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Abstract

Coasean arguments against the Pigouvian perspective are well established. A central tenet in this criticism argues that a Pigouvian tax may be a source of inefficiency: if parties were to bargain in the presence of a Pigouvian tax, (allocative) inefficiencies would occur—the so-called Buchanan-Stubblebine-Turvey Theorem. By analyzing a Coasean environment where the appropriation of property rights is costly, we show Coasean bargaining in the presence of a pre-existing (Pigouvian) tax may be superior. This has implications for policy where dual regulatory environments exist, such as regulation at the state and federal level, as well as environmental liability and litigation.

Keywords: Coasean bargaining; Pigouvian taxation

JEL *classification numbers*: D62; D72; H23; Q50

1 Introduction

As is well known, the seminal work by Coase (1959, 1960) provides a rigorous rebuttal of the Pigouvian perspective. In particular, Coase (1960) argued that the Pigouvian prescription to externalities was entirely misguided as this perspective failed to take into account the reciprocal nature of harm. Further, Coase (1960) showed that if parties could costlessly bargain (and property rights were well defined), an efficient level of harm would be reached without the requirement of direct government action. As a result, the 'Coase Theorem' argued that efficiency is independent of the initial endowment of liability.

A central theme within the Coasean perspective is that Pigouvian taxation, instead of alleviating the problem of harm, actually creates additional distortions. This argument was first constructed within Buchanan and Stubblebine (1962) and interpreted and modified by Turvey (1963), whereby in a Coasean environment—where agents have the ability to costlessly bargain—the presence of a Pigouvian tax provides additional incentives to reduce harm, which leads to an allocatively inefficient equilibrium. In particular, Buchanan and Stubblebine (1962, p. 383) argue "that full Pareto equilibrium can never be attained via the imposition of unilaterally imposed taxes and subsidies until all marginal externalities are eliminated." Turvey (1963, p. 310) also develops this idea by arguing that "[w]hether A and B are persons or firms, to levy a tax on A which is not received as damages or compensation by B may prevent optimal resource allocation from being achieved." We refer to this as the Buchanan-Stubblebine-Turvey Theorem.[1] This theorem can be easily illustrated in a figure. Consider a Coasean environment where players bargain over the level of harm, h. Figure 1 represents the marginal damages of a player $D'(h)$ as well as the marginal benefits of another player $B'^{N}(h)$ where superscript N denotes a 'no-tax' case. In the traditional Coasean argumentation, h^*_N is the efficient equilibrium level of harm. What the Buchanan-Stubblebine-Turvey Theorem argues is that under the presence of a Pigouvian tax, marginal benefits adjust to $B'(h)$ and—due to the ability to bargain—an alternative equilibrium level of harm is determined at h^*. Thus Coasean bargaining in the presence of a pre-existing Pigouvian tax generates allocative inefficiencies.

This theorem is a conventional—and seemingly uncontroversial—Coasean perspective on the inefficiencies of Pigouvian taxation; accordingly, this has been frequently discussed in en-

[1] We borrow this term from Mohring and Boyd (1971). Further, it is also stated in Turvey (1963) that the use of a tax can only be Pareto superior if there exists a double tax-subsidy scheme where the non-taxed player obtains full compensation.

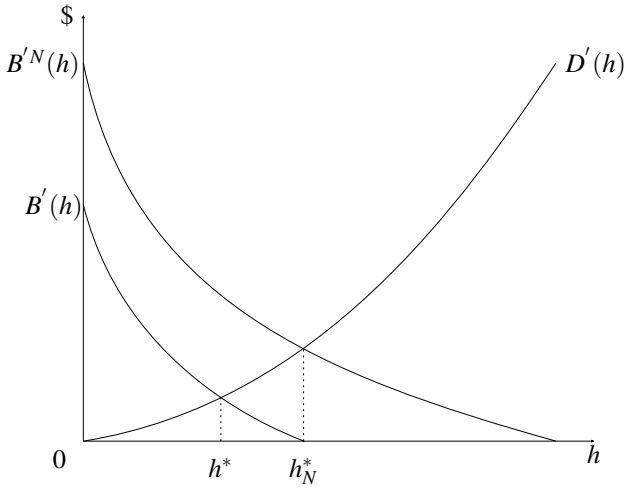

Figure 1: An illustration of the Buchanan-Stubblebine-Turvey Theorem.

vironmental economics textbooks and literature surveys (e.g., Baumol and Oates, 1988; Cropper and Oates, 1992).[2] The implications of this result are significant. If players are likely to bargain then a tax should not be levied on the level of harm. This may be relevant to cases where, for example, a federal government levies a tax but players bargain over the level of harm at the state (local) level (e.g., local negotiation over property rights for air pollution, resource extraction, and so on).[3] Although the Buchanan-Stubblebine-Turvey Theorem is intuitive, it is unclear whether this theorem holds for an environment where attribution and enforcement of property rights is costly.

In this article we evaluate the overall efficiency of Coasean bargaining in the presence of Pigouvian taxation. We analyze a two-stage Coasean environment, where—in the first stage—the initial endowment of property rights is costly to appropriate. In the second stage players bargain over the level of harm. Allowing property rights to be initially costly to appropriate diverges from the standard Coasean paradigm, but it is intuitive when one considers the process of acquiring property rights is far from costless: in reality activities such as violent conflict, litigation, and lobbying, are frequently observed. Such efforts represent *ex ante* transaction costs, which are both endogenously determined by players and a pre-condition for Coasean bargaining. Our results show that, in a costly Coasean environment, a pre-existing

[2]For a recent discussion on Coasean and Pigouvian perspectives see Anderson and Parker (2013) and Banzhaf et al. (2013). For a general analysis of the 'Coase Theorem' see Schweizer (1988) and for an application to environmental economics see Medema (2014).

[3]A common misconception is that this argument may be directly transplanted into the debate on hybrid market-based environmental regulation, where a cap-and-trade market is combined with a price mechanism (e.g., price ceiling). Thus hybrid mechanisms should be undesirable. Such a *prima facie* conclusion is unwarranted. As outlined by Medema (2014), there is little in common with the existence of a cap-and-trade market and the bilateral bargaining procedure discussed in Coase (1960).

(Pigouvian) tax may be Kaldor-Hicks and even Pareto superior. The intuition is as follows. As property rights are now costly to appropriate, the presence of a (Pigouvian) tax reduces the value of Coasean bargaining and reduces the equilibrium effort used to appropriate property rights. What we show is that the reduction in appropriation efforts may outweigh any reduction in efficiency due to distorted equilibrium harm levels. That is, the use of Pigouvian taxation assists in reducing endogenous *ex ante* transaction costs and can lead to improvements in efficiency. Hence, once it is recognized that the Coasean solution is not costless the case for a Pigouvian tax is strengthened considerably.

To model the initial appropriation of property rights we use contest theory, where players invest in sunk effort to obtain property rights (e.g., Congleton et al., 2008).[4] In particular, we use a common appropriation mechanism—an all-pay auction—to represent the institutions governing the appropriation of property rights. We can consider cases where property rights are non-existent (such as common-pool resources) or where property rights need to be enforced. Thus the use of appropriation activities can be interpreted as a process where initially non-contractible levels of harmful activities can be explicitly defined (via a court, lobbying, violent force, and so on), which allows contracting and thus Coasean bargaining to commence.

Generally, advocates of the Pigouvian perspective have dealt with the Buchanan-Stubblebine-Turvey Theorem by simply conceding the argument that "where small numbers are involved, the imposition of a 'corrective' Pigouvian tax may be too much of a good thing—it can produce a misallocation rather than eliminating it" (Baumol, 1972, p 308). Thus, only when the numbers involved are sufficiently large, Pigouvians argue that the Buchanan-Stubblebine-Turvey Theorem is irrelevant—this argument is similar to the conventional criticism of Coasean bargaining being unworkable for large numbers (Aivazian and Callen, 1981).[5] Relaxing the assumption on how property rights are appropriated in society—by introducing endogenous *ex ante* transaction costs—we are able to provide an argument that may favor a dual regulatory prescription. We can thus show that if property rights are costly to appropriate the presence of a pre-existing (Pigouvian) tax in a Coasean environment may be beneficial to all. Although the

[4]Glazer and Konrad (1999) have investigated levying taxes within contest structures. In particular, they focus on taxes levied on contest efforts as well as taxes on profits obtained from participating in the contest (net of contest efforts). For taxes on profit, they show that the tax structure is an important factor in determining how equilibrium contest efforts change. As we follow the Pigouvian tradition, our focus here is on levying a tax based on the marginal damage of harm at equilibrium (or some sub-optimal variant). In order to fully replicate the Buchanan-Stubblebine-Turvey Theorem, our taxation system is intentionally separated from the contest institution and, instead, levied on the player prior to participation in the contest.

[5]Also see Parisi (2003) and Robson (2012) for further discussions about Coasean bargaining in the large numbers case.

level of equilibrium harm is similar to that discussed in Buchanan and Stubblebine (1962) and Turvey (1963), we show that overall efficiency may increase with the establishment of a Pigouvian tax. Therefore we are able to defend Pigouvian taxation from the Coasean perspective and thus provide a stronger case for using the Pigouvian remedy as a policy instrument.

Due to the relative orthodoxy and *prima facie* intuition associated with the Buchanan-Stubblebine-Turvey Theorem, few have attempted to extend or even contradict this argument. Recently, however, Rosenkranz and Schmitz (2007) have attempted to investigate under what circumstances Coasean bargaining can justify Pigouvian taxation. They find the use of Pigouvian taxation can help alleviate the hold-up problem in bargaining. In contrast, we focus on cases where the property rights can be *de jure* non-existent (e.g., common-pool resources), or where property rights are insecure (i.e., costly to enforce and/or ambiguously defined), where conflict, lobbying, and litigation can be used to obtain property rights. Costly appropriation is thus a method that resolves the non-contractiblity of harm and allows exchange. Robson and Skaperdas (2008) model costly property right appropriation and find that, in some cases, going to court Pareto dominates bargaining whereas MacKenzie and Ohndorf (2013a,b) investigate the Pareto improvements that occur due to the *a priori* capping of transfers on tort law damages and the implementation of bargaining restrictions, respectively. This article is similar to Robson and Skaperdas (2008) and MacKenzie and Ohndorf (2013a,b) in that costly appropriation is taken into account when there exists the potential for Coasean bargaining, however, these works do not consider the efficiency of Coasean bargaining in the presence of Pigouvian taxation—the main objective of this article. Thus by combining the theory of property right appropriation with the literature on Coasean bargaining we provide a new insight on the traditional argumentation presented in Coasean and Pigouvian perspectives.

Our article contributes to the wider debate on transaction costs within Coasean bargaining. Under the conventional "normative Coase theorem" interpretation, lawmakers should "[s]tructure the law so as to remove the impediments to private agreements" (Cooter and Ulen, 1997, p. 89). That is, legal systems should be designed in order to improve the potential gains from trade, which will allow (additional) bargaining. Yet, as our analysis shows, this perspective is called into question when the initial appropriation of property rights is costly: a change in the legal system that improves bargaining gains may also generate large appropriation costs, which reduces aggregate welfare. If the initial appropriation of property rights is costly then the existence of a (Pigouvian) tax may be efficiency enhancing. Consequently,

in such a Coasean environment, a lawmaker should consider taxation rather than reducing impediments to private agreements.

This article is structured as follows. In Section 2 the framework of Coasean bargaining with Pigouvian taxation is described. In Section 3 the results are explained. In Section 4 we provide some concluding remarks.

2 The model

2.1 Preliminaries

Consider a situation in which player X causes harm to player Y.[6] The harm-producing activity generates a private benefit to player X, which we denote as $B^N(h)$ where $h > 0$ is the level of harm and the notation "N" denotes the 'no-tax' benchmark. Let $\bar{h}_N$ be defined such that $B'(\bar{h}_N) = 0$, that is, $\bar{h}_N$ is the level of harmful activity that player X would choose in absence of any regulation or institutional influences. For all $h \in [0, \bar{h}_N]$ we assume $B'^N(h) > 0, B''^N(h) \leq 0, B^N(0) = 0$, and define $B^N(\bar{h}_N) = \bar{B}^N$. For all $h \in [0, \bar{h}_N]$, player Y experiences harm denoted by $D(h)$ with $D(0) = 0, D'(h) > 0, D''(h) \geq 0$, and $D(\bar{h}_N) = \bar{D}^N$.

Following Coase (1960), we allow the creation of property rights over the level of harm, which is divisible over $[0, \bar{h}_N]$. In contrast to the standard Coasean paradigm, however, we do not assume that the property rights are provided in an *ad hoc* manner. Instead, we allow the initial endowment of property rights to be determined by players' costly efforts, which we denote as $x, y \in \mathbb{R}_+$, for players X and Y, respectively. This could, for example, represent litigation, conflict, or rent seeking. As such, these efforts can be interpreted as *ex ante* transaction costs, the level of which is endogenously determined by the players' choices in effort. Thus, by expending effort, player $j \in \{X, Y\}$ has a probability $p_j(x, y)$ of winning the property rights. Throughout this article we will assume that the initial endowment of property rights is given by the following assumption.[7]

[6] We follow the standard Coasean paradigm and focus on the two-player case. Our framework can be extended to allow for n players. In such a setting two groups can be formed where the allocation of property rights is determined by aggregate group efforts and then group Coasean bargaining occurs. After, individuals either have intra-group bargaining over the rents or, as commonly modeled in the literature, an intra-group sharing rule exists (Congleton et al., 2008).

[7] See the appendix for an alternative formulation.

Assumption 1. *Player X's probability of obtaining the property rights is given by* $p_X(x,y)$ *where*

$$p_X(x,y) = \begin{cases} 1 & \text{if } x > y \\ \frac{1}{2} & \text{if } x = y \\ 0 & \text{if } x < y \end{cases} \tag{1}$$

and $p_Y(x,y) = 1 - p_X(x,y)$ *for all* $x, y \in [0,\infty)$.

The process of initial property endowment is thus determined via an all-pay auction, where the agent with the largest level of effort has a probability of one of obtaining the property rights. In absence of Coasean bargaining, if the property rights are awarded to player X, then they will receive a benefit of $\bar{B}^N$ whereas player Y will suffer harm relating to $\bar{D}$. Alternatively if player Y obtains the property rights then it will initially experience zero harm and player X will therefore also experience zero benefit.[8] As argued in Coase (1960), the initial endowment of property rights creates an opportunity for players to benefit from exchange over the level of harm.[9] Let us denote $h_N^* = \arg\max_{h\in[0,\bar{h}_N]} \{B^N(h) - D(h)\}$ as the efficient Coasean bargaining solution. We follow Coase (1960) and assume property rights are attributed to one player. In the appendix, however, we provide an alternative framework where players may receive a share of property rights.

Let τ be a per-unit tax levied on player X's harmful activity such that $B(h) \equiv B^N(h) - \tau \cdot h$, where $B^N(h)$ is player X's benefit under a 'no-tax' situation for a level of harmful activity $h \in [0,\bar{h}_N]$. As standard, the tax distorts player X's benefit function to internalize the harm generated.[10] As a consequence, the domain of the benefit function reduces to the interval $[0,\bar{h}] \subseteq [0,\bar{h}_N]$, where $\bar{h}$ is implicitly defined by $B'(\bar{h}) = 0$. Although we will consider a general form of taxation, note that a Pigouvian tax is the special case where $\tau = D'(h_N^*)$, and hence $\bar{h} = h_N^*$. When considering the case of a tax, we will assume that the tax has been implemented prior to the commencement of Coasean bargaining (and any costs of establishing this tax are sunk). We, therefore, have the Coasean bargaining solution under the presence of a tax, $h^* = \arg\max_{h\in[0,\bar{h}]} \{B(h) - D(h)\}$. Hence, for Coasean bargaining to occur $B(h) > D(h)$

[8] Alternatively, this structure could be framed in the converse of harm, i.e., harm avoidance. In such as case, Coasean bargaining occurs over player X's abatement cost and player Y's damages.

[9] The non-contractability of property rights prior to bargaining is a result of the property rights being *de jure* non-existent or insecure (ambiguously defined or costly to enforce). Thus the contest—through use of appropriation efforts—provides a process by which enforceable property rights are established, which provides the basis for bargaining.

[10] We initially assume that the revenue generated from the tax is not used in any form. We relax this assumption later in the article.

for $h \in [0, \bar{h}]$ has to hold, which we assume throughout. Note that given our assumptions on players' benefit (damage) functions it follows that $\bar{h} \leq \bar{h}_N$ and $h^* \leq h_N^*$. Thus, in the presence of taxation the equilibrium harm level will be lower than that experienced in the Coasean bargaining game without a tax. In other words, there is an inefficiently high level of precaution from player X due to the presence of the tax: the so-called Buchanan-Stubblebine-Turvey Theorem (Buchanan and Stubblebine, 1962; Turvey, 1963). Let us begin in a Coasean environment where there is a pre-existing (Pigouvian) tax.

2.2 Coasean bargaining in the presence of (Pigouvian) taxation

In our analysis, the all-pay auction will provide an initial endowment of property rights to a player at one of the domain extremes $\{0, \bar{h}\}$.[11] Specifically, if player X obtains the property rights the initial starting point for bargaining is $h = \bar{h}$. Alternatively, player Y may obtain the property rights and therefore $h = 0$. With property rights being distributed to either player, gains from exchange are feasible as a positive internalization rent can be shared via a bargaining process. Thus let the rent under a tax be denoted by I_j for $j \in \{X, Y\}$, which is defined as:

$$I_X \equiv \bar{D} - ((\bar{B} - B(h^*)) + D(h^*)) \qquad \text{if agent X wins the property rights,} \tag{2}$$

$$I_Y \equiv \bar{B} - ((\bar{B} - B(h^*)) + D(h^*)) \qquad \text{if agent Y wins the property rights,} \tag{3}$$

where $\bar{D} \equiv D(\bar{h})$ and $\bar{B} \equiv B(\bar{h})$. From (2) and (3), the total internalization rent that can be obtained by the winner of the contest is their opponent's total possible loss minus the costs (reductions in benefits) that are payable as compensation to the party holding the property right in order to achieve the post-bargaining equilibrium. It is indeed within the Coasean logic that the total equilibrium cost $((\bar{B} - B(h^*)) + D(h^*))$, i.e., own cost plus compensation, must always be borne by the party not holding the property right in order to reach the bargaining outcome h^*. Given I_j is the maximum internalization rent possible, we allow players' bargaining powers to influence the distribution of the internalization rent. In particular, the

[11] This follows the conventional Coasean paradigm. It is easy to extend this to allow for initial bargaining positions other than the extremities. This can be done by allowing for a parameter $\phi > 0$ where the domain extremes are given by $\{0 + \phi, \bar{h} - \phi\}$ such that the initial benefits and damages are given by $B(\bar{h} - \phi)$ and $D(0 + \phi)$. Our results continue to hold if the proportional reduction in rent shares are the same across the tax and non-tax cases. For analysis on restrictions to the externality domain see MacKenzie and Ohndorf (2013b).

rents acquired by the winning players X and Y are given by

$$R_X \equiv \mu_X \cdot I_X \geq 0, \tag{4}$$

$$R_Y \equiv \mu_Y \cdot I_Y \geq 0, \tag{5}$$

respectively, where $\mu_j \in [0,1]$ is a share parameter determined by the bargaining power of the winning player j.[12] This representation of the bargaining powers is general enough to allow for any bargaining game, such as the Nash bargaining solution or the alternating-offers game. Also note that we make no assumption on the relationship between μ_X and μ_Y, thus if player X is able to secure a larger share of rent when winning, this does not preclude player Y doing the same when winning the contest.

Players' expected payoffs are therefore:

$$U_X(x,y) = p_X(x,y) \cdot (R_X + \bar{B}) - (1 - p_X(x,y)) \cdot (D(h^*) + R_Y - B(h^*)) - x, \tag{6}$$

$$U_Y(x,y) = p_Y(x,y) \cdot (R_Y) - (1 - p_Y(x,y)) \cdot ((\bar{B} - B(h^*)) + D(h^*) + R_X) - y. \tag{7}$$

If player X wins the contest without bargaining, they receive $\bar{B}$. Bargaining will only occur if player X receives at least the same level of pay-off. In addition to $\bar{B}$, after bargaining, X will receive his share of the internalization rent, i.e., R_X. If, on the other hand, player X loses, they will pay damage compensation and rent to player Y, $D(h^*) + R_Y$, and receive a benefit of $B(h^*)$. If player Y wins they receive R_Y but if they lose they pay R_X as well as compensation to player X, $(\bar{B} - B(h^*))$, as well as experiencing damage of $D(h^*)$. Following the Coasean logic, even if a player loses, they still have an incentive to bargain as the losses will always be greater without bargaining.

In the first-price all-pay auction with complete information, the party with the largest appropriation effort secures the property rights with certainty. We allow both players to play mixed strategies. The expected payoff functions in (6) and (7) can hence be written in the general form $p_j(x,y)W_j - (1 - p_j(x,y))L_j$, with $j \in \{X, Y\}$ where W_j and L_j are the respective

[12] Correspondingly, the loser will receive an internalization rent: $(1 - \mu_X) \cdot I_X$ for (losing) player Y and $(1 - \mu_Y) \cdot I_Y$ for (losing) player X.

awards and losses. Collecting $p_j(x,y)$ and defining $v_j = W_j + L_j$, this can be re-arranged to:

$$p_X(x,y)v_X - L_X - x, \tag{8}$$

$$p_Y(x,y)v_Y - L_Y - y. \tag{9}$$

In this format, it is well known (e.g., Hillman and Riley, 1989) that if $v_X \geq v_Y$, then the equilibrium is indeed in mixed strategies. In equilibrium, the agents' optimal cumulative bid distribution function are given by

$$G_X = \begin{cases} \frac{x}{v_Y} & \text{for } x \in [0, v_Y] \\ 1 & \text{for } x > v_Y \end{cases} \tag{10}$$

and

$$G_Y = \begin{cases} \left[1 - \frac{v_Y}{v_X}\right] + \frac{y}{v_X} & \text{for } y \in [0, v_Y] \\ 1 & \text{for } y > v_Y. \end{cases} \tag{11}$$

For these strategies, the expected payoffs of both players are therefore:

$$U_X = -L_X + G_Y v_X - x = -L_X + v_X - v_Y, \tag{12}$$

$$U_Y = -L_Y + G_X v_Y - y = -L_Y. \tag{13}$$

Noting from (6) and (7) that

$$v_X = v_Y = (\bar{B} - B(h^*)) + D(h^*) + R_X + R_Y. \tag{14}$$

It follows that both players have an identical valuation of the property rights, and the expected payoffs of players X and Y are $U_X = -L_X$ and $U_Y = -L_Y$, which can be rewritten as:

$$U_X = -(D(h^*) + R_Y - B(h^*)), \tag{15}$$

$$U_Y = -((\bar{B} - B(h^*)) + D(h^*) + R_X). \tag{16}$$

2.3 Benchmark: the elimination of taxes

Let us now consider a Coasean environment where there does not exist a (Pigouvian) tax. In such a case bargaining yields allocative efficiency, which also implies that the respective

internalization rents are larger. Setting $\tau = 0$ the expected payoffs of players X and Y are given by:

$$U_X^N(x,y) = p_X(x,y) \cdot (R_X^N + \bar{B}^N) - (1 - p_X(x,y)) \cdot (D(h_N^*) + R_Y^N - B^N(h_N^*)) - x, \tag{17}$$

$$U_Y^N(x,y) = p_Y(x,y) \cdot R_Y^N - (1 - p_Y(x,y)) \cdot ((\bar{B}^N - B^N(h_N^*)) + D(h_N^*) + R_X^N) - y. \tag{18}$$

Again, we assume that property rights are allocated via an all-pay auction which takes place prior to the Coasean bargaining process. Note that for the standard Coasean environment, players' net gains v_j are also identical, as

$$v_X^N = v_Y^N = (\bar{B}^N - B^N(h_N^*)) + D(h_N^*) + R_X^N + R_Y^N. \tag{19}$$

Hence, we can solve the game, with simple Coasean bargaining, analogously to the tax case. The expected payoffs of players X and Y in equilibrium are then given by:

$$U_X^N = -(D(h_N^*) + R_Y^N - B^N(h_N^*)), \tag{20}$$

$$U_Y^N = -((\bar{B}^N - B(h_N^*)) + D(h_N^*) + R_X^N). \tag{21}$$

3 Results

We are now ready to compare the expected payoffs of players with and without a (Pigouvian) tax. For player X, comparison of (15) with (20) and simplification reveals

$$U_X - U_X^N = -(1 - \mu_Y)(I_Y^N - I_Y). \tag{22}$$

The sign of this term is (weakly) negative. For player Y, comparing (16) with (21), and noting our initial assumptions on the benefit and cost curves, we find that player Y has a higher expected payoff in the presence of a tax:

$$U_Y - U_Y^N = \mu_X(I_X^N - I_X) - (I_Y^N - I_Y) + (\bar{B}^N - \bar{B}) > 0. \tag{23}$$

Summing up over (22) and (23), yields the difference in aggregated welfare Δ:

$$\Delta = \mu_X(I_X^N - I_X) - (2 - \mu_Y)(I_Y^N - I_Y) + (\bar{B}^N - \bar{B}). \tag{24}$$

From (24) note that the first and last terms are positive, whereas the second term is negative.

To provide further insight, we can decompose Δ into distinct elements that focus on appropriation costs and welfare. To consider how equilibrium appropriation costs change, note that aggregate appropriation costs under a tax are given by:

$$E[x+y] = v_X = v_Y = (\bar{B} - B(h^*)) + D(h^*) + R_X + R_Y. \tag{25}$$

Similarly, for the case without a tax, the aggregate appropriation costs are given by

$$E[x^N + y^N] = v_X^N = v_Y^N = (\bar{B}^N - B^N(h_N^*)) + D(h_N^*) + R_X^N + R_Y^N. \tag{26}$$

Subtracting (25) from (26) and simplifying shows that:

$$E[x^N + y^N - (x+y)] = \mu_X(I_X^N - I_X) - (1-\mu_Y)(I_Y^N - I_Y) + (\bar{B}^N - \bar{B}) > 0. \tag{27}$$

Hence, appropriation costs are unambiguously lower under a tax regime compared to a 'no-tax' regime. Subtraction of (27) from (24) reveals a residual component $-(I_Y^N - I_Y) < 0$, which is the loss in allocative efficiency due a movement from h_N^* to h^*. Thus a trade-off exists when a tax is introduced: appropriation costs decrease but losses associated with an inefficient allocation of h increase. Obviously, from (24), a tax situation is Kaldor-Hicks superior if the winning bargaining power of X and Y is sufficiently large, i.e., if μ_X and μ_Y are close enough to 1. Note that efficiency gains can also result for $\mu_X > 0$ if $(I_X^N - I_X)$ is large enough. This, in turn, is more likely for a relatively steep marginal damage curve. Finally, if the difference $I_Y^N - I_Y$ is relatively small then Kaldor-Hicks improvements exist. This condition is equivalent to a relatively flat benefit function $B(h)$. This is further discussed within an example in Subsection 3.1.

From (24) and taking into account that $-(I_Y^N - I_Y) + (\bar{B}^N - \bar{B}) > 0$, we can establish a sufficient condition for Kaldor-Hicks improvements by comparing ratios of the players' bargaining powers and their potential rents, as established in the following proposition.

Proposition 1. *A sufficient condition of Kaldor-Hicks superiority of the tax case is:*

$$\frac{\mu_X}{(1-\mu_Y)} > \frac{(I_Y^N - I_Y)}{(I_X^N - I_X)} \tag{28}$$

Proposition 1 shows that efficiency improvements depend on either relatively strong bargaining powers (left hand side) or a steep marginal damage curve relative to the marginal benefit curve (right hand side). On closer inspection of the role of bargaining powers, reflected by the parameters μ_i for $i \in \{X, Y\}$, another interesting result is obtained. From (23) it can be shown that player Y is unambiguously better off in terms of expected payoff when a tax exists. From (22), if $\mu_Y = 1$ then $U_X - U_X^N = 0$ and player X is indifferent between both situations. In summary:

Proposition 2. *If $\mu_Y = 1$ then a (Pigouvian) tax in a Coasean environment is Pareto superior to Coasean bargaining without a tax.*

Proposition 2 shows that in a Coasean bargaining game where property rights are appropriated via an all-pay auction, the existence of a (Pigouvian) tax can even result in Pareto superiority.[13] In such a case, the cost from appropriation under the standard Coasean setting is larger or equal to players' cost under a tax regime. The difference in appropriation costs, then, more than offsets the inefficiency caused by the over-internalization of harm identified within the Buchanan-Stubblebine-Turvey Theorem.

To illustrate this case, notice that in Figure 2, the term $B^N(h_N^*) - D(h_N^*) - (B(h^*) - D(h^*))$ corresponds to the area $abef$. Notice further that this area represents the difference in internalization rent, $R_Y^N - R_Y = \mu_Y(I_Y^N - I_Y)$. As for $\mu_Y = 1$, $R_Y^N - R_Y$ also corresponds to the area $abef$, it follows that $U_X - U_X^N = 0$, i.e., player X is indifferent between the tax and the 'no-tax' case. Thus, it is intuitive that Pareto improvements always exist when $\mu_Y = 1$.

If player Y, the victim, wins and they are able to capture the entire rents (therefore $R_Y = I_Y$), then Pareto improvements exist. Note that this holds independently of the bargaining power of player Y when they lose $(1 - \mu_X)$, or the bargaining power of player X when they win (μ_X). Thus, for $\mu_Y = 1$, the existence of Pareto improvements can be established without any assumption on the bargaining power of winning player X.

3.1 Linear marginal benefits and damages

To exemplify the general results derived in the previous section and for further analysis, it is useful to discuss a linear functional specification. Let the marginal benefits and marginal

[13] We have assumed that the bargaining powers remain identical for the tax and 'no-tax' cases. If, however, we relax this assumption, such that there now exists two levels of bargaining power $\{\mu_Y, \mu_Y^N\}$, Pareto improvements are more likely if μ_Y^N is sufficiently larger than μ_Y

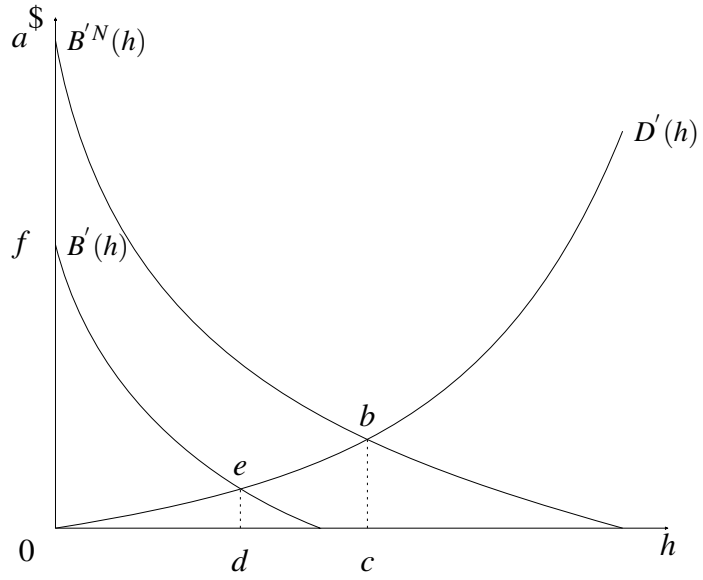

Figure 2: Pareto superiority of the tax case.

damages be given by:

$$B'(h) = \alpha - \beta \cdot h - \tau, \tag{29}$$

$$D'(h) = \omega \cdot h, \tag{30}$$

where $\alpha > 0$ is the intercept of the marginal benefit function and $\beta, \omega > 0$ represent the respective slopes. Note that the Pigouvian tax rate τ cannot plausibly exceed intercept α and the 'no-tax' case can be derived by choosing $\tau = 0$.

Substituting (29) and (30) into (2) and (3) yields:

$$I_X = \frac{\omega^2(\alpha - \tau)^2}{2\beta^2(\beta + \omega)}, \tag{31}$$

$$I_Y = \frac{(\alpha - \tau)^2}{2(\beta + \omega)}. \tag{32}$$

Using (31) and (32), we can observe that the welfare effect of a pre-existing tax level τ compared to the 'no-tax' case is given by:

$$\Delta = \frac{\tau(2\alpha - \tau)\left(\omega^2\mu_X + \beta\left(\omega - \beta + \beta\mu_Y\right)\right)}{2\beta^2(\beta + \omega)}. \tag{33}$$

Using (33) it is easily shown that for a maximum to occur (and hence an optimal tax rate

to exist) we require the following condition to be satisfied:

$$\omega^2 \mu_X + \beta\omega > (1 - \mu_Y)\beta^2. \tag{34}$$

Notice that this is always satisfied when $\omega \geq \beta$, that is, the slope of the marginal damage function is equal to or larger than the slope of the marginal benefit function. Hence, the tax case is always more efficient if the marginal damages to Y are steeper than X's marginal benefits. Yet, even if $\omega < \beta$ the condition can still be satisfied as long as μ_X and μ_Y are relatively large compared to the absolute values of the slopes. This is consistent with Proposition 1 derived above. Notice that for the linear case, the right-hand side of condition (28), which relates the relative bargaining powers to the relative differences in internalization rents, is indeed determined by the relative slopes. In this case, $(I_X^N - I_X)$ is larger for higher values of ω, while $(I_Y^N - I_Y)$ becomes smaller with lower values of β. The marginal effect of the tax rate on Δ is

$$\frac{d\Delta}{d\tau} = \frac{(\alpha - \tau)\left(\omega^2 \mu_X + \beta\left(\omega - \beta(1 - \mu_Y)\right)\right)}{\beta^2(\beta + \omega)}, \tag{35}$$

which is non-negative for $\tau^* \leq \alpha$ if the relative slope $\frac{\omega}{\beta}$ and/or the winners' bargaining powers are large enough. Thus for linear marginal curves—with a sufficiently large relative slope $\frac{\omega}{\beta}$ or bargaining powers—*any* tax levied will be welfare improving. Note that this includes the special case of a Pigouvian tax: set at the level of marginal damages in equilibrium.

Optimization of (33) with respect to τ yields additional insights, summarized in the following proposition.

Proposition 3. *For $\tau \in (0, \alpha]$ and if* (34) *holds then $\Delta > 0$ and the welfare-maximizing per-unit tax rate is given by $\tau^* = \alpha$.*

For linear marginal curves, the optimal tax rate reduces the level of equilibrium harm to zero. As a result, Coasean bargaining will no longer be feasible. Hence, in this case, the regulator favors reducing appropriation costs over losses due to over-internalization of harm. Simply put, the regulator would rather experience welfare losses from a zero level of activity rather than experiencing the losses from appropriation activities. Note that this interior solution only holds if (34) is satisfied. In all other cases, e.g., for a sufficiently steep marginal benefit curve, the optimum lies in the corner solution $\tau^* = 0$. Hence, the case for taxation ultimately depends on the slopes of the damage and benefit functions as well as the

strength of the winners' bargaining powers.

3.2 Tax revenue and appropriation

For the analysis above we assumed that tax revenue collected is not recycled or used in any form, thus our findings are, in fact, quite conservative. If one were to consider the use of the tax revenue generated, then it is clear that additional benefits can be achieved by, say, investing in public goods or simply tax restitution.[14] It follows that if an all-pay auction represents the allocation of property right endowments, the existence of a Pigouvian tax may result in improvements over-and-above those discussed here. To see this, note that the amount of tax revenue generated is given by τh^*.[15] Generally, comparison of the tax revenue versus the potential loss from player X in (22) reveals the following proposition:

Proposition 4. *If $\tau h^* > (1-\mu_Y)(I_Y^N - I_Y)$ then a tax and lump-sum rebate system levied on player X is Pareto superior to Coasean bargaining without a tax.*

Hence, a policymaker's choice of tax level is associated with a trade-off. As τ increases we will also observe h^* decreasing and $(I_Y^N - I_Y)$ increasing. Whether the tax case is actually Pareto superior or not will depend on the relative elasticities associated with the marginal benefit and cost functions. Again, as noted in Proposition 2, the bargaining power of player Y has a pivotal role in the potential Pareto superiority of a tax system: a large μ_Y can counteract an increase in $(I_Y^N - I_Y)$ and decrease in h^*.

As we have allowed costly appropriation of property rights under Coasean bargaining, it is also likely that the rents within a Pigouvian regime may be appropriated. In particular, it is realistic to consider a scenario where generated tax revenues are obtained by the players (or a third party) by use of costly appropriation activity. Let us assume that such appropriation for this tax revenue can also be represented by the all-pay-auction from (1). Note that the contested prize might be smaller or larger, than the actual tax revenue τh^*. We therefore specify the prize in this rent-seeking game as $\lambda \tau h^*$, with $\lambda > 0$. Hence, cases for which $\lambda < 1$, could represent a reduction in the redistributed tax money due to bureaucratic friction or

[14] Comparing taxation with and without bargaining, Shibata (1972) argues that Pareto improvements do not exist, as—under an existing tax—the use of bargaining will alter the level of harm and the associated tax revenue, which reduces the revenue recipient's utility (a third party). The structure of our model is distinct. We compare Coasean bargaining with and without a tax. Thus the relative comparative scenarios are those of a bargaining game where tax revenue is (or is not) generated. Clearly a third party would benefit from any generated tax revenue.

[15] The application of a similar refund scheme has been beneficial, for example, see Sterner and Isaksson (2006) for a successful refunded tax system in Sweden and, for a more general analysis, see Gersbach and Requate (2004).

earmarking (MacKenzie and Ohndorf, 2012). On the other hand it might be conceivable that the revenue is used to reduce other distortionary taxes. Such cases, with a revenue-recycling effect, might be represented by $\lambda > 1$.[16] The players' expected payoffs from appropriating the Pigouvian tax revenue are then:

$$p_X(x,y)\lambda\tau h^* - x, \tag{36}$$

$$p_Y(x,y)\lambda\tau h^* - y. \tag{37}$$

It is well known that the expected aggregate appropriate costs from this game are $\lambda\tau h^*$, i.e., the rent is fully dissipated. Also, from Hillman and Samet (1987), full dissipation will occur for any number of players (or third party members) that have identical values for the tax revenue.[17] Thus if third parties—outside of the Coasean bargaining game—attempt to appropriate the tax revenue, we would continue to see full rent dissipation. Thus we have an independence result, which shows that the appropriation of Pigouvian tax revenue does not distort Δ derived in (24).[18] We summarize these findings in the following proposition.

Proposition 5. *If tax revenue is contestable then Δ, the relative Kaldor-Hicks efficiency of a (Pigouvian) tax, is independent of tax revenue.*

A natural question to pose is: how sensitive are our results to the use of an all-pay auction, which has the property of full rent dissipation? In the appendix, we show the result of a similar Coasean environment but where the appropriation mechanism is now modeled by another popular contest mechanism: an imperfectly discriminating 'Tullock' contest (Tullock, 1980). The Tullock contest differs from an all-pay auction in that the probability of winning is now not discrete; instead, the probability is based on a player's effort relative to total effort. As a result, equilibrium efforts in a Tullock contest are smaller than that of an all-pay auction. When our Coasean environment is modeled in such a way, we show that a similar result occurs. In fact, in this case, if the tax rate is not particularly large, it yields Kaldor-Hicks superiority even with lower rent dissipation.

[16] On revenue recycling effects see, for example, Goulder (1995), Parry (1995), and Goulder et al. (1999).

[17] For asymmetric valuations see Hillman and Riley (1989).

[18] It is also possible that efforts are expended to distort the level of the tax itself or to delimit the Coasean bargaining space. If additional efforts were expended to alter the tax rate—Player Y preferring a higher tax rates and Player X a lower one—then additional costs are added to the Pigouvian regime. Thus the relative efficiency of a Pigouvian regime will be reduced and it may result in taxation no longer being efficient relative to Coasean bargaining.

4 Concluding remarks

The purpose of this article is to investigate if Pigouvian taxation levied in a Coasean environment is superior to a case without taxation. From the early literature on Coasean bargaining, the Buchanan-Stubblebine-Turvey Theorem (Buchanan and Stubblebine, 1962; Turvey, 1963) argues that the existence of a Pigouvian tax in an environment where players can bargain will result in distortions in the level of harm. For example, federal taxation over harm-producing activities—where the level of harm is negotiated at the local level—is a highly undesirable scenario.

In this article we take a fresh look at the Buchanan-Stubblebine-Turvey Theorem. By relaxing the assumption on how property rights are allocated in society we show that efficiency improvements may exist if a Pigouvian tax is levied. We allow players to expend costly effort in order to appropriate property rights. This can, for example, be interpreted as violent conflict, litigation, as well as lobbying activities. Property rights can be *de jure* non-existent or costly to enforce/define. By providing a realistic environment within which property rights are allocated we show the Pigouvian tax reduces the gains from Coasean exchange. As a result, this may reduce equilibrium appropriation effort more than the loss from allocative inefficiency. Our results continue to hold when rent seeking over the tax revenue is taken into account.

A strong case in favor of pre-existing green taxes can be established within the original application of the Coase Theorem; namely, environmental liability and litigation. Within Coase (1960), property rights are attributed via the establishment of liability through a court order. The actual bargaining process can then be interpreted as some sort of settlement between plaintiff and defendant. Note, however, that due to the assumption of zero transaction costs, costs of litigation are generally not considered in the original formulation of the Coase Theorem. Within models in the field of Law and Economics, these costs are generally derived by modeling the lawsuit as a contest. When integrating the cost of litigation into the Coasean framework, several established efficiency implications of the Coase Theorem tend to change (Robson and Skaperdas, 2008; MacKenzie and Ohndorf, 2013a,b). As shown above, this also holds true for the Buchanan-Stubblebine-Turvey result. Hence, when it comes to environmental liability and litigation, it is quite likely that a pre-existing tax is efficiency enhancing, as it 'dampens' the controversy and hence overall spending in litigation. An example for such

a situation might be the consent decree between the US EPA and several diesel engine manufacturers on emission restrictions, which resulted after a settlement in the 'Not-To-Exceed standard' for newly introduced Diesel engines. As laid out in Morriss et al. (2005, 2009), the cost for additional emission reductions imposed on the manufacturers (and hence the matter of controversy) was significant. Yet, it can be argued that these costs would have been higher if pre-existing fuel taxes and other incentive mechanisms[19] had not put additional pressure on emissions per mile driven.[20]

It is to be noted that fully internalizing taxes are mainly a theoretical construct as, in reality, green taxes tend to be too low to yield the first-best level of externality (e.g., Ciocirlan and Yandle, 2003).[21] In our model, we do not assume the tax level to be necessarily fully internalizing. Indeed, as shown in our linear specification, if the slope of the marginal damage function is equal to or larger than the slope of the marginal benefit function then *any* level of tax will be efficiency improving.

Our article thus provides a formal argument in favor of taxation when there is a potential for negotiation in the level of harm. Our analysis can provide insights to the separation of regulatory responsibilities, such as in environmental federalism as well as environmental liability and litigation issues.

[19] In 1991 an emissions trading system for NO_x emissions of Diesel engines was introduced (Morriss et al., 2009).

[20] Another example for internalization of external cost via a lawsuit with settlement and pre-existing taxes is the Tobacco Master Settlement Agreement, see Sloan and Trogdon (2004), Sung et al. (2005), and Morriss et al. (2009).

[21] Interestingly, Pigou himself was aware of the political economy issues relating to taxes, as he stated: "we cannot expect that any public authority will attain, or will even wholeheartedly seek, that ideal. Such authorities are liable alike to ignorance, to sectional pressure and to personal corruption by private interest. A loud-voice part of their constituents, if organized for votes, may easily outweigh the whole " (Pigou, 1932, p. 332).

Appendix: Tullock contest

The Tullock contest success function is given by $p_X(x,y)$ where

$$p_X(x,y) = \begin{cases} \frac{x}{x+y} & \text{if } \max\{x,y\} > 0, \\ \frac{1}{2} & \text{otherwise,} \end{cases} \tag{A.1}$$

and $p_Y(x,y) = 1 - p_X(x,y)$. In this 'Tullock' contest, the player with the highest effort now has a probabilistic chance of obtaining the property rights. It can be shown that the difference in players' expected payoff when a tax is introduced is as follows:

$$\Delta_X = U_X - U_X^N = \frac{1}{4}\left((1-\mu_X)\left(\bar{B} - \bar{B}^N\right) + \mu_X\left(\bar{D} - \bar{D}^N\right) + (\mu_X - 3\mu_Y + 3)\,K\right), \tag{A.2}$$

$$\Delta_Y = U_Y - U_Y^N = \frac{1}{4}\left(3\left((1-\mu_X)\left(\bar{B}^N - \bar{B}\right) + \mu_X\left(\bar{D}^N - \bar{D}\right)\right) - (3\mu_X - \mu_Y - 3)\,K\right), \tag{A.3}$$

where $K = B(h^*) - B^N(h_N^*) - D(h^*) + D(h_N^*) < 0$. Summation of (A.2) and (A.3) shows that a situation with a pre-existing Pigouvian tax in a Coasean bargaining game can be Kaldor-Hicks superior to a case without a tax, as

$$\Delta_X + \Delta_Y = \frac{1}{2}\left((1-\mu_X)\left(\bar{B}^N - \bar{B}\right) + \mu_X\left(\bar{D}^N - \bar{D}\right) + (3 - \mu_X - \mu_Y)\,K\right). \tag{A.4}$$

Note that this term is positive, indicating Kaldor-Hicks improvements, if K is small enough, which holds for a sufficiently low τ.

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