https://climatestrategies.org/wp-content/uploads/2017/12/CS_report-Dec-2017-4.pdf

Mendelsohn and Dinar, (2006), "The distributional impacts of climate change on rich and poor countries", *Environment and Development Economics*, April 2006, Vol. 11, Issue 2, pp. 159-178

Metcalf G., Paltsev S., Reilly S., Jacoby H. and Holak J. (2008), "Analysis of U.S. Greenhouse Gas Tax Proposals", MIT Joint Program on the Science and Policy of Global Change, Report No. 160. April 2018

Metcalf G. (2015), "A conceptual framework for measuring the effectiveness of green fiscal reforms". Paper presented at the Green Growth Knowledge Platform Third Annual Conference on "Fiscal Policies and the Green Economy Transition: Generating Knowledge, Creating Impact", Venice, Italy, January 29–30, 2015

Métivier C., Postic S., Alberola E. and Vinnakota M. (2017), "Global panorama of carbon prices in 2017", Institute for Climate Economics, October 2017

Mickwitz P. (2003), "A Framework for Evaluating Environmental Policy Instruments", *Evaluation*, 2003, Vol. 9, Issue 4, pp. 415-436

Millimet D. and Roy J. (2016), "Empirical test of the pollution haven hypothesis when environmental regulation is endogenous", *Journal of Applied Econometrics*, 2016, 31, pp. 652-677

Morris A. and Mathur A. (2015), "The distributional burden of a carbon tax", pp. 97-119. In: *Implementing a US carbon tax: challenges and debates* (2015), Parry, Morris and Williams, Routledge

Murray B. and Rivers N. (2015), "British Columbia's revenue neutral carbon tax: A review of the latest "grand experiment" in environmental policy", *Energy Policy*, Vol. 86, November 2015, pp. 674-683

Naegele H. and Zaklan A. (2017), "Does the EU ETS cause carbon leakage in European manufacturing?", Deutsches Institut für Wirtschaftsforschung Discussion paper

Nordhaus W. (2007), "To tax or not to tax: Alternative approaches to slowing global warming", *Review of Environmental Economics and Policy*, Winter 2007, Vol. 1, issue 1, pp. 26-44

Nordhaus W. (2015), "Climate Clubs: Overcoming Free-riding in International Climate Policy", *American Economic Review* 2015, 105(4): 1339–1370

Organe consultatif sur les Changements Climatiques (OcCC) (2007), "Les changements climatiques et la Suisse en 2050", available at: http://www.occc.ch/pdf/855.pdf

OECD (2015), *The economic consequences of Climate Change*, OECD publishing, Paris, available at: https://dx.doi.org/10.1787/9789264235410-en

OECD discussion paper (2017), "Designing Carbon Pricing Instruments for Ambitious Climate Policy", available at: http://www.minambiente.it/sites/default/files/archivio/allegati/sviluppo_sostenibile/g7_cmp_oecd_2017_09_28_rome.pdf

Ostrom E.. (1990). *Governing the Commons: The Evolution of Institutions for Collective Action*. New York, NY: Cambridge University Press, 1990

Paavola J. (2012), "Climate Change: The ultimate tragedy of the commons?". In : Cole D. and Ostrom E. (2012), *Property in Land and other Resources*, Lincoln Institute of Land Policy, pp. 417-438

Parry I. (2015), "Carbon Tax Burdens on Low-Income Households: A Reason for Delaying Climate Policy? ", CESifo working paper, No 5482

Partnership for Market Readiness (2015), "Carbon leakage: Theory, Evidence and Policy Design", Technical note 11, October 2015, The World Bank, available at: https://openknowledge.worldbank.org/bitstream/handle/10986/22785/K8516.pdf?sequence=1&isAllowed=y

Patt A. and Lilliestam J. (2019), "An alternative to carbon taxes", ETH Zürich Zukunftsblog, available at: https://www.ethz.ch/en/news-and-events/eth-news/news/2019/01/blog-patt-lilliestam-carbon-tax.html

Pechar E., Murray B. and Pizer W. (2018), "The Relationship between policy design choices, carbon prices and ambition: evidence from the field", Duke Environmental and Economics Working Paper Series, August 2018

Perman R.. Ma Y., McGilvray J. and Common M. (2003), *Natural Resource and Environmental Economics (Third edition)*, Pearson education

Potoski M. and Prakash A. (2006), *The Voluntary Environmentalists: Green clubs, ISO 14'001 and voluntary environmental regulations*, Cambridge University Press

Potoski M. and Prakash A. (2012), "Voluntary Environmental Programs: A comparative perspective", *Journal of policy analysis and management,* Vol. 31, No. 1, pp. 123-138 (2012)

Rausch S., Metcalf G. and Reilly J. (2011), "Distributional impacts of carbon pricing: A general equilibrium approach with micro-data for households", *Energy Economics*, 33, pp. 20-33

Reinaud J. (2008), "Issues behind competitiveness and carbon leakage: focus on heavy industry", International Energy Agency (OECD) information paper, available at: https://pdfs.semanticscholar.org/9d34/f6b4b6b0923b02f81b5021163606c383ddf8.pdf

Rivers N. (2012), "Policy Forum: The Distribution of Costs of a Carbon Tax Among Canadian Households", *Revue Fiscale Canadienne*, 2012, Vol. 60, No. 4, pp. 899-915

Rivers N. and Schaufele B. (2015), "Salience of carbon taxes in the gasoline market", *Journal of Environmental Economics and Management*, Vol. 74, November 2015, pp. 23-36

Rocchi P., Serrano M., Roca J. and Arto I. (2018), "Border carbon adjustements based on avoided emissions : Adressing the challenge of its design", *Ecological Economics*, Vol. 145, march 2018, pp.

Saelen H. and Kallbekken S. (2011), "A choice experiment on fuel taxation and earmarking in Norway", Ecological Economics, September 2011, Vol. 70, Issue 11, pp. 2181-2190

Sato M. and Dechezleprêtre A. (2015), "Asymetric industrial prices and international trade", Center for Climate Change Economics and Policy, Working Paper No. 202, February 2015

Scott S. and Eakins J. (2004), "Carbon taxes: which households gain or lose?", ERTDI Report series 20, Environmental Protection Agency, Johnstown Castle

Stern P. (2000), "Toward a Coherent Theory of Environmentally Significant Behavior", Journal of social issues, 2000, Vol. 56, No. 3, pp. 407-424

Stiglitz, J. and Stern N. (2017), *Report of the High-Level Commission on Carbon Prices*

Sverker C. Jagers, Johan Martinsson and Simon Matti (2018) ,"The impact of compensatory measures on public support for carbon taxation: an experimental study in Sweden", *Climate Policy*, DOI: 10.1080/14693062.2018.1470963

Tamiotti L. (2011), "The legal interface between carbon border measures and trade rules", *Climate Policy*, Vol. 11, Iss. 5, pp. 1202-1211

The New York Times (December 6 2018), "Yellow Vest' Protests Shake France. Here's the Lesson for Climate Change.", available at: https://www.nytimes.com/2018/12/06/world/europe/france-fuel-carbon-tax.html

The Oxford Institute for Energy Studies (2018), "The EU ETS phase IV reform: implications for system functioning and for the carbon price signal", available at: https://www.oxfordenergy.org/publications/eu-ets-phase-iv-reform-implications-system-functioning-carbon-price-signal/

The Washington Post (December 4 2018), "France's protesters are part of a global backlash against climate-change taxes", available at: https://www.washingtonpost.com/world/europe/frances-protesters-are-part-of-a-global-backlash-against-climate-change-taxes/2018/12/04/08365882-f723-11e8-863c-9e2f864d47e7_story.html?utm_term=.7ce7e1fc8497

Tjernström E., Tietenberg T. (2008), "Do differences in attitudes explain differences in national climate change policies?", *Ecological Economics*, 2008, Vol. 65, Issue 2, pp. 315-324

Tietenberg T. and Lewis L. (2012), *Environmental and natural resource economics*, Pearson education

Tresch R. (2008), *Public Sector Economics*, Palgrave Macmillan,

Van Asselt H. and Brewer T. (2010), "Addressing competitiveness and leakage concerns in climate change policy: an analysis of border adjustment measures in the US and the EU", *Energy policy*, Vol. 38, issue 1, January 2010, pp. 42-51

Wang Q., Hubacek K., Feng K., Wei Y. and Liang Q. (2016), "Distributional effects of carbon taxation", *Applied Energy*, 2016, Vol. 184, pp. 1123-1131

Wier M., Birr-Pedersen K., Jacobsen H. and Klok J. (2005), "Are CO2 taxes regressive? Evidence from the Danish experience", Ecological Economics, 2005, 52, pp. 239-251

Wong P. (2015), "From Copenhagen to Paris: Climate Change and the limits of Rationality, Multilateralism and Leadership", *The Brown Journal of World Affairs*, Issue 2, Spring 2015, pp. 267-282

World Bank and Ecofys (2018), "State and trends of carbon pricing 2018", May 2018, Washington DC, World Bank publications

Wu T. and Thomassin P.J. (2018), "The impact of Carbon Tax on Food Prices and Consumption in Canada", Conference on July 28- August 2, Vancouver, British Columbia, International Association of Agricultural Economists

Yamazaki A. (2017), “Jobs and climate policy: evidence from British Columbia’s revenue neutral carbon tax”, *Journal of Environmental Economics and Management*, Vol. 83, May 2017, pp. 197-216

Yip C.(2018), “On the labor market consequences of environmental taxes”, *Journal of environmental Economics and Management*, Vol. 89, May 2018, pp. 136-152

Zhang Z. and Baranzini A. (2004), “What do we know about carbon taxes? An inquiry into their impacts on competitiveness and distribution of income”, *Energy Policy*, March 2004, Vol. 32, Issue 4, pp. 507-518

Zvěřinová I., Ščasný M., Kyselá E. (2013), “What Influences Public Acceptance of the Current Policies to Reduce GHG Emissions?”, CECILIA2050, optimal EU climate policy, Prague, Charles University Environment Center.