TEACHING CLIMATE CHANGE TO ECON 101 STUDENTS

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Abstract

There is a growing recognition that ECON 101 does not adequately prepare students to address the pressing issues of our times including climate change. However, options such as the CORE text are unsuitable because of information overload and the use of advanced technical concepts and techniques. The objective in this paper is to introduce climate change to ECON 101 students in a way that minimizes student confusion, instructor workload, and upholds Mankiw's approach of clarity before nuance. A new approach is delineated based on popular books, magazine articles, a YouTube video, and simple exercises. This five-part approach consists of emphasizing the urgency of climate change, thinking outside the box through geoengineering, the limits of individual actions like buying local or going vegan, the comparative outlook on various policy tools with a simple equation solving exercise, and game theory to broach the issue of international collaboration.

Keywords: ECON 101, CORE, teaching economics, climate change

JEL Classification: A22, Q54

Introduction

There is a growing recognition that ECON 101 does not adequately prepare students to address the pressing issues of our times including climate change, economic inequality, and the future of work with automation (Bowles and Carlin, 2020). Among all these issues, climate change stands out, as Krugman warns that if greenhouse gas emissions are not limited then none of the other issues of healthcare spending, budget deficits, and inequality will matter (Krugman, 2020, p. 327). Yet, ECON 101 students are trained more to solve for equilibrium, calculate elasticities, and determine the profit maximizing solution, than addressing contemporary issues. For instance, I use the Mankiw, Kneebone, and McKenzie (2020a) textbook to teach ECON 101, where economic inequality does not appear until Chapter 20 and climate change is subsumed in a section on externalities that is briefly covered towards the end of term.

The objective in this paper is to explore how best to introduce climate change to ECON 101 students in a way that causes the least disruption for both instructors and students who are engaged with the mainstream neoclassical paradigm. To this end, the motivation for this paper is offered through a brief review of a few recent papers on teaching climate change and economics in Section 2. This is followed by a critical evaluation of three alternatives to the Mankiw, Kneebone, and McKenzie textbook in Section 3. Having delineated the concerns with these substitutes, a new way of introducing climate change to ECON 101 students through a video, articles, and exercises from other books is presented through a five-part approach in Section 4. Concluding remarks are presented in Section 5.

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Motivation

In their review of teaching climate change and ECON 101, Liu, Bauman, and Chuang (2019) indicate that for most textbooks, climate change is subsumed in the chapters on externalities or environmental economics. Therefore, they suggest addressing the topic more broadly beyond the externality framework. They are concerned that the way climate change is presented may lead students to think of it as a "minor aberration" and allow instructors to skip the topic altogether due to its location in the textbook. Additionally, they mention that despite the consensus position among climate scientists that human beings are largely responsible for global warming, some textbooks eschew that scientific consensus. Finally, they state that while all textbooks emphasize the key message that incentive-based mechanisms are better than command-and-control regulations, most textbooks do not delve into a preference between a cap-and-trade program and carbon taxes.

Lewis and Wichman (2021) indicate that instructors are increasingly teaching climate change content because of demand from economics students. Based on their survey of various courses, they mention that while externalities are usually taught in depth, topics like tipping points and geoengineering are now being included in some courses. Gonzales-Ramirez, Caviglia-Harris, and Whitehead (2021) confirm that the most common topic is how incentive-based approaches (permits and taxes) to addressing externalities are more efficient than command-and-control policies (standards). They survey the literature to showcase a multitude of games that have been designed for pedagogical purposes. Several of these games are quite time intensive, with a few being semester long with weekly discussions.

These games include Corrigan (2011), which delves into illustrating the relative strengths of various market-based approaches to addressing externalities, as textbooks don't generally address this comparison. However, this game assumes prior economic knowledge on marginal analysis and externalities. Duke and Sassoon (2017) also present a game but mention that the literature indicates that while students recall more of the acquired knowledge, the evidence of improved learning through such activities is modest. Even in the game designed by Caviglia-Harris and Melstrom (2015) where prior economic knowledge on marginal analysis and externalities is not required and which only takes 20 minutes of class time, there are concerns. The issues include excessive time and preparation required of instructors for seemingly low level of improved learning results. Other concerns are about relatively weaker students getting embroiled with the logistics of games or failing to act rationally and getting results contrary to what the instructor expected to show. Thus, such a situation could lead to both student confusion and instructor frustration despite spending so much time and effort.

Just as there are concerns with using games as pedagogical tools, there are issues with including extra reading material to teaching climate change. Basu (2021) opines that while it is important to remain updated with material beyond the textbook, instructors must be mindful of assigning additional reading that yield diminishing returns if students find them overwhelming and too much work. Likewise, with large class sizes and without proper help on grading, instructors may find their workload burdensome as well. Similarly, innovations in teaching pedagogy like Decker (2020), which uses isoquants and isocosts to compare emission taxes and subsidies, are not necessarily suitable for ECON 101 students who get lost in technical logistics instead of learning the basic results. All such innovations in teaching climate change, take us back to Mankiw, who argues that the capacity of students to absorb information does not expand just because economic knowledge does (Mankiw, 2020b), that we must avoid information

overload and that less is more (Mankiw, 2020c). In short, Mankiw remains a proponent of clarity before nuance.

To recapitulate, the brief literature review shows that it is increasingly important to teach climate change and emphasize that human beings have been responsible for global warming. It underscores topics like tipping points, geoengineering, and the comparative outlook on policy tools. However, it shows the limits in using innovations in teaching pedagogy like games, advanced tools like isoquants, or extraneous readings, as students may get confused by logistical details and instructors may get frustrated with increased workload only to achieve modest improved learning results. Therefore, it is important that before we start piling up ECON 101 with more detail, we ensure clarity and avoid information overload. It is this principle of clarity before nuance that should guide our initiatives on teaching climate change to ECON 101 students.

Alternatives

While Mankiw highlights the principle of clarity before nuance, it is also true that the treatment of climate change in his textbook is inadequate. This is because climate change is subsumed in a section on externalities and is not presented as an urgent issue to be discussed. Additionally, topics including tipping points, geoengineering, individual actions, and international collaboration are starkly missing. The various policy tools on climate change are also not adequately compared. This necessitates investigating alternatives to the Mankiw, Kneebone, and MacKenzie textbook to find the most effective way of teaching climate change to ECON 101 students. Three disparate options including the CORE text for introduction to economics, the microeconomics principles textbook by Ragan (2020), and the chapter on climate change in the Tietenberg and Lewis (2015) textbook on environmental and resource economics are reviewed below.

CORE: The Economy

The first option is the CORE text, which has recently been promoted by Bowles and Carlin (2020) in the *Journal of Economic Literature*. They mention that the CORE text emphasizes feasible sets, indifference curves and Nash equilibrium, and concede that on the complexity of language, the CORE text is "somewhat more complex than Mankiw's." The CORE textbook is freely available online and blends both micro and macro topics in the same chapters. While it introduces the issue of the environment early on, it is only in the capstone Chapter 20 that it delves into details on the economics of the environment. Divided into ten sections, this chapter makes use of intermediate microeconomics concepts like the marginal rate of transformation and the marginal rate of substitution, to offer a technical discussion with the use of graphs on the environment-consumption frontier and indifference curves. This allows to capture the trade-off and citizen preferences between the environment and consumption.

Section 5 of the chapter provides the more conventional graph on marginal abatement costs and highlights the problems of the cap-and-trade approach including oversupply of permits and falling prices, which reduce the incentives to abate emissions. However, Section 7 returns to intermediate microeconomics concepts of income and substitution effects in the context of an environment tax. Section 8 illustrates a tipping point as an unstable equilibrium at which environmental degradation is irreversible. Any uncertainty on the tipping point substantiates the use of prudential policy like a cap-and-trade program, as opposed to a tax, for it can guarantee

the emission level. Finally, Section 9 focuses on why addressing climate change is difficult by alluding to the difficulty in international collaboration through the Prisoner's Dilemma.

Overall, it seems that in trying to do too much, the CORE text disrupts the sequential introduction of economic concepts in favour of an eclectic approach. It links to various extraneous reports and articles and uses exercises involving present value calculations and scatter plots. As such, the problem of information overload becomes overwhelming. Moreover, it zig-zags between intermediate and principles level concepts, and adequately addresses the topic far later in Chapter 20. Thus, the use of advanced technical concepts and the late location of the topic do not facilitate using the CORE text as a viable alternative to the Mankiw, Kneebone, and MacKenzie textbook to teach climate change to ECON 101 students.

The Ragan Textbook

While the CORE text offers an unorthodox approach, the Ragan (2020) textbook provides a more conventional approach to the topic of climate change that is suitable for ECON 101 students. While it also introduces the topic later in Chapter 17, it does offer more detail than the Mankiw, Kneebone, and MacKenzie textbook. Ragan expressly states the consensus amongst scientists that human beings are contributing to climate change through greenhouse gas emissions. He confirms climate change as the mother of all externalities and alludes to the consequences of the loss of fresh water supplies, displacement of people with rising sea levels, extinction of some species, destruction of wildlife habitat, reduced food yields, and increased intensity of storms and volatility of weather.

Ragan emphasizes that some environmental damage is inevitable with the production of goods and services. Although, he also states that several European countries have achieved emission reductions along with continued growth in GDP. Focusing on pollution abatement, he confirms the main point that market-based policies (taxes and permits) are more efficient than command-and-control regulation because they are cost effective and incentivize innovation. Moreover, in underscoring the problems with both emission taxes and cap-and-trade systems, he chiefly emphasizes the issue of measuring pollution with accuracy. Similarly, on renewable energy, he mentions the issues of scarcity of sites for hydro energy, safe storage for nuclear energy, and capital costs for solar and wind energy. Finally, he emphasizes that significant reduction in emissions will not result from individual small actions in our daily lives.

Overall, while simpler than the CORE text, Ragan (2020) offers more detail and presses the urgency of climate change compared to the Mankiw, Kneebone, and MacKenzie textbook. However, it has several issues of its own. First, it does not consider topics like tipping points and geoengineering. Second, the comparison of various policies on abatement is effectively lost in the wordy text. Third, students may find the graphical presentation confusing as the letter Q is used to denote both quantities of goods and pollution abatement. Fourth, the graphical analysis does not use the marginal abatement and marginal damage framework, which is usually used in environmental economics courses. Finally, climate change is a small section of the chapter, which is situated late in the book. This necessitates looking at another option to the Mankiw, Kneebone, and MacKenzie textbook to teach climate change to ECON 101 students.

The Tietenberg and Lewis Chapter

The benefit of considering a chapter from the Tietenberg and Lewis (2015) textbook on environmental and resource economics is that it directly focuses on climate change instead of embedding the topic in a chapter on externalities. The authors state outrightly that it is extremely

likely that human beings have been the dominant cause of global warming and that we need to act now despite limited information to avoid acting under future emergency conditions. They briefly mention geoengineering and indicate how game theory helps explain the difficulties in international collaboration. While they mention the Prisoner's Dilemma to explain lack of collaboration and showcase how cooperation can be achieved by linking climate change with other issues like international debt, trade agreements or sharing R&D, they do not illustrate these ideas with specific games.

Similarly, in addressing carbon taxes and emission trading systems (ETS), they do not use the graphical model with marginal abatement costs and marginal damages. The authors indicate that carbon taxes and emission trading are more effective at reducing emissions than renewable resource subsidies and regulation. However, they express concerns with both taxes and permits. Specifically, they state that emission trading markets are susceptible to market power and price manipulation and that there have been issues of over allocation of permits in the EU ETS. Likewise, they mention that countries like Norway have had reported increases in emission because of extensive exemptions on the carbon tax.

Overall, the benefit of using the chapter from Tietenberg and Lewis (2015) is that it directly addresses climate change instead of a sub-topic under externalities, and that the material comes from a course in environmental and resource economics. However, the treatment of topics like geoengineering and tipping points are inadequate. Similarly, the use of visual illustrations through graphs and games is starkly lacking. Moreover, it does not offer a thorough comparative discussion on taxes and permits. Therefore, this chapter is inadequate as a supplementary resource to the Mankiw, Kneebone, and MacKenzie textbook to teach climate change to ECON 101 students.

To recapitulate, while the Mankiw, Kneebone, and MacKenzie textbook does not present climate change as a pressing issue to be effectively addressed, each of the alternatives are not suitable either. The CORE text has been recently promoted in the *Journal of Economic Literature,* as a call to change the way we teach Economics. However, it is fraught with information overload and advanced technical concepts and techniques. The Ragan textbook offers more detail through a conventional approach, but it seems wordy and offers graphical analysis that is not consistent with the approach usually used in environmental economics courses. Similarly, borrowing a chapter from the Tietenberg and Lewis textbook is inadequate as it is bereft of graphical analysis despite addressing climate change directly. This necessitates charting a new approach to teaching climate change to ECON 101 students.

Presenting Climate Change to ECON 101 Students

In developing an effective way to teach climate change to ECON 101 students, it is important to avoid information overload and ensure that any pedagogical tools like games, assigned readings, and exercises are sequentially introduced at a level that ECON 101 students can connect with without being overwhelmed by workload and logistical details. To this end, I have compiled material from the Pindyck and Rubinfeld (2018) intermediate microeconomics textbook, the Field and Olewiler (2011) environmental economics textbook, popular books *Super Freakonomics* (2009) and *When to Rob a Bank* (2015) by Levitt and Dubner, a couple of articles from the magazine *Alberta Views,* and a video from Dhruv Rathee's educational channel on YouTube. Both the textbooks utilize much easier games and graphical analysis than those presented in the educational literature and the CORE text. The chapters from *Super*

Freakonomics and *How to Rob a Bank* help instructors retain student interest. The *Alberta Views* articles advance student understanding through the currency of issues.

Rathee's video in Hindi but subtitled in English is structured, succinct, and shows the point that people outside the western world are also deeply concerned about climate change. Finally, keeping in mind Mankiw's point on clarity before nuance, these supplementary resources are introduced systematically through a five-part approach, which consists of emphasizing the urgency of climate change, thinking outside the box through geoengineering, the limits of individual actions like buying local or going vegan, the comparative outlook on various policy tools with a simple equation solving exercise, and game theory to broach the issue of international collaboration. The idea in the following presentation is not to reinvent the wheel on various concepts but to showcase how the five topics can be broached through a simple and engaged manner with supplementary resources.

The Urgency of Climate Change

ECON 101 textbooks usually focus on addressing externalities and view climate change as just another issue for discussion. They usually do not address tipping points. On the other hand, the CORE text illustrates a tipping point using an "S" shaped graph that shows an unstable equilibrium at which environmental degradation becomes irreversible. However, instead of delving into the details of this graph, the key point is to simply emphasize the implication that we need to act prudently now before it is too late to rectify irreversible damage to the environment. This is because if we reach the tipping point, then additional efforts to curb climate change would not amount to much, as global warming is related to the stock (as opposed to the flow) of carbon emissions in the atmosphere.

In this regard, Dhruv Rathee's video "Extreme heat wave in Canada" is helpful as it allows students to visually understand the urgency of the issue (Figure 1). The video indicates that 50 degrees Celsius observed in July 2021 in Lytton, British Columbia is a temperature that is not even expected in places like New Delhi, India. It shows that some places like Canada are experiencing global warming more than average and highlights the danger of even 35 degrees Celsius at much higher humidity levels. With heat wave related fatalities, the video emphasizes that individual solutions of keeping the thermostat lower or biking instead of driving may not be enough to arrest this change and that governments will have to take a strong stand on ending fossil fuel subsidies and imposing a carbon tax. The video can also engender a discussion on which government policies (regulation, taxes, and permits) would be most effective against climate change.

Figure 1: Dhruv Rathee's Video "Extreme Heat Wave in Canada"

Image Source: https://i.ytimg.com/vi/o-TMOeCDeus/maxresdefault.jpg
Video: https://www.youtube.com/watch?v=o-TMOeCDeus

Thinking Outside the Box: Geoengineering

Another topic that is usually not considered in ECON 101 is that of geoengineering, which offers a more hopeful outlook based on human ingenuity and innovation. Thus, the pessimism evoked by tipping points can be balanced by the optimism created by geoengineering. In this regard, Chapter 5 from *Super Freakonomics* by Levitt and Dubner (2009) and the *Alberta Views* magazine article "Can Climate Change Be Reversed?" by Kopecky (2019) are suitable. These resources are more suitable for ECON 101 students than the more formal reports referred to in the CORE text.

The chapter from Levitt and Dubner (2009) offers a controversial picture of geoengineering but one that is important to consider in the worst-case scenario of catastrophic outcomes with global warming. The authors refer to a U.S. private company, Intellectual Ventures, according to which global warming solutions including conservation efforts, alternative energy like wind power, and cap-and-trade programs are too little, too late, and too optimistic (p. 186-187). Intellectual Ventures supports a Budyko's blanket, which is about injecting SO_2 to the stratosphere that would wrap the planet in a protective layer, reduce global temperature and possibly reverse global warming (p. 193-197). However, a Budyko's blanket could make people complacent and increase the incentive to pollute (p. 197).

In a similar vein, Kopecky (2019) states that climate risk remains even if we stop all carbon emissions today and that it is impossible to achieve a 1.5 degrees Celsius warming target without negative emissions technology. In this regard, he mentions Direct Air Capture (DAC), which is about taking more CO_2 from the atmosphere than we release to it, and Air to Fuels (ATF), which is about adding hydrogen to CO_2 to create carbon neutral synthetic fuels to replace fossil fuels. However, he cautions that such carbon engineering should be carefully considered due to side effects. Similarly, Tietenberg and Lewis (2015) state that generally such approaches

are fraught with uncertainties and may have possible adverse effects. This opens room for discussion with students on topics of risk and unintended consequences associated with geoengineering, as a colder Earth would be more hostile to life than a warmer Earth.[2] Nonetheless, including geoengineering as a discussion topic helps students think outside the box (the usual standards, taxes, and permits) to address climate change.

The Limits of Individual Small Actions

As mentioned earlier, Ragan (2020) emphasizes that significant reduction in emissions will not result from individual small actions in our daily lives. This point can be substantiated through Chapter 7 from *When to Rob a Bank* by Levitt and Dubner (2015). The authors provide a very interesting observation that greenhouse gas (GHG) emissions from walking 1.5 miles and replacing those calories by drinking milk are equivalent to those from simply driving the same distance (p. 167). The reason is that GHG emissions are connected to milk, as methane, which is a more potent GHG than CO_2, is released due to cow farts in a dairy farm. Therefore, the authors suggest that instead of jumping on the "buy local" bandwagon, turning to a vegan diet would be more effective in tackling climate change (p. 179).

However, Van Tighem (2020) states in his *Alberta Views* magazine article, "An Environmentalist's Case for Beef" that big corporations that promote "beyond meat" products profit by mass producing plant commodities. This is problematic, as genetically modified crops are grown on depleted soil that is supplemented by chemical fertilizers and pesticides, which kill native vegetation, destroy wildlife habitat, imperil biodiversity of wildlife and fish, and facilitate more emissions, as carbon cannot be safely stored in depleted soil. Therefore, instead of a vegan diet, he suggests grass fed beef, as it sustains biodiversity and living soil, which effectively stores carbon. Thus, introducing ECON 101 students to the ideas propounded by Levitt and Dubner (2015) and Van Tighem (2020) helps them understand that arresting climate change is not as simple as walking, buying local, or going vegan. On the other hand, individual small actions contribute to the overall public morality on climate change. This is important, as civic virtue facilitates the implementation of effective government policies on climate change (Field and Olewiler, 2011, p. 176).

Comparative Analysis of Policy Tools

Since individual efforts are not sufficient, governments will have to take a strong stand on climate change through policy tools that include standards, carbon taxes, and cap-and-trade programs. In contrast to the topics on tipping points, geoengineering, and individual small actions, much of this discussion is already contained in ECON 101 textbooks in the chapters on externalities or the economics of the environment. However, as noted earlier, Liu, Bauman, and Chuang (2019) indicate that while all textbooks emphasize that market-based mechanisms (taxes, permits) are better than standards, most textbooks do not delve into a preference between a cap-and-trade program and carbon taxes. In this regard, material from various chapters of Field and Olewiler (2011) can be stitched together to evaluate the policies comparatively. Additionally, in contrast to the more advanced tools used in the CORE text, this textbook also facilitates a simple numerical exercise that helps with the comparative evaluation of policies.

Table 1, which is based on material from Chapters 11, 12, and 13 of Field and Olewiler (2011), offers a comparative outlook on standards, taxes, and permits by showcasing the issues pertaining to each of the policy tools. This is a more effective way of presenting detailed

[2] I am grateful to the anonymous referee for this point.

information than wordy text. Additionally, this tabulated information is more comprehensive than that presented in each of the three alternatives discussed in Section 3.

Table 1: Comparison of Policy Tools

Theme	Standards	Carbon Tax	Emission Trading
Technological Incentives	No incentive to do better than achieving the emission standard	Incentivizes investment in new technologies to limit tax payment	Incentivizes R&D to reduce emissions to sell permits
Cost effectiveness	Technology standards take away flexibility to abate emissions at lower costs	Tax is cost-effective even if the regulator does not know about the marginal abatement costs (MACs)	Like a carbon tax, MACs are equalized
Firm behaviour	Firms engage in lobbying and delay compliance	Firms with market power may pass the tax cost to consumers	Firms can exercise market power and price manipulation
Government Behaviour	Governments avoid imposing stringent penalties to avoid economic dislocation	Governments may provide tax exemptions, especially considering international competitiveness	Governments may end up offering too many permits
Enforcement issues	Firms may install technology but ignore equipment maintenance and training of personnel	Regulator faces issues in setting the tax rate, monitoring performance, and collecting tax bills	Regulator has to monitor polluters to check if emissions are consistent with the number of permits
Government Revenues	No revenues are associated with emission or technology standards	Governments can use revenues to offer rebates to low-income households, and reduce distortionary taxes	Governments can make revenues if permits are auctioned instead of freely allocated
Political feasibility	Firms only have to worry about abatement costs instead of taxes or buying permits in addition to abatement costs	Citizens are usually wary of additional taxes	Politically easier to justify permits than taxes
Design Issues	Information requirement is high for cost-effective individual standards	The regulator may have to iterate to get the right tax rate	If permits are freely allocated, firms may increase emissions to get more permits

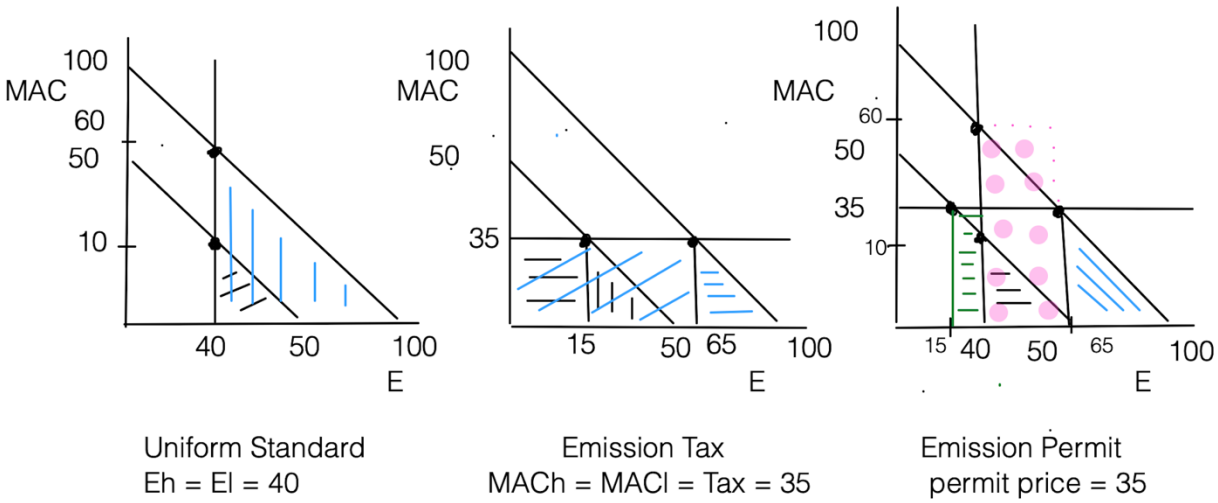
The policy tools can also be comparatively evaluated based on their cost effectiveness through the help of a numerical exercise for advanced student cohorts that are more well prepared mathematically. Chapter 14 of Field and Olewiler (2011) offers a problem that can be simplified and adapted for ECON 101 students (p. 229). This approach, which rests on solving simple equations, is consistent with the equilibrium solving exercise in the Mankiw, Kneebone and MacKenzie textbook. While calculator intensive, this exercise is familiar for students, who are already prepared to solve simultaneous equations and determine areas on graphs. This contrasts with the advanced graphical analysis in the CORE text that rests on intermediate level concepts of indifference curves, income and substitution effects, present value calculations, and scatter plot diagrams.

In what follows a simple problem of comparing the firms' compliance costs under a uniform standard, emission tax, and tradable emission permits are compared. The basic idea is

that the cost-effective solution arises when the marginal abatement cost (MAC), which is the cost of abating one more unit of emission, is equalized across the firms. In this regard, consider two firms H and L with high and low MACs that are based on emissions E_H and E_L respectively. Assume that the total emissions are limited to a total of 80 units.

$MAC_H = 100 - E_H$
$MAC_L = 50 - E_L$
$E_H + E_L = 80$

Figure 2: Analyzing uniform standard, emission tax, and tradable emission permits



Note: *Pictures are not drawn to scale.*

Figure 2 indicates three graphs that showcase the impact of a uniform standard, emission tax, and tradable emission permits respectively. In the absence of any market-based or command-and-control regulation, firms H and L would not abate any emission, which would mean $E_H = 100$ and $E_L = 50$. A uniform standard would impose a limit of $E_H = E_L = 40$ units of emissions for each of the firms, which would necessitate firms H and L to abate 60 and 10 units of emissions respectively. This would yield $MAC_H = 60$ and $MAC_L = 10$. Total abatement costs (TACs) are $TAC_H = ½ (60)(60) = 1800$ (blue area) and $TAC_L = ½ (10)(10) = 50$ (black area) with a grand total TAC = 1850.

An emission tax would be set through the principle that $MAC_H = MAC_L$, which would yield the tax rate that provides the cost-effective solution. Thus, using the equation $MAC_H = MAC_L$ along with the condition $E_H + E_L = 80$ would allow to solve for cost-effective emission levels of $E_H = 65$ and $E_L = 15$, and $MAC_H = MAC_L = 35$, which is also the tax rate. It becomes clear that firms H and L would have to abate 35 units of emissions each. Total abatement costs are $TAC_H = TAC_L = ½ (35)(35) = 612.5$ each (blue and black triangle areas) with a grand total TAC = 1225. While firm H pays a tax on 65 units and firm L pays a tax on 15 units, which yield (65)(35) = 2275 (blue rectangle area) and (15)(35) = 525 (black rectangle area) respectively with a total of 2800, this amount is transferred to the government. The tax cost of the firm is offset by

the revenue benefit of the government. Overall, the cost is 1225, which is lower than the 1850 with a uniform standard. Thus, an emission tax yields the cost-effective solution.

For simplification purposes, emission permits can be allocated equally. Therefore, $E_H = E_L = 40$, which yields $MAC_H = 60$ and $MAC_L = 10$. This means that firm H values the permit at 60 and firm L at 10. A mutually beneficial trade can occur between them where firm L sells permits, and firm H buys them. The way the price is set is through the same principle of $MAC_H = MAC_L$. This condition along with the stipulation $E_H + E_L = 80$ yields the same permit price as the tax rate of 35. At a permit price of 35, firm H emits 65 units and buys (65-40 = 25) permits. Similarly, firm L emits 15 units and sells (40-15 = 25) permits. The cost and revenue of permits (25*35 = 875) (green rectangle and dotted pink rectangle area) offset each other. This leaves the total abatement costs as $TAC_H = TAC_L = ½ (35)(35) = 612.5$ each (blue and black triangle areas) with a grand total TAC = 1225. Thus, both permits and taxes as policy tools yield the cost-effective solution compared to uniform standards. Table 2 indicate these mathematical results in a concise form.

Table 2: Analyzing uniform standard, emission tax, and tradable emission permits

Uniform Standard	Emission Tax	Tradable Emission permits
Standard imposed: $E_H = E_L = 40$ Amount abated: H: 100 – 40 = 60 L: 50 – 40 = 10 $MAC_H = 100 – E_H = 60$ $MAC_L = 50 – E_L = 10$ $TAC_H = ½ (60)(60) = 1800$ $TAC_L = ½ (10)(10) = 50$ $TAC = TAC_H + TAC_L =$ **1850**	Solving for tax rate: 1) $E_H + E_L = 80$ 2) $MAC_H = MAC_L$ $100 – E_H = 50 – E_L$ Solving 1 and 2: $E_H = 65$ $E_L = 15$ $MAC_H = MAC_L = Tax = 35$ Amount abated: H: 100 – 65 = 35 L: 50 – 15 = 35 $TAC_H = ½ (35)(35) = 612.5$ $TAC_L = ½ (35)(35) = 612.5$ $TAC = TAC_H + TAC_L =$ **1225** Tax paid: H: (65)(35) = 2275 L: (15)(35) = 525 Total tax paid = 2800 offset by government revenue	Permits allocated: $E_H = E_L = 40$ Value of the permits: $MAC_H = 100 – E_H = 60$ $MAC_L = 50 – E_L = 10$ Solving for permit price: 1) $E_H + E_L = 80$ 2) $MAC_H = MAC_L$ $100 – E_H = 50 – E_L$ Solving 1 and 2: $E_H = 65$ $E_L = 15$ $MAC_H = MAC_L = price = 35$ Amount abated: H: 100 – 65 = 35 L: 50 – 15 = 35 $TAC_H = ½ (35)(35) = 612.5$ $TAC_L = ½ (35)(35) = 612.5$ $TAC = TAC_H + TAC_L =$ **1225** Permits needed: H: 65 – 40 = 25 (buys) L: 15 – 40 = -25 (sells) H: cost = 25*35 = 875 L: revenue = 25*35 = 875 offset each other

International Collaboration with Game Theory

Having considered topics that underscore the urgency of climate change, thinking outside the box, the limits of individual actions, and the issues of various policy tools, it is also important to highlight concerns on international collaboration. This is because addressing climate change requires concerted international action. Tietenberg and Lewis (2015) allude to the free rider problem, that is, that countries incur the marginal costs of abating emissions but receive only a fraction of the marginal benefits of their actions, which incentivizes them to free ride on the efforts of others. Additionally, according to Ragan (2020), there are concerns that developed countries want equal participation, as they don't want developing countries free riding. However, developing countries indicate that the primary responsibility should fall on the developed countries that are responsible for the bulk of the GHG emissions stock, and that developed countries can help by making large financial contributions to them (Ragan, 2020, p. 425). Such issues lead to problems in international collaboration on climate change.

However, Tietenberg and Lewis (2015) mention the strategy of issue linkage through which cooperation of climate change can be achieved by linking climate change agreements with economic agreements like forgiving international debt, signing free trade agreement, or sharing R&D. While they mention the Prisoner's Dilemma to explain lack of collaboration and highlight the strategy of issue linkage in game theory, they do not visually illustrate these ideas with specific games. Since ECON 101 students are introduced to the Prisoner's Dilemma and the strategy of issue linkage is a minor addition through a bargaining strategy game, pay off matrices for these games can be constructed by borrowing and adapting from Chapter 13 of the Pindyck and Rubinfeld (2018) textbook (p. 500-501). This approach is much simpler than those in the literature reviewed in Section 2 that are time intensive, require too much preparation, and where relatively weaker students get confused with the logistics of games.

The simple Prisoner's Dilemma and the bargaining strategy game with the respective pay-off matrices are illustrated in Table 3. Matrix A showcases the Prisoner's Dilemma game to indicate that the dominant strategy for both countries is to emit. It shows that a country incurs abatement costs which makes it less competitive compared to others who remain competitive and obtain benefit from the other country's abatement. Thus, it shows that while both countries can be better off by abating (10, 5), the incentive to free ride on the efforts of others leads them to the inferior solution (-5, -5).

Table 3: Prisoner's Dilemma and the Bargaining strategy games

A	Country 1		
Country 2		Abate	Emit
	Abate	10, 5	-10, 15
	Emit	15, -10	-5, -5

B	Developing Countries		
Developed Countries		Collaborate	Don't collaborate
	Business as usual	10, 5	10, 10
	Take responsibility	15, 8	5, 15

C	Developing Countries		
Developed Countries		No treaty	Trade agreement
	No treaty	5, 5	5, 10
	Trade agreement	10, 5	20, 20

Matrix B shows that the dominant strategy for developing countries is to not collaborate. This leads to the Nash equilibrium (10,10) where there is no international collaboration, and it is business as usual. Developed countries would prefer that developing countries collaborate for them to justify taking equal responsibility on climate change. Thus, while the outcome is (10, 10), developed countries would prefer (15, 8). This can be achieved by issue linkage. Therefore, consider Matrix C, which presents another game that shows that the dominant strategy for both developed and developing countries is to enter into free trade agreements, which yields the Nash equilibrium (20, 20). It is here, developed countries could bargain by withholding free trade agreements, which yields the outcome (5, 10), unless the developing countries collaborated on climate change actions in Matrix B.

If developing countries collaborate, developed countries would enter into a free trade agreement, which would yield a total outcome of 20 + 8 = 28 for developing countries. If developing countries don't collaborate, developed countries would withhold the free trade agreement, which would yield a total outcome of 10 + 10 = 20 for developing countries. Since 28 > 20, issue linkage through this bargaining strategy would facilitate international collaboration on climate change. Thus, ECON 101 students can learn about issues of international collaboration through game theory in a simpler way than semester long time-consuming games and excessive assigned readings.

Concluding Remarks

The objective in this paper was to explore how to introduce climate change to ECON 101 students in a way that causes the least disruption for both instructors and students who are engaged with the mainstream neoclassical paradigm. This is because of the growing recognition that ECON 101 textbooks do not prepare students to address pressing contemporary issues and because of the challenge posed by Bowles and Carlin (2020), who have promoted the CORE text as a viable alternative to conventional textbooks like Mankiw, Kneebone, and MacKenzie (2020a). To this end, a review of the literature on teaching climate change and economics and three principal options to either replace or supplement the Mankiw, Kneebone, and MacKenzie

textbook was undertaken. The objective was to minimize student confusion and instructor workload and to uphold Mankiw's approach of clarity before nuance.

The literature review showcased games and additional readings that were time intensive, increased instructor workload for modest improved learning results, and which could overwhelm students by embroiling them in the logistics of techniques instead of learning the basic ideas. The issue of information overload was also highlighted in the case of the CORE text, which was found to be fraught with advanced technical concepts and techniques that are not suitable for introducing climate change to ECON 101 students. Similarly, other options were not found to be adequate either due to the wordy text or lack of visual illustrations. Thus, a new approach was delineated based on material that comprised of popular books, magazine articles, a YouTube video, and exercises suitable for ECON 101 students based on other textbooks.

The five-part approach consisted of emphasizing the urgency of climate change, thinking outside the box through geoengineering, the limits of individual actions like buying local or going vegan, the comparative outlook on various policy tools with a simple equation solving exercise, and simple game theory to broach the issue of international collaboration. These five topics are usually missing or inadequately presented in textbooks. Other instructors can make use of this approach based on material specific to their respective jurisdictions. They can consider it in its entirety or focus more on some aspects based on the background and preparation level of their student cohort. In essence, this five-part approach offers a renewed approach to introducing climate change to ECON 101 students.

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