CESifo WORKING PAPERS

7583
2019

March 2019

For want of a chair: teaching price formation using a cap and trade game

Stefano Carattini, Eli P. Fenichel, Alexander Gordan, Patrick Gourley

CESifo

Impressum:

CESifo Working Papers
ISSN 2364-1428 (electronic version)
Publisher and distributor: Munich Society for the Promotion of Economic Research - CESifo GmbH
The international platform of Ludwigs-Maximilians University's Center for Economic Studies and the ifo Institute
Poschingerstr. 5, 81679 Munich, Germany
Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email office@cesifo.de
Editor: Clemens Fuest
www.cesifo-group.org/wp

An electronic version of the paper may be downloaded
· from the SSRN website: www.SSRN.com
· from the RePEc website: www.RePEc.org
· from the CESifo website: www.CESifo-group.org/wp

CESifo *Working Paper No. 7583*
Category 9: Resource and Environment Economics

For want of a chair: teaching price formation using a cap and trade game

Abstract

The tradable or transferable permit system, "cap and trade", is one of the most innovative policy options developed by environmental economists. Over the last 40 years, cap and trade programs have been used around the globe by some of the world's biggest economies. By placing a cap on a bad, whether a pollutant or excess fish mortality, and then allowing firms to buy and sell the right to generate it, policy makers combine government intervention with market-based incentives in order to improve welfare and internalize the externality. Such programs represent a great opportunity for economics instructors to show students how economic theory can be used in the real world by policy makers while teaching foundational economic concepts. By using an in-class game that utilizes a mobile app or paper-based interaction to create a market for a pollutant (or another rival but non-excludable resource), students can learn several important tenants of economics. These include how prices are formed and how price-based incentives lead to voluntary, as if cooperative, behavior by agents. This active learning method engages students while improving their comprehension of price formation, gains from trade, voluntary response to incentives, and an important environmental economics policy.

JEL-Codes: A200, Q310, Q380.

Keywords: classroom game, price formation, cap and trade, emissions trading scheme, carbon tax, catch shares, individual transferable quotas.

Stefano Carattini
Department of Economics
Andrew Young School of Policy Studies
Georgia State University / Atlanta / USA
scarattini@gsu.edu

Eli P. Fenichel
School of Forestry & Environmental Studies
Yale University
New Haven / CT / USA
eli.fenichel@yale.edu

Alexander Gordan
Department of Economics
Andrew Young School of Policy Studies
Georgia State University / Atlanta / USA
agordan1@student.gsu.edu

*Patrick Gourley**
Department of Economics
University of New Haven
West Haven / CT / USA
PGourley@newhaven.edu

*corresponding author

March 19, 2019
We thank Marion Dumas, Roger Fouquet, Humberto Llavador, and James Rising for very useful comments on an earlier version of this paper. Carattini acknowledges support from the Grantham Foundation for the Protection of the Environment, and the Centre for Climate Change Economics and Policy, which is funded by the UK Economic and Social Research Council.

1 Introduction

Students are experienced price takers. In most of their economic transactions, they act as atomic price taking consumers. These experiences can be a barrier, making it hard to teach students how prices form, because while students have ample experience as price takers, they have little experience with price formation. Where do prices actually come from? What happens if a buyer or seller negotiates a price for a limited resource? When should agents engage in a trade, and how do individual gains from trade relate to social welfare? These are some of the most fundamental economic topics, and it is crucial that students learn the basics of price formation. Traditional lecture can successfully deliver these points, but a superior method is to use an in-class game that takes advantage of active-learning (see Holt 1996). To that end, we have developed a "cap and trade" game, playable with either a mobile app or paper cards supported by an excel spreadsheet, that teaches price formation as well as other economic concepts in a policy relevant context.

Tradable or transferable permits, commonly called cap and trade, is one of the key contributions of environmental economics to public policy (Baumol and Oates 1998; Phaneuf and Requate 2017). Cap and trade was first developed and tested on a large scale in the United States with a system of gasoline credits. Less than 40 years later, it has become a global standard in environmental governance (Newell and Rogers 2003; Voß 2007). Emissions trading schemes stimulate innovation in addition to reducing emissions (Calel and Dechezleprêtre 2016; Calel 2018; Cui et al. 2018). Rights-based transferable permits are the basis for managing pollutants and reigning in over-fishing, and also represent the foundation for payments for ecosystem services (Sterner and Robinson 2018). Carbon emissions trading schemes are operational in North America, Europe, and Asia. The largest current emissions trading scheme (ETS), the European Union Emission Trading System (EU ETS), covers 11,000 installations in 31 countries, which represent about 45% of the EU's greenhouse gas emissions (Ellerman et al. 2016). Transferable permits programs represent a great opportunity to combine government regulation with incentive-based market mechanisms to increase social welfare in presence of an externality.

Transferable permits programs begin with a cap on the amount of a pollutant or another unpriced good such as excess fish mortality. Ideally, the cap reflects the optimal level of externality, e.g. the optimal level of greenhouse gas emissions. In practice, the cap is often the result of a political-economic equilibrium. Even so, as long as the cap is binding and not excessive, it will still enhance welfare irrespective of whether it is "optimal." As a specific example, focus on emissions of a given pollutant. Under a cap and trade scheme, if a firm wishes to emit the capped pollutant, as a by-product of a given good or service that it produces, it must have a permit for each unit of emissions. Permits are created by the regulator, which then allocates them to the emitters. The creation of permits is a clarification of rights (Sterner and Robinson 2018) that enables Coasian exchange (Coase 1960). After the initial permit allocation, firms are free to buy and sell permits in a market. The negotiating process of firms in a market leads to the formation of a price for the scarce resource, the right to generate an externality. The transferable permits system connects price-based incentives with rights. The price incentive leads firms that have the greatest abatement costs, i.e. for which reducing emissions is costlier, to buy permits or shut down, and firms that have the lowest abatement costs to sell permits to increase net revenue. The resulting market clearing price equals the marginal abatement cost at the final quantity of emissions. In contrast to command and control, which prohibits or requires certain behaviors from firms, trading transferable permits in a market enables firms to self-organize and determine among themselves which firms should reduce the externality. This leads to firms behaving as if they are cooperating to achieve a social goal. Some firms continue to emit at a price. Over time, the cap can be adjusted in an incremental fashion, allowing firms time to adapt and innovate to lower abatement costs. Generally, such market based systems achieve a given level of externality reduction at least cost.

Transferable permits programs integrate many critical economic concepts. Often it is difficult to make these economic theories understandable if students do not have any personal experiences to relate to. Especially at the undergraduate level, where simple models are necessary to facilitate understanding, students often ask, "How does this apply to the real world?" By using a cap and trade game in class, an instructor can teach students several important economic concepts. First, students learn how transferable permits works, and see how economic theory is put to work to make society better off. Second, students see how prices are formed, based on supply and demand. Third, by comparing a market price to a corrective (Pigovian) tax, students can compare quantity-based and price-based market mechanisms.

From a pedagogical perspective, this game has the potential to increase learning outcomes. Repeated studies show that active learning and in-class games increase students' comprehension (Dickie 2006; Emerson and Taylor 2004; Freeman et al. 2014). Active learning can take many forms, from having students act out scenes to engaging in mock trials or other role-playing exercises (Whiting 2006; Gourley 2018). In-class games or experiments are also among the best options for active learning available to the lecturer (Durham et al. 2007; Duke and Sassoon 2017). By using the app version of this game, students can use a familiar technology, their smartphones, in an instructional setting. The strength of having students engage in a mock emissions trading scheme is that, by face-to-face buying and selling permits, they can see how prices are formed first-hand, and externalities addressed at the lowest cost for the economy. This can be more effective than having an instructor explain how prices are set, and how market-based instruments are superior to command and control. As recalled by Fouquet (2003), who developed at the time of the Kyoto Protocol an early classroom game on cap and trade among countries, the pedagogical mantra goes as follows: "tell them and they will forget, show them and they will remember, involve them and they will understand" (p. S143).

From a policy perspective, this exercise provides a rebuttal to the resistance some environmentalists have about pricing pollution. No less a figure than the late Edmund Muskie, a long-time senator and Secretary of State, declared, "We cannot give anyone the option of polluting for a fee." This view is shared by others in the environmental community, who believe that outright bans are superior to market based regulation. Students may easily see the benefits of a cap, but may miss the economic efficiency of trading. While some would argue that ethical reservations cannot be addressed by teaching emissions trading, experimental evidence suggests that providing information on pay-offs, and having participants maximizing them in an experimental game, may improve people's perception of pollution markets (Braaten et al. 2015). In the same spirit, our classroom exercise shows how market based regulation can in fact result in a better societal outcome.

2 An Overview of Cap and Trade in Real-World Policy Making

According to the Environmental Protection Agency (EPA), the idea of a cap and trade program on emissions (emissions trading) originated with one of the EPA's forerunners, but was not tried on a national scale until the middle of the 20$^{\text{th}}$ century when the EPA sought to decrease the environmental impact of several pollutants. The largest program targeted sulfur dioxide, a key component of acid rain.[1] The Acid Rain Program originated from the 1990 Clean Air Act, and established an emissions trading system for sulfur dioxide (Stavins 1998). The original aim was to reduce emissions to 50% with respect to 1980 levels. The program was deemed a success by most commentators, with benefits vastly exceeding costs. Annual benefits have been as high as \$100 billion, with annual costs at less than \$10 billion (Burtraw 1999; Chestnut and Mills 2005). Much of this is due to a fall in mortality caused by improved air quality. Mortality decreased by up to five percent because of lower sulfur dioxide emissions (Barreca et al. 2017).

The success of the Acid Rain Program in the United States led to additional emissions trading schemes, tackling other pollutants. While the Acid Rain Program concentrated on sulfur dioxide, current schemes focus on addressing climate change and carbon emissions. The best known emissions trading scheme is arguably the EU ETS, but emissions trading schemes are part of the climate policy package in Canada, New Zealand, South Korea, Switzerland, and the city of Tokyo (World Bank and Ecofys 2018). China recently launched a pilot scheme, followed by a broader scheme (Karplus 2018). These examples show the potential for schemes to be adopted by areas as large as entire continents, and as small as individual cities, or companies. In the United States, emissions trading schemes are currently in place in California (linked with the Canadian province of Québec) and in the Northeast (as the Regional Greenhouse Gas Initiative). Emissions trading has been also used by private companies, such as BP, to price carbon within the firm (Victor and House 2006). As internal carbon pricing becomes increasingly popular among companies (CDP 2017; Gillingham et al. 2017), additional schemes may be implemented in the private sector. At the federal level in the United States, a proposal to implement an emissions trading scheme (Waxman-Markey Bill) was approved by the House in 2009, but never made it to the Senate floor. Similar systems, known as catch shares, have been highly effective at allocating fish harvests helping to rebuild fish stocks (Newell et al. 2005; Grafton et al. 2006; Costello et al. 2008; Birkenbach et al. 2017), and payments for ecosystem services more broadly have expanded globally (Salzman et al. 2018).

An alternative market mechanism is a Pigovian tax on externalities (Phaneuf and Requate 2017). For example, a carbon tax could have the same behavioral effects as a cap and trade system, but in the case of a tax, the regulator sets a price and then the market determines the quantity. During the in-class game,

[1] See https://www.epa.gov/airmarkets/acid-rain-program for a full account (last accessed in October 2018).

students will see how cap and trade systems and taxes compare to each other. If the tax is set properly, then students will see that the two policies deliver a similar result.[2] With respect to carbon taxes, emissions trading schemes have the advantage that they provide certainty on the amount of emissions (assuming full compliance). On the other hand, a carbon tax provides certainty on the cost of regulating emissions. These are aspects that can also be included in the game (see more below on comparing a carbon tax with an emissions trading scheme).

3 The In-class Game

3.1 Setting up the game

For this game, each student represents a facility subject to a cap and trade program. The activity relies on a game of musical chairs, where each chair represents an emissions allowance. Students will have to choose whether they wish to buy a chair and be allowed to emit, or not emit. For physical preparation, a relatively large space needs to be cleared and two rows of chairs need to be placed in the center of the room, back-to-back, as seen in Figure 1. Alternatively, chairs could be placed in a circle, but this requires an even greater amount of space. One should make sure that students have enough room to comfortably walk completely around the chairs.

In order to run the game properly, it can be played with either paper sheets generated through an Excel workbook or a mobile app. While the game can be played with either the workbook or the app, we suggest all instructors look at the workbook before playing the game. The instructor workbook and video demo of the app can be found online at https://github.com/efenichel/musical_chairs. We describe below, in separate sections, how to play the game with either method.

It is important to explain to the students that each chair represents one emissions allowance and that a game of musical chairs will be used to define the initial allowance.[3] Those that get a chair will start the game with one emissions allowance, which can be either sold on the market or used for polluting. Each student can have either zero or one chair. In either case, a chair represents a higher private benefit. However, each chair that is occupied increases the social cost of pollution, as it represents an additional unit of emissions.

To prepare a class for the transferable permits game, we encourage instructors first to describe to students how a cap and trade program works. One can emphasize that emissions trading and catch shares schemes have been quite successful in the real world, and that the popularity of transferable permits programs continues to grow among policymakers (World Bank and Ecofys 2018). It is also useful to quickly review the concept of externality, since the game is organized around an externality. After discussing the private

[2] Differences may emerge, however, in terms of surplus, especially if, in the emissions trading scheme, permits are allocated for free (grandfathered) to firms, for instance based on past emissions (see Martin et al. 2014). This is an aspect that may be discussed in class. Please refer to Phaneuf and Requate (2017), and other textbooks, for a formal analysis.

[3] We have found that using musical chairs keeps students interested. In the event that musical chairs cannot be played due to space or other constraints, another randomization process could also be used to determine who is provided an initial allocation of permits.

and social payoffs when all players have a chair or when chairs are completely banned, play begins with a round of musical chairs. The instructor should pull about three chairs so that not all students can have a chair. However, it is important that enough chairs are left remaining so that more chairs can be removed in subsequent rounds, to get closer to the social optimum. The instructor can decrease the shortage as he or she sees fit, if there are fewer students playing. This is different than standard musical chairs, when the number of chairs is usually one less than the number of players. The number of chairs, or allowances, corresponds to the "cap" of the program. Instructors should play music for around a minute, as the students walk around the chairs, and then stop the music at random. When the music stops, every student must find their own chair to sit in. After the dust settles, some students will be left standing. This solves the initial allocation dilemma faced by policy makers. Lotteries have been suggested for initial allocation of permits (Tietenberg 2003). While we are unaware of random distribution of permits in practice, the main pedagogical objectives of the game can be achieved with this stylized version of actual emissions trading schemes. Musical chairs also serve to pique students' interest. Next, the trade portion of the game begins.

The instructor should repeat that each student without a chair has the opportunity to pay another student, who owns a chair, for the right to sit in the chair, and that each student with a chair can sell the chair he or she occupies. To simplify the game, each student can only sit in one chair. At this stage, it is important to remind the students that each firm's goal is only to maximize its own profit. None of the firms are interested in maximizing social welfare or increasing the efficiency of the allocation of resources. Instructors should remind the students that if they buy a chair, then their total profits will correspond to the profits "with chair" minus the price they paid for the chair. For students that sell a chair, their profits will be the profits "without chair" plus the amount they received for the chair.

Students are then free to buy and sell their chairs. With only a few students standing, however, it is possible that few trades occur. If no trades are occurring or students are still internalizing the logic of the game, the instructor can step in and ask standing students the difference between their firm's profits if they have a chair or do not have a chair, and explain that they should offer less than that amount to a sitting student. A sitting student should not accept an amount unless they are better off doing so. After several minutes or after the trading seems to peter out, the instructor should give a 30 second to one-minute warning before all trading must cease. Multiple trades are allowed. If a student buys (sells) a chair and then finds that someone wishes to buy his or her new chair (sell them a chair) for a better price, he or she should feel free to engage in an additional trade.

For example, there is a player, call her Nancy, whose firm receives a benefit of $3,869 if she has a chair and $1,081 if she does not. There is a second player, Arnold, whose firm receives a benefit of $13 if he has a chair and $5 if he does not. After a round of musical chairs, if Arnold has a chair and Nancy does not, it is in both their interests for Nancy to buy Arnold's chair. What the price will be is unclear. Depending on how hard each of them bargains, Nancy could pay Arnold anywhere between $9 and $2,787 dollars to be allowed to have Arnold's chair. On the other hand, if after a round of musical chairs Arnold is standing and

Nancy has the chair, then neither will be interested in trading. Arnold may offer Nancy up to $7 for the chair, but Nancy should decline.

3.2 Playing the game with the spreadsheet

The first spreadsheet in the Excel workbook, called "generate", allows the instructor to alter the parameters of the game (see Figure 2). Cell A2 is the number of students playing the game. The instructor should update cell A2 to the correct number of participants and then press the "Generate Balance Sheets" button to print off each individual students payoff sheet. Cell B26 allows the instructor to change the cost function of emissions, the default of which is $85c^2$, where c is the number of chairs (emitters). By altering 85 to some other number, Cells A34 and A36 will update the optimal number of chairs and tax, respectively.

Each student payoff sheet lists 1) the profits a student's firm realizes if they have a chair (emit), 2) the profits a student's firm realizes if they do not have a chair (do not emit), and 3) the difference between the two. This difference can be thought of as the firm's marginal abatement cost. Each student should be given a payoff sheet and told that it represents their firm. We suggest providing two double sided sheets of a letter (A4) sheet of paper for a total of four identical pages per student. Once the student payoff sheets are printed and distributed to students, the instructor then clicks the button "Setup Game" and uses the spreadsheet "gamesheet" for the rest of the game (see Figure 3). Note that the correct number of players needs to be determined in advance of clicking "Setup Game".[4]

The instructor should dispay the "gamesheet" in the Excel instructor workbook via a projector. We recommend adjusting the generate sheet to the exact number of players (since not all students may show up to class) and pressing the "Setup Game" button prior to displaying. The game works well with at least nine students, and the gamesheet is set up to allow for up to 25 players. If the class is larger than that, additional students can be spectators of the 25 students playing the game, and by watching may be better suited to answer the questions the instructor asks throughout the game. The top left of the spreadsheet displays the cost of each chair and the social cost function of each chair.[5] Column B and C list the payoffs that each student realizes if they have or do not have a chair, respectively. This is then summed at the bottom of the spreadsheet, which lists the total private benefit, social costs, and social net benefits. Payoffs for the initial two scenarios are intentionally blacked out. Columns D-F are filled in during the trading game, and later columns are for taxation based rounds, which are discussed below. To fill in columns D-F, the instructor will need to go around the room and collect payoffs for each player. Rows 32 and 34-37 are set up to automatically calculate the total private benefit, social cost, tax revenue, and social net benefit based on the inputs in Columns D-F and Column H, but row 33 must be filled in by the instructor.

Using the Excel spreadsheet, instructors can show that the total private benefit is maximized when

[4] If, for example, the instructor printed off 20 payoff sheets and only 18 students attended the game when is played, then the final two payoff sheets would need to be discarded. Cell A2 needs to be updated to 18, and then the "Setup Game" button can be clicked. Once the game has started, additional students may not join.

[5] This can be altered at the instructor's discretion.

each student emits. However, total social cost is also maximized. This is displayed in Cells B32 and B34, respectively. If none of the students are allowed to emit, then total social cost falls to zero, but the associated drop in total private benefit is larger than the drop in social cost, as seen by comparing B32, B34, and B37 to C32, C34, and C37. Therefore, the total social net benefit if everyone pollutes is higher than if no one does. This is consistent with reality; eliminating all pollution would have disastrous consequences for society (as shown by Pigou 1920).

Once the trading round is complete, the instructor first records the total number of chairs in Cell D33 for Round 1 (Cell E33 during Round 2, and Cell F33 during Round 3). Then, the instructor asks each student about his or her final profit including gains or losses trades. With this information, the instructor fills in the relevant rows in Column D with each student's profit (see Figure 3). The order in which the rows are filled in does not matter. As long as the trading occurred following the rule that all students should maximize profit, the social net benefit will be higher than before the cap was instituted but no trades had occurred. That is, instituting the cap improves social welfare, as this addresses the externality. However, allowing agents to trade creates additional gains, which would be left on the table if the emissions quotas were not tradable. Make sure that students understand that even though total private benefit decreases as chairs are removed, the social cost decreases faster because of the quadratic nature of the cost function. This is made clear by comparing the social net benefits across Row 37 in the spreadsheet.

Next, instructors can repeat the musical chairs game, but only after removing an additional chair or two. Instructors should allow students to buy and sell the right to the chairs and again determine the total social welfare. It is important to not carry results from previous rounds forward, and students should record trades on a fresh ledger sheet. By the second round, students should be comfortable with the buying and selling of chairs and with determining their firm's profit. After the second round, net social benefit should increase again relative to just a quota without tradable permits, once again showing the strength of emissions trading programs. The students should begin to see that there is an optimal number of chairs. If the cap is too loose or too stringent, then the net social benefit will not be maximized. Social welfare is maximized when the quota is equal to the optimal amount of pollution. This will occur when the marginal abatement cost is equal to the marginal damage and trade is allowed. The figure in the game sheet is useful for illustrating this point.[6] A useful activity is to let the class try to guess the (optimal) number of chairs that maximizes social welfare.

Students also learn a more fundamental economics lesson after several rounds. First, students will set their own willingness-to-pay or willingness-to-accept depending on whether or not they have a chair. When negotiating with other students, this will help them discover how prices are formed when neither the buyer nor the seller are price takers. Students learn that trading in one's own interest is sufficient to increase social welfare with each trade. The instructor should determine the highest price that any student paid for a chair, and write down that price. As more and more chairs are taken away in subsequent rounds, the highest price

[6] Depending on the level of class, instructors can go into detail about the concave-up nature of the cost function and the concave-down nature of the benefit function.

should continue to grow as chairs become a scarcer resource.

The emissions trading result can then be compared to a tax on having a chair. To make this comparison salient, the instructor should put all the chairs back into play, and explain that each student can occupy a chair and emit, and receive the emissions profit. However, if a student chooses to emit, then he or she must pay for the chair - a tax. The instructor should ask students what tax would reproduce the same number of chairs that the class had with the transferable permits exercise that led to the greatest social welfare. This tax level is the efficient Pigovian tax. It may take some prompting, but students generally will discern that the last price paid for a chair during the trading round with the greatest social net benefit is the amount of the tax. If the tax were lower than the last price paid during trading, then too many students would elect to pay the tax, sit in chairs, and emissions would be too high. If the tax were greater than the last price paid during trading, too many students would choose to not emit, abandon chairs, and emissions would be lower than the optimal amount. In the spreadsheet version of the game, the tax is entered in Cell J2 (see Figure 4).

Students can then choose to either sit in a chair, emit, pay the tax, and receive the emissions profit, or forgo a chair, not emit, and not have to pay the tax, but receive the non-emissions profit. The instructor should then ask each student his or her post-tax profits, reminding them to subtract off the size of the tax. These amounts are entered using column H. If the student is sitting in a chair, then his or her associated cell in Column I should stay equal to one, as that student must pay the tax. If a student elects to stand, then the student's tax cell should be changed to zero. Cells H32-H37 will automatically populate and display the total private benefits, number of chairs, social costs, tax revenue, and social net benefits. The instructor can then increase the tax to different amounts, and explain that an emissions trading program with a different cap can end with a similar level of emissions. It is important that instructors explain that the tax revenue is ultimately part of the net social benefit. It is also important that students understand that programs place a cap on the number of permits allowed and the market decides the price, while a tax places a price on emitting, and the market decides the quantity.

3.3 Playing the game with the app

To access the app, one must first obtain login credentials by visiting the classEx website at "https://classex.de/", clicking the "Get Free Login Credentials" button, and filling out the submission form (see Llavador and Giamattei 2017). Note that approval can take up to several days, but is generally granted within 24 hours. After credentials are granted, instructors and participants can login at "https://classEx.uni-passau.de." The approval email granting credentials will include a password for the experimenter/lecturer (instructor) and the participants (students).[7] The players of the game do not have to make an account; any number of students can use the same participant login password. After logging in, click "repository" near the top of the screen,

[7] Note that the app can be used by a participant of the game on either a computer or mobile phone. Instructors should use the app on a computer, as the screen can be shown to participants during the game.

search "For Want of a Chair", and import the newest version of the game by clicking the plus button. The game is now playable on the instructor's home screen and can be played by clicking the "play" button.

The app is straightforward, however, it is crucial that instructors familiarize themselves with its functionality. Fortunately, classEx allows instructors to play mock rounds of the game with up to 30 dummy participants. Before playing the game with students, we highly recommend instructors play several rounds of the game until he or she is familiar with the program. To do so, press the "continue" button, and then click the "test participant" button x times to generate x players. Each of these players can be controlled from the instructor's computer, allowing him or her to play through the entire game as if it were in a class.

Once the "play" button has been clicked, participants may enter the game by using the participant login. Once all students are logged in, the participants should play a game of musical chairs to determine who has the right to emit. After the chair allocation is established, the instructor clicks the "continue" button. Each participant's screen will then ask the student to state whether they have or do not have a chair. Each student should click their correct state (see Figure 5). Once all players have made their chair declaration, the instructors clicks the "continue" button. The instructor screen will refresh and proceed to a calculation page. It is important to wait five seconds before clicking the "continue" button again. The next screen shows the private benefits, the social costs, and net social benefits of all the players. The instructor should display this to students, and can ask what effect trading will have. Students should be able to intuit that after trading, the net social benefit will increase. The instructor then clicks again the "continue" button to begin the first round of trading.

At this point each participant's screen will display their profit with a chair, without a chair, and the difference (see Figure 6). Students are now free to buy and sell their chair as they see fit. The instructor then tells students with chairs to begin making offers to sell their chair, and students without chairs to make offers to buy chairs. Students with chairs should not offer less than the difference in profit, and students without chairs should not offer more than the difference in profit. For standing students, buying a chair is straightforward. Once they find a player and have agreed upon a price, they should enter the seller's ID number (located immediately above the buy/sell button) into the "other" cell, and the dollar amount in the "offer" cell, and then hit the "buy" button.[8] When this occurs, the seller's screen will change and they will be able to accept or reject that offer. For sitting students, selling a chair works the same way. Players can also sell a chair and then buy a different one, and vice-versa, should it be economically profitable to do so.

After each trade occurs, the instructor's screen will update to reflect the trade. After all trades have finished, the instructor clicks the "continue" button, and then the drop-down "ok" button to confirm they wish to end that trading round. After waiting five seconds at the subsequent calculation stage, click the "continue" button again. Now displayed on the screen are the private benefits, social costs, and net social benefits both before and after trading. As will be clear, the trading system increased net social benefits. In subsequent rounds, additional chairs should be removed to allow the net social benefits to be closer to the

[8]The video demo at https://github.com/efenichel/musical_chairs shows how to do this.

optimum. As many additional rounds as desired can be played, and the number of chairs can be altered each round.

In the unlikely event of the game going awry, it is easy to reset everything. The instructor should click the “restart game” button and can begin again with the chair allotment. Also, the social cost of each chair can be altered by clicking the “parameters” button. Finally, the instructor should not over explain the app. Experience has taught the authors that the functionality will become evident quickly, usually after one round. It will generally be quickest to start the app with a minimum of instruction, and walk the students through the first round.

The emissions trading result can then be compared to a tax on having a chair. To make this comparison salient, the instructor should put all the chairs back into play, and explain that each student can occupy a chair and emit, and receive the emissions profit. However, if a student chooses to emit, then he or she must pay for the chair - a tax. If a student chooses to stand, then they realize the non-emissions profit. The instructor should ask students what tax would reproduce the same number of chairs that the class had with the transferable permits exercise that led to the greatest social welfare. This tax level is the efficient Pigovian tax. It may take some prompting, but students generally will discern that the last price paid for a chair during the trading round with the greatest social net benefit is the amount of the tax. If the tax were lower than the last price paid during trading, then too many students would elect to pay the tax, sit in chairs, and emissions would be too high. If the tax were greater than the last price paid during trading, too many students would choose to not emit, abandon chairs, and emissions would be lower than the optimal amount.

In the app, the instructor clicks the “Begin Tax Round” button when he or she is finished with the emissions trading rounds. The instructor then selects the size of the tax they wish to have that round and clicks the “Continue” button. All participant displays will now state the current tax, the profit with a chair, and the profit without a chair. Each student then selects whether they want a chair or not. Once all students have made their selection, the instructor clicks the “Continue” button, waits 5 seconds, and then clicks the “Continue” button again to proceed past the calculation stage. The instructor’s screen then compares the results from the tax round to the final round of trading. When the tax is set at the correct level, the net social benefits from the tax round should be approximately equal to the net social benefits from the trading round. The instructor can then increase the tax to different amounts, and explain that an emissions trading program with a different cap can end with a similar level of emissions. It is important that instructors explain that the tax revenue is ultimately part of the net social benefit. It is also important that students understand that programs place a cap on the number of permits allowed and the market decides the price, while a tax places a price on emitting, and the market decides the quantity.

3.4 Extensions

The game concludes after several rounds of trading. We recommend three rounds of musical chairs plus a discussion of the tax version of the game because that works well within standard class time constraints. Additional extensions, however, are also possible. The first is to play additional rounds, but continuing to lower the cap (number of chairs). Eventually the net social benefit will decrease, as there are too few emissions permits available and the price for the permits only allows firms with very high benefits of emitting to be able to afford the chairs. It is worth reiterating that the optimal level of pollution in a society is not zero, and that if the cap is set too low, then society will suffer.

Another extension is to mention that there is some doubt that the initial allocation of permits does not affect the final allocation, in contradiction to the Coase theorem (Coase 1960; Hahn and Stavins 2011). Ask the students what complications they could foresee happening. Why might a firm that is awarded a permit initially keep a hold of that permit even if they would not purchase a permit had they not been part of the initial allocation? An important possibility is transactions costs, which violate the Coase theorem. The instructor could induce transactions cost by restricting trading partners or establishing a trading fee. Interestingly, in some groups, transaction costs will manifest themselves. Students will sometimes only try to buy or sell permits from the students immediately around them. If an efficiency increasing trade consists of two students on the opposite side of the room buying and selling a chair, then the trade might not occur. Thus, even if the "transaction cost" is only moving across a room to find a student to bargain with, it may prevent a mutually beneficial trade from occurring. Other possibilities that could be discussed include that risk adverse firms deciding that they should keep a permit "just in case", to a firm deliberately wanting to keep permits away from competitors. There may also be transaction costs in the form of learning-by-doing, where firms initially are unsure of the optimal amount of permits they need (Hintermann 2010). This can result in an inefficient allocation.

Other possible extensions can involve any nuances included in current transferable permits programs. For example, some economists have advocated for a hybrid model, where an ETS allows for free market buying and selling permits, but a price floor is also placed on a permit, which is currently done in the United Kingdom as a part of the EU ETS (Goulder and Schein 2013). How could this change the outcome of the game? How would firms feel about such a restriction? Another facet to some current ETSs is the inclusion of a "release valve", where if the price of permits goes too high, more permits are issued. Conversely, a problem of excess supply of permits, due for instance to an unexpected economic downturn, could also be addressed by the regulator, via back-loading of permits. Permits could also be banked by firms, and be used in future periods (Hepburn et al. 2016). Why would these features be included in an ETS? How would firms feel about it? Private citizens or environmental groups also have the opportunity to buy permits and essentially remove them from the market. How would that affect the price?

These optional extensions can provide an excellent opportunity for students to see how various policy options could impact the final allocation of resources. Along with the extensions, instructors can also continue the discussion by relating other issues in actual trading schemes. For example, what steps can firms take to reduce their marginal abatement cost over time? How can regulators ensure compliance? How can they define the social cost of carbon and the optimal cap? What if multiple schemes are linked, so firms can trade across wide areas? Or whether carbon credits can be used to purchase carbon offsets in developing countries? If some firms are polluting in heavily populated areas that cause more damage, how can the ETS be modified? There are many routes the instructor can take that will show students the complications of emissions regulation, including extending the social welfare function to include unregulated local pollution (potentially affected by the "hotspot issue", cf. Fowlie et al. 2012), allowing students to purchase multiple chairs, or having several groups trading first within and then across groups,

4 Conclusion

In-class games are a useful way to incorporate learning-by-doing to facilitate learning. By using the emissions trading game described in this paper, an instructor has an opportunity to reach students who do not learn best through a traditional lecture format. Our experience suggests that students' understanding of emissions trading schemes may be limited when they are only lectured to. While setting a cap on emissions may be very intuitive, the benefits of allowing emissions trading are not obvious to many. The game works well with introductory undergraduate and advanced graduate audiences. The authors have used the game for approximately ten years in settings from freshmen seminars to graduate courses in environmental economics, in classes as small as nine and as demonstrations in classes of over 150, and in our own courses and as guest lecturers. In student evaluations, the game is often mentioned as a highlight in the class that helps cement learning. Furthermore, informal discussions with students makes clear that the learning benefits are substantial.

After several rounds of the game, students should have a clearer picture of how prices are formed in a market, the similarities and differences between a tax and a quota, and how emissions trading systems operate. Traditional lecture often shows prices forming through a simple intersection of a demand and supply curve, and as students are generally price takers in their own lives, price formation is often simply explained through "the invisible hand" or a function of the market. By creating a new market and using chairs as a representation of a scarce good, the emissions permit, students will be able to witness price formation first hand. By then instituting a tax, students can see how two different policies can have similar results. It is sometimes unclear to many students how lessons from economics can be implemented in the real world, and emissions trading schemes represent a great example of economic theory informing public policy. However, the game goes beyond teaching an important environmental policy instrument, and teaches several important economic concepts making it suitable in a wide range of economics courses.

References

World Bank and Ecofys. State and trends of carbon pricing – 2018. Technical report, The World Bank, Washington DC, 2018.

Alan I. Barreca, Matthew Neidell, and Nicholas J. Sanders. Long-run pollution exposure and adult mortality: Evidence from the acid rain program. Technical report, National Bureau of Economic Research, 2017.

William J. Baumol and Wallace E. Oates. *The Theory of Environmental Policy*. Cambridge University Press, New York, 1998.

Anna M. Birkenbach, David J. Kaczan, and Martin D. Smith. Catch shares slow the race to fish. *Nature*, 544:223–226, 2017.

Ragnhild Haugli Braaten, Kjell Arne Brekke, and Ole Rogeberg. Buying the right to do wrong – An experimental test of moral objections to trading emission permits. *Resource and Energy Economics*, 42: 110–124, 2015.

Dallas Burtraw. Cost savings, market performance and economic benefits of the US Acid Rain Program. In Steve Sorrell and Jim Skea, editors, *Pollution for Sale: Emissions Trading and Joint Implementation*, pages 43–62. Edward Elgar, 1999.

Raphael Calel. Adopt or innovate: Understanding technological responses to cap-and-trade. Working Paper 6847, CESifo Working Paper, 2018.

Raphael Calel and Antoine Dechezleprêtre. Environmental policy and directed technological change: Evidence from the European carbon market. *Review of Economics and Statistics*, 98(1):173–191, 2016.

CDP. Putting a price on carbon: Integrating climate risk into business planning. Technical report, Carbon Disclosure Project, 2017.

Lauraine G. Chestnut and David M. Mills. A fresh look at the benefits and costs of the US acid rain program. *Journal of Environmental Management*, 77(3):252–266, 2005.

Ronald Henry Coase. The problem of social cost. *The Journal of Law and Economics*, 56(4):837–877, 1960.

Christopher Costello, Steven D. Gaines, and John Lynham. Can catch shares prevent fisheries collapse? *Science*, 321:1678–1681, 2008.

Jingbo Cui, Junjie Zhang, and Yang Zheng. Carbon pricing induces innovation: Evidence from China's regional carbon market pilots. *AEA Papers and Proceedings*, 108:453–457, 2018.

Mark Dickie. Do classroom experiments increase learning in introductory microeconomics? *The Journal of Economic Education*, 37(3):267–288, 2006.

Joshua M. Duke and David M. Sassoon. A classroom game on a negative externality correcting tax: Revenue return, regressivity, and the double dividend. *The Journal of Economic Education*, 48(2):65–73, 2017.

Yvonne Durham, Thomas McKinnon, and Craig Schulman. Classroom experiments: Not just fun and games. *Economic Inquiry*, 45(1):162–178, 2007.

A. Denny Ellerman, Claudio Marcantonini, and Aleksandar Zaklan. The European Union Emissions Trading System: Ten years and counting. *Review of Environmental Economics and Policy*, 10(1):89–107, 2016.

Tisha L. N. Emerson and Beck A. Taylor. Comparing student achievement across experimental and lecture-oriented sections of a principles of microeconomics course. *Southern Economic Journal*, pages 672–693, 2004.

Roger Fouquet. The carbon trading game. *Climate Policy*, 3:S143–S155, 2003.

Meredith Fowlie, Stephen P. Holland, and Erin T. Mansur. What do emissions markets deliver and to whom? Evidence from Southern California's NOx trading program. *American Economic Review*, 102(2):965–993, 2012.

Scott Freeman, Sarah L. Eddy, Miles McDonough, Michelle K. Smith, Nnadozie Okoroafor, Hannah Jordt, and Mary Pat Wenderoth. Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, 111(23):8410–8415, 2014.

Kenneth Gillingham, Stefano Carattini, and Daniel Esty. Lessons from first campus carbon-pricing scheme. *Nature*, 551(7678):27, 2017.

Lawrence H. Goulder and Andrew R. Schein. Carbon taxes versus cap and trade: A critical review. *Climate Change Economics*, 4(03):1350010, 2013.

Patrick Gourley. Farmer Brown v. Rancher Wyatt: Teaching the Coase theorem. *The Journal of Economic Education*, 49(2):194–199, 2018.

R.Q. Grafton, R. Arnason, T. Bjorndal, D. Campbell, H.F. Campbell, C.W. Clark, R. Connor, D.P. Dupont, R. Hannesson, R. Hilborn, J.E. Kirkley, T. Kompas, D.E. Lane, S. Munro, G.R. Pascoe, D Squires, S.I. Steinshamn, B.R. Turris, and Q. Weninger. Incentive-based approaches to sustainable fisheries. *Canadian Journal of Fisheries and Aquatic Sciences*, 63:699–710, 2006.

Robert W. Hahn and Robert N. Stavins. The effect of allowance allocations on cap-and-trade system performance. *The Journal of Law and Economics*, 54(S4):S267–S294, 2011.

Cameron Hepburn, Karsten Neuhoff, William Acworth, Dallas Burtraw, and Frank Jotzo. The economics of the EU ETS market stability reserve. *Journal of Environmental Economics and Management*, 80:1–5, 2016.

Beat Hintermann. Allowance price drivers in the first phase of the EU ETS. *Journal of Environmental Economics and Management*, 59(1):43–56, 2010.

Charles A. Holt. Classroom games: Trading in a pit market. *Journal of Economic Perspectives*, 10(1): 193–203, 1996.

Valerie Jean Karplus. Institutions and emissions trading in China. *AEA Papers and Proceedings*, 108: 468–472, 2018.

Humberto Llavador and Marcus Giamattei. Teaching microeconomic principles with smartphones – lessons from classroom experiments with classEx. Technical Report 1584, Department of Economics and Business, Universitat Pompeu Fabra, 2017.

Ralf Martin, Mirabelle Muûls, Laure De Preux, and Ulrich J. Wagner. Industry compensation under relocation risk: A firm-level analysis of the EU Emissions Trading Scheme. *American Economic Review*, 104 (8):2482–2508, 2014.

Richard G Newell and Kristian Rogers. The US experience with the phasedown of lead in gasoline. Technical report, Resources for the Future, 2003.

Richard G. Newell, James N. Sanchirico, and Suzi Kerr. Fishing quota markets. *Journal of Environmental Economics and Management*, 49:437–462, 2005.

Daniel J. Phaneuf and Till Requate. *A Course in Environmental Economics Theory, Policy, and Practice*. Cambridge University Press, New York, 2017.

A. C. Pigou. *The Economics of Welfare*. Macmillan and Co., London, 1920.

James Salzman, Genevieve Bennett, Nathaniel Carroll, Allie Goldstein, and Michael Jenkins. The global status and trends of payments for ecosystem services. *Nature Sustainability*, 1:136–144, 2018.

Robert Stavins. What can we learn from the grand policy experiment? Lessons from SO_2 allowance trading. *Journal of Economic Perspectives*, 12:69–88, 1998.

Thomas Sterner and Elizabeth J. Z. Robinson. Selection and design of environmental policy instruments. In Partha Dasgupta, Subhrendu Pattanayak, and Kerry Smith, editors, *Handbook of Environmental Economics Vol. IV*, volume 4. Elsevier, 2018.

Tom Tietenberg. The tradable-permts approach to pretecting the commons: Lessons for climate change. *Oxford Review of Economic Policy*, 19(3):400–419, 2003.

David G. Victor and Joshua C. House. BP's emissions trading system. *Energy Policy*, 34(15):2100–2112, 2006.

Jan-Peter Voß. Innovation processes in governance: The development of 'emissions trading' as a new policy instrument. *Science and Public Policy*, 34(5):329–343, 2007.

Cathleen Whiting. Data-based active learning in the principles of macroeconomics course: A mock fomc meeting. *The Journal of Economic Education*, 37(2):171–177, 2006.

Figures

Figure 1: Chairs as emissions allowances

$\sqcup$	$\sqcup$	$\sqcup$	$\sqcup$	$\sqcup$
$\sqcap$	$\sqcap$	$\sqcap$	$\sqcap$	$\sqcap$

Figure 2: Generate Spreadsheet

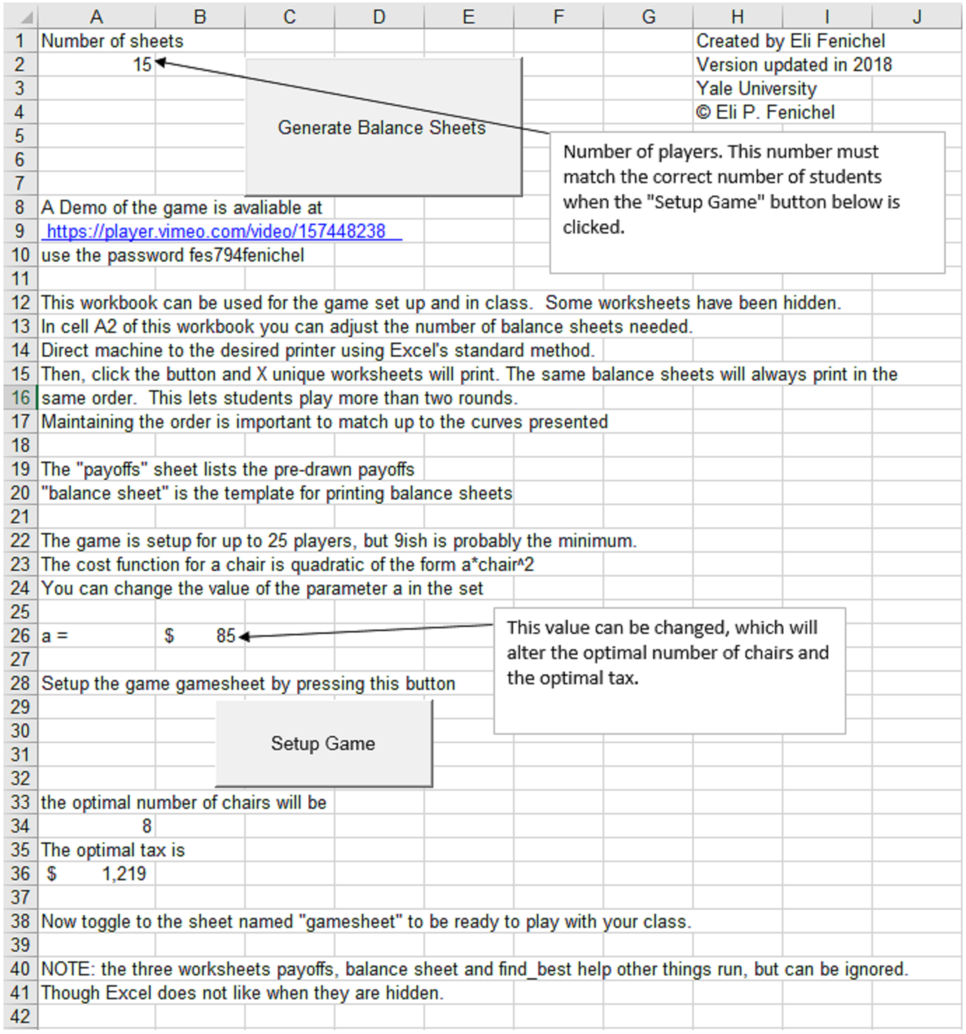

Figure 3: Gamesheet Spreadsheet

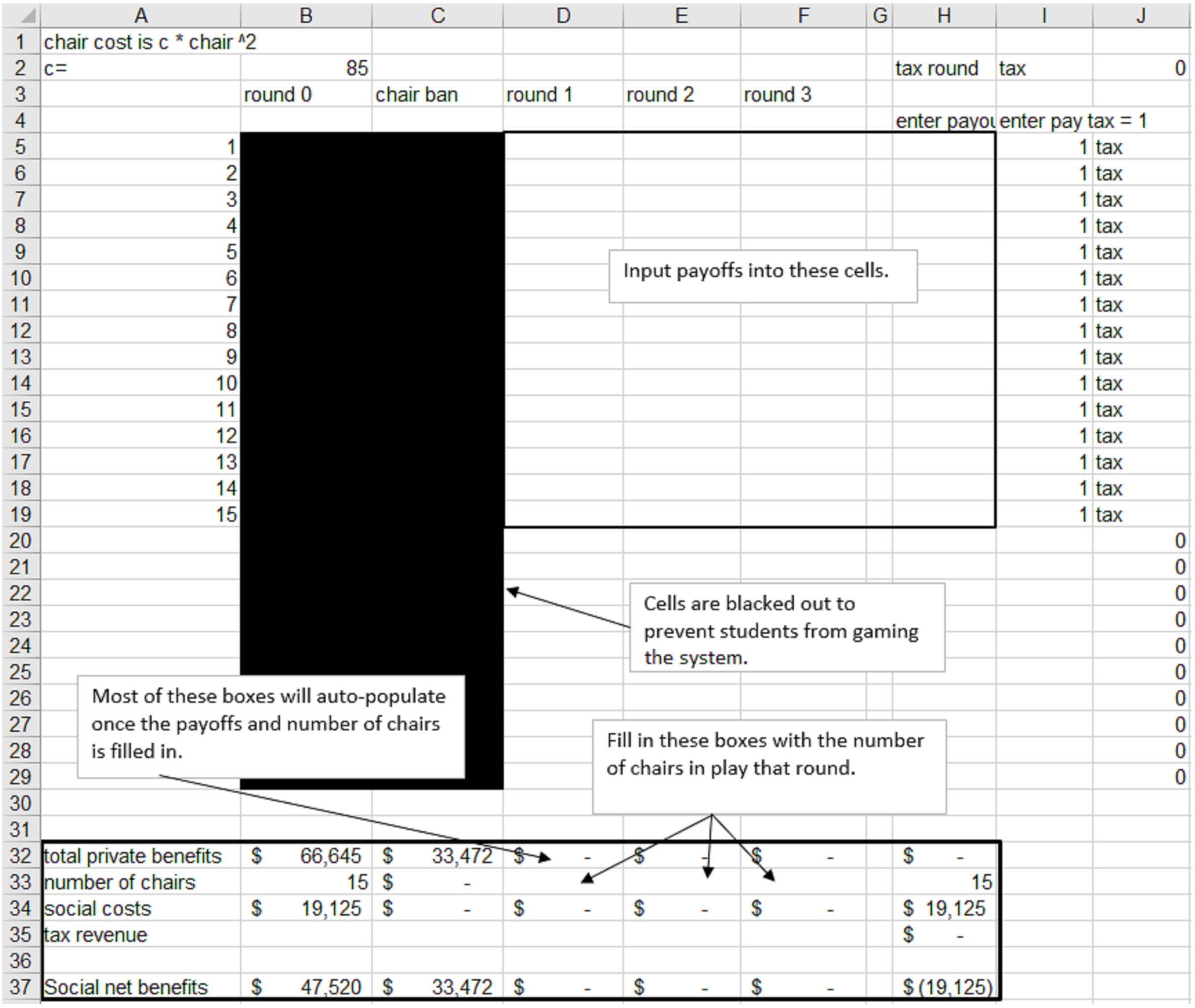

Figure 4: Tax Round Spreadsheet

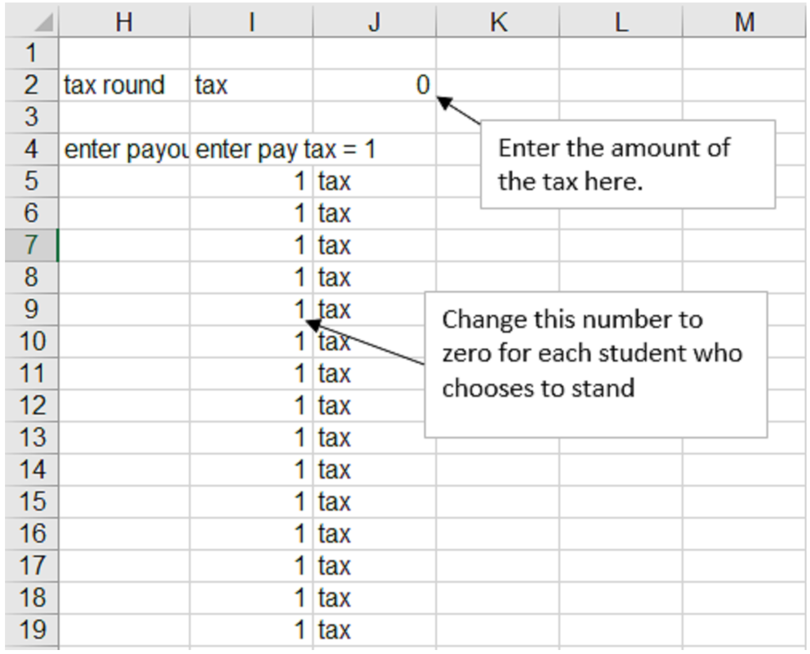

Figure 5: Participant Chair Selection Screen

Figure 6: Participant Trading Screen