Regulating Carbon in a Small Open Economy

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Abstract

California has embarked on a bold experiment in trying to reduce carbon emissions without causing undue harm to the state's economy. The goal is made more difficult by the State's inability to erect protective tariffs to restrict imports from states and countries without costly carbon regulations. Without coordinated international action to reduce greenhouse gas emissions, this is the same problem faced by many countries, even the US: how to balance the dual goals of carbon reduction and industrial competitiveness. After reviewing the literature on this issue, this paper sets up a simple theoretical model and examines how carbon taxes or tradeable permit systems should be modified to account for the surplus loss from regulation due to carbon leakage. Several cases are considered, including a single instrument (carbon tax or permits), an emission regulation coupled with an output subsidy (as in output-based rebating), and the case where leakage also generates damage from increased carbon emissions outside the jurisdiction.

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I INTRODUCTION

A major innovation of the 2016 Paris Climate Agreement was the movement away from coordinated mutually agreed upon multilateral emission reductions by country in favor of bottom-up unilateral country-by-country voluntary pledges for emission reductions. Whether this works for managing the climate problem remains to be seen. But this decentralized approach suggests a key problem faced by countries, particularly smaller countries: how to unilaterally reduce emissions without placing domestic industry (and jobs) at a competitive disadvantage. The political economy of domestic support for environmental action requires that efforts to limit carbon emissions be individually rational (countries are not worse off by taking action) or at least, actions do not generate significant adverse outcomes for domestic jobs and income.

This paper addresses the question of how environmental regulations should be adapted to achieve the dual goals of environmental protection and preservation of jobs and economic surplus associated with domestic polluting industries. We focus on two instruments: a carbon tax and a tradeable permit system. The dual social criteria are domestic pollution damage and consumer and producer surplus. Foreign environmental damage generated by leakage associated with domestic environmental regulation is not considered (though it can be important).

When environmental regulation puts domestic industry at a disadvantage relative to foreign n competitors, the result is increased imports from unregulated jurisdictions, at the expense of domestic production. This in turn increases overall pollution with decreased domestic pollution more than offset by increased foreign pollution. This phenomenon of a reduction in domestic pollution resulting in increased foreign pollution is known as *leakage*.

There are two dimensions of leakage which are of interest to the policy community. One is environmental -- the extent to which overall (foreign and domestic) emissions and environmental damage are reduced by applying environmental regulation only domestically (with leakage attenuating the impact of domestic actions). The other dimension of concern to policymakers is the extent to which other domestic goals such as domestic value-added and employment are reduced as production activity “leaks” overseas as environmental regulations drive up domestic production costs. Much of the literature to date is concerned with the first of these two consequences of leakage – the diminishment of the environmental objectives of a regulation due to emissions increases overseas. But policymakers in a small jurisdiction are often more interested in the second of these two dimensions of the problem – local economic surplus and local incremental damage from local action. That is the subject of this paper.

II BACKGROUND

A. The Policy Context.

The threat of leakage has been of major concern in proposed or enacted regulation of carbon (a cause of climate change). The Waxman-Markey bill (The American Clean Energy and Security Act: HR 2454) passed the US House of Representatives in 2010 but failed to pass the Senate. The bill included provisions to protect domestic industries from competition from foreign unregulated jurisdictions. Figure 1 is reproduced from an EPA analysis of the bill, showing three characteristics of each of many six-digit (NAICS) industries: energy intensity, trade intensity and emissions levels. The bill sought to identify industries which might be particularly hurt by pricing carbon (a tradeable permits system in this case) and allocate extra permits to those industries. The vertical access shows the trade intensity of industries – basically how significant trade is to the industry (defined as the sum of imports and exports relative to the sum of imports and domestic production, in value terms). The horizontal axis is energy intensity, a proxy for carbon intensity (defined as the value share of energy inputs relative to sectoral output). The diameter of the circle for each industry represents the relative size of the industry, in terms of greenhouse gas emissions. The Waxman-Makey bill defines "trade vulnerable" industries as those with an energy intensity greater than 5% and a trade intensity greater than 15%. Trade vulnerable industries are given extra emissions allowances, amounting to a subsidy to those industries (since the allowances have value).

There are several things to note from this figure. One is that trade vulnerable industries constitute a relatively small fraction of total industrial sectors, at least as the NAICS is divided up. Thus much of the economy is unlikely to be directly vulnerable to leakage from carbon regulation. A second point to note is that these measures are relatively *ad hoc* though intuitive, without a rigorous basis (such as how the market would respond to an additional $1 of regulatory costs). A third point, not entirely obvious from the figure, is that it is the health of domestic industry that is more important to policymakers than the extent to which domestic greenhouse gas reductions are offset of foreign greenhouse gas increases due to leakage (as underscored in the first paragraph of Fischer and Fox, 2011).

The European Emissions Trading System (EU ETS) is similarly concerned about the domestic implications of carbon regulations:

> "To safeguard the competitiveness of industries covered by the EU ETS, the production from sectors and sub-sectors deemed to be exposed to a significant risk of carbon leakage receive a higher share of free allowances in phase 3 of the EU ETS (2013- 2020), compared to the other industrial installations."[1]

Again, the issue associated with leakage concerns injury to domestic industry from the EU ETS, not the offsetting emissions that might occur in other countries without costly carbon regulations (though it would be misleading to suggest the EU has no concern for the aggregate emissions implications of its policies).

The EU ETS approach to "safeguarding competitiveness" is similar to Waxman-Markey (though the EU ETS dates from earlier and actually went into effect). Trade exposed industries are identified and additional allowances are allocated to these industries, a form of a subsidy.

California provides an example of a significantly smaller economy (with 39 million residents and a GDP similar to Italy) attempting to regulate greenhouse gases without the legal ability to erect border controls or tariffs to protect domestic industry. California's industries are particularly vulnerable to competition from neighboring states (eg, Nevada) as well as foreign countries (eg, China). Leakage has played a significant role in the development of carbon policy in California. Critics of taking action at the

[1] From EC website, accessed 28 Nov. 2016: ec.europa.eu/clima/policies/ets/allowances/leakage_en

state level suggest that it is futile to reduce emissions in a single state because the emissions will have negligible impact on the state's climate and in addition, leakage will result in little if any global reduction in carbon emissions. Proponents of California's action suggest that the main purpose of the unilateral state action is to demonstrate that carbon emissions can be reduced without harming the vitality of the domestic economy; ie, without harming the competitiveness of domestic industry.

California took a qualitatively similar approach as Waxman-Markey and the EU ETS (also drawing on Australia's Carbon Pollution Reduction Scheme) in the sense of identifying emissions or energy intensity separately from trade exposure. The state then classified sensitive industries into high, medium and low (see Figure 2 for a selection of chosen industries). Subsidies in terms of freely allocated emissions permits (rather than having to purchase permits in an auction) were granted to the industries with higher leakage risk. The free allocation of permits is slated to decline over time.

In summary, all of the policy approaches reviewed here to deal with leakage take a similar approach. All are primarily concerned with retaining competitiveness of domestic industries and all are relatively *ad hoc* in terms of how industries are protected.

B. Theory.

The review of policy in the previous section suggests the obvious question: for a jurisdiction exposed to international trade, is there a theoretically correct way to adjust a first best emission fee or tradeable permit system to provide the optimal tradeoff between reducing environmental damage and protecting domestic industry? There are several related literatures which will not be discussed, simply acknowledged. One is the literature on optimal tariffs, though that tends to focus on market power. Another is the literature on relevant geographic and product markets, defining the extent to which industries can pass on to consumers additional costs (from monopoly rent or environmental regulation).

Although integrating environment into models of trade dates at least from the 1970s (eg, Markusen, 1975; Oates and Schwab, 1988; Krutilla, 1991), the first comprehensive treatment of the issue is by Hoel (1996). Although his paper focuses on a coalition of countries cooperating on environmental protection, it can also be interpreted as a single country emitting pollution and engaged in international trade. He develops a theoretical general equilibrium trade model with multiple traded and nontraded goods. The model also includes fuels which are an input to production but also a source of damaging carbon emissions. Focusing on one country with a consumption vector c (of traded and non-traded goods), global emissions z, net import vector m, domestic utility U(c) and domestic pollution damage E(z), the social optimum involves choosing c and z to maximize U(c)-E(z), conditional on balanced trade between foreign and domestic. Thus concern is for overall consumption as well as environmental damage, with consumption effectively national income because of the balanced trade requirement.

Hoel (1996) compares three equilibria: first-best, carbon tax couple with border taxes/subsidies, carbon tax with no border adjustments. He finds that a uniform carbon tax coupled with border adjustments can support the first best outcome. But if border adjustments are precluded, the first best is unattainable. In this case, the second best involves differentiated carbon taxes, varying from sector to sector.

Carolyn Fischer, in a series of papers with various coauthors, has addressed various aspects of second best taxation in the presence of potential leakage. In Fischer and Fox (2007) she considers the case of applying a first best tradeable permit system but providing a subsidy to domestic producers based on their goods output. The net effect is that the environmental regulation provides incentives at the margin to reduce emissions, while the output-based subsidy helps the domestic firms compete with imports. Specifically, the authors consider a tradeable permit system with the initial allocation of permits either (1) auctioned with revenue recycling (efficient emissions but leakage), (2) grandfathered, based on historic emissions (windfall rents but also leakage), or (3) allocated and updated based on output (higher marginal abatement costs but less leakage). (As in Bohringer and Lange (2005), several types of output based allocation are considered.) The authors develop an empirical general equilibrium model with trade and taxation to compare these regulatory approaches for the US. They conclude that output based allocation of permits can be designed to perform almost as well (in terms of efficiency) as auctioned permits, and considerably better than grandfathered permits. However, the paper is silent on the tradeoff between domestic consumption and emissions, the issue addressed by Hoel (1996).

In an innovative contribution to the literature, Fischer and Fox (2012) consider a two country model (home and foreign) and consider the performance of several policies designed to simultaneously address pollution and home economic activity. They look at small perturbations around a first best emissions tax and use comparative statics to determine the relative performance of four anti-leakage policies, used in conjunction with an emission tax: import tax, an export rebate, full border adjustments and output-based rebating. Rather than be specific about non-emissions objectives, they compare the performance of the four anti-leakage policies on four criteria: home goods consumption (a proxy for jobs, income and economic activity), imports, exports, and foreign own-good consumption. They derive theoretical results but also analyze these policies using a computable general equilibrium model of the US. They conclude that while full border adjustments perform best, such an approach may conflict with existing free trade agreements. Output-based rebating performs almost as well and is likely politically more tractable.

Fowlie (2012) explicitly addresses motivates the question posed in this paper: “Policymakers are looking to strike an appropriate balance between curbing domestic greenhouse gas emissions and protecting the competitive position of domestic manufacturing in the near-term” (Fowlie, 2012, p137). She then turns to developing a model which quantifies this tradeoff, particularly in the context of output-based subsidies. Her model is simple but insightful. She posits a single aggregate good from producers with linear marginal costs of production with a fixed emissions-output ratio and facicing linear aggregate demand. Foreign suppliers are characterized by a linear supply schedule. Linearity allows her to solve the model in closed form. She then posits a social welfare function which consists of consumer surplus from aggregate consumption plus producer surplus from domestic production less the costs of imports and less environmental damage, both domestically and foreign. Unfortunately she is unable to find a closed form solution to this problem, nor solve for the environmental regulation which might support the solution. Instead she develops a simulation model to examine the common criteria (see policy section above and Fig. 1) for eligibility for refunding compliance costs in full: trade exposure and emissions intensity. A striking implication of the results of the simulation model is that it is the combination of trade exposure and emissions intensity which determine which firms should receive subsidies, not the more lexicographic thresholds represented in Fig. 1. For example, her results suggest that a line from the origin of Figure 1, proceeding to the upper right would divide firms into eligible for the subsidy (above the line) or not (below the line). This suggests that the policy prescriptions that have been developed to deal with trade exposed industries need further refinement.

III. A MODEL OF A TRADE EXPOSED POLLUTING INDUSTRY

We examine an open economy producing and trading in an aggregate good. Production generates pollution, which we conveniently call carbon. Domestic output is q_d and net imports are denoted q_f, leading to aggregate domestic consumption Q and price p(Q). Domestic firms are price takers and without loss of generality, we treat producers as making joint price-taking production decisions. There are no border adjustments and we will consider two policy instruments: an emissions tax on domestic emissions, τ, and a subsidy to domestic output, σ. As in Fowlie (2012), domestic welfare is defined as consumer surplus from consumption plus producer surplus from domestic production, less the cost of imports and less environmental damage, assumed proportional to emissions, e (δ per unit emissions). Initially we will only be concerned with damage from domestic emissions. This runs counter to the fact that a domestic environmental regulation may result in leakage which will increase foreign emissions which will in turn damage the domestic environment. However, as was discussed earlier, much of the policy discussion dismisses the environmental consequences of leakage-induced foreign emissions.

We will examine several types of regulations – emission taxes alone, emission taxes with an output subsidy. Results will then be extended to tradeable permit systems. Finally, the case of foreign damage will be considered.

Let production costs for domestic production be given by C(q,e), a constant returns cost function ($C_q>0$, $C_e<0$, $C_{qe}<0$). Further, let e be domestic emissions and δ environmental damage per unit of emissions. Costs can also be written in terms of the unit cost function $C(q,e) = q\, c(\varepsilon)$ where $\varepsilon=e/q$, the emissions output ratio. Note that $c' < 0$ and $c'' > 0$, from the assumptions on C. Define social welfare as the following

$$W = {}_0\int^{Q} p(x)dx - C(q_d,e) - p(Q)q_f - \delta e \qquad (1)$$

In all of the cases we will consider, our goal is to maximize welfare, subject to market constraints (ie, how firms respond to a decentralized regulation) and import supply ($S'>0$)

$$q_f = S(p(Q)) \qquad (2)$$

which implies (since q_f is not chosen directly but follows from the choice of q_d)

$$dq_f = S'p'(dq_d + dq_f)$$

$$\Rightarrow \quad dq_f = [S'p'/(1-S'p')]dq_d \qquad (3)$$

Note that the term in brackets is negative, since domestic production and imports move in opposite directions.

To determine the optimal domestic production and emissions, solve $\partial W/\partial q_d=0$, $\partial W/\partial e=0$, and Eqn. (2), recognizing that q_f is a function of q_d. The result is

$$p(Q) = C_q + [p' q_f/(1-S' p')] \qquad (4a)$$

and

$$C_e = - \delta. \qquad (4b)$$

In other words, price equals marginal revenue when demand is elastic. When there is some slope to demand, a wedge is driven between marginal cost and price, resulting in higher marginal cost and thus more domestic production (the term in brackets in Eqn. 4a is negative). Secondly, note that marginal cost of emission control equals marginal damage. Secondly, marginal cost of domestic production should be greater than price. This implies that domestic production is greater than in the case of elastic demand, and as a consequence, imports lower and emissions greater.

<u>Result #1:</u> In balancing domestic surplus and environmental damage, when there is some slope to domestic demand, it is desirable to expand domestic production so that marginal cost exceeds price, though marginal conditions on emissions will remain unchanged (marginal abatement costs equated to marginal damages). However, emissions will be higher than the case when demand is perfectly elastic.

The simple interpretation is that because domestic production produces valuable surplus, it is desirable to increase domestic production above what would be associated with efficiency (price equals marginal cost).

Clearly, this outcome can be supported by a combination of emission taxes (equal to marginal damage) and per unit production subsidies (equal to the negative of the last term in Eqn 4a). But we do not know if that outcome is budget balancing or not. One suspects that "it depends." We thus turn to several alternative regulatory approaches.

A. Emission tax alone

We now consider the case of an emission fee but without any output-based or other kind of subsidy. We would expect that the dual objectives of emission reduction and protection of domestic industry would not be attainable with a single instrument. Our approach to examining this question will be to first determine how domestic industry will respond to an arbitrary emission fee, τ. The second step is to examine the welfare implications of different fee levels. Ideally we would like to determine the optimal second-best fee. But that turns out to be difficult, so we will confine the analysis to identifying an interval for that second best fee.

Because costs, C, are constant returns, we can simplify the model by substituting $\varepsilon=e/q_d$, which is the emissions-output ratio. Costs become $q_d c(\varepsilon)$, welfare becomes

$$W = {}_0\int^Q p(x)dx - q_d c(\varepsilon) - p(Q)q_f - \delta q_d \varepsilon \qquad (5)$$

and profits for industry can be simply stated as

$$\Pi = \{p(Q) - c(\varepsilon) - \varepsilon\tau\}q_d \qquad (6)$$

for which first order conditions are

$$\partial \Pi / \partial q_d = p(Q) - c(\varepsilon) - \varepsilon\tau = 0 \qquad (7a)$$

$$\partial \Pi / \partial \varepsilon = - q_d \{c'(\varepsilon) - \tau\} = 0 \Rightarrow \tau = -c'(\varepsilon) \qquad (7b)$$

We can totally differentiate these two equations to obtain

$$P'(Q)\, dQ - c'(\varepsilon)\, d\varepsilon - \varepsilon\, d\tau - \tau\, d\varepsilon = 0 \qquad (8a)$$

$$d\tau + c''\, d\varepsilon = 0 \qquad (8b)$$

These two equations plus Eqn. (3) can be solved for

$$dq_d/d\tau = \varepsilon(1-S'p')/\, p' < 0 \qquad (9a)$$

$$d\varepsilon/d\tau = - 1/c'' < 0 \qquad (9b)$$

and $$de/d\tau = d\,(\varepsilon\, q_d)/d\tau = \varepsilon' q_d + q_d'\, \varepsilon < 0 \qquad (9c)$$

These are the qualitative results one would expect: an emission fee reduces domestic production and domestic emissions.

Differentiating Eqn. (5), treating qd and ε as functions of τ, yields, with some simplifying

$$W' = p(Q)\, Q' - q_d\, c'\varepsilon' - cq_d' - p'S'Q' - pS'P'Q' - q_d\delta\varepsilon' - \varepsilon\delta q_d'$$

$$= -\{p'S'/(1-S'p')\, q_d' + (\tau - \delta)\, e' \qquad (10)$$

If one sets W'=0, it is not clear how to derive a closed form solution for τ from Eqn. (10). What we can do however is examine the sign of W' at $\tau = 0$ and $\tau = \delta$. Since the first term in Eqn. (10) is unequivocally negative, this implies $W'|_{\tau=\delta} < 0$. This is intuitive. With no gain from domestic production, the emission tax would be set at δ. With even a modest gain from reducing τ, the optimal τ must be less than δ. For $\tau = 0$, the sign of W' is ambiguous. The first term in Eqn. (10) is the slope of the marginal imports with respect to emission tax function (from Eqn. 3). If this is particularly strong (an increase in τ from $\tau = 0$ leads to a very significant drop in domestic production), then a negative emission tax may be appropriate.

> Result #2. With an emission tax alone, it is efficient to tax emissions at a level lower than marginal damage. We cannot conclude that the second-best emission tax should even be positive.

B. Emission Tax with Output Subsidy

We now consider the case of an emissions tax which is rebated to firms as an output subsidy. Firms do not see the connection between these actions and thus the incentives for pollution reduction are not diluted by the fact that the revenue get rebated. Furthermore, we assume all of the emissions fee revenue is rebated. It would be more realistic, but more complicated, to relax this budget constraint. As in the previous section, we can simplify the model by substituting $\varepsilon = e/q_d$, which is the emissions-output ratio.

The regulatory instruments we will use are an emissions tax, τ, and an output subsidy, σ. By construction, we require that

$$\sigma q_d = \tau e \Rightarrow \sigma = \tau \varepsilon \qquad (11)$$

In order to determine the magnitude of the tax/subsidy, we take two steps: first determine how industry will respond to arbitrary taxes and subsidies; and then determine the welfare maximizing tax and subsidy.

Profit for industry are thus:

$$\Pi = \{p(Q) – c(\varepsilon) – \varepsilon\tau + \sigma\}q_d \quad (12)$$

for which first order conditions are

$$\partial\Pi/\partial q_d = p(Q) – c(\varepsilon) – \varepsilon\tau + \sigma = 0 \Rightarrow p(Q) – c(\varepsilon) = 0 \quad (13a)$$

$$\partial\Pi/\partial\varepsilon = - q_d\, c'(\varepsilon) – qd\tau = 0 \Rightarrow \tau = -c'(\varepsilon) \quad (13b)$$

Note that Eqn 11 allows the final simplification in Eqn. 13a. In fact Eqn. 13a can also be written as

$$P(Q) – C_q(q_d,\varepsilon) - \varepsilon\, c' = 0 \quad (14)$$

which states that faced with the tax and subsidy, the firm will produce such that marginal cost is greater than price, expanding output (which is what a subsidy on output would be expected to achieve). Eqn. (13) defines the choices that the domestic firms will make. In order to fine the second-best welfare maximizing emission tax and subsidy, we need to total differentiate Eqn. (13) and use Eqn (3) to eliminate dq_f. Doing so, results in two equations in two unknowns: $dq_d/d\tau$ and $d\varepsilon/d\tau$, which we denote as q_d' and ε' respectively:

$$q_d' = -c'(1-S'p')/(c''p') < 0 \quad (15a)$$

and $$\varepsilon' = - 1/c'' < 0 \quad (15b)$$

Note also that because $e = \varepsilon q_d$, we have

$$e' = \varepsilon' q_d + q_d' \varepsilon < 0 \qquad (16)$$

Thus as the emission tax increases, domestic production unequivocally declines, despite the fact that revenue is recycled. Furthermore, emissions decline as do emissions per unit of output.

> Result #2: When domestic emission fee revenue is rebated based on output, then a positive emission tax still results in leakage (imports substituting for reduced domestic production), though more modest than if the revenue were not rebated.

We now turn to the optimal second best tax, again assuming that all revenue is output-based rebated. This means there is effectively one policy instrument, τ, and we are interested in the level that maximizes welfare. First, totally differentiate Eqn. (5) and divide through by dτ; the prime marks below on a variable x means dx/dτ:

$$W' = p(Q)\, Q' - q_d c'\varepsilon' - c q_d' - p'SQ' - pS'P'Q' - q_d\delta\varepsilon' - \varepsilon\delta q_d'$$

$$= -\{p'S/(1-S'p') + \varepsilon\delta\} q_d' - q_d\varepsilon'(\delta-\tau) \qquad (17)$$

It is difficult to set Eqn. (17) to zero and solve for an optimal τ. What we can do is evaluate W' at τ=0 and τ=δ, corresponding to no regulation and a standard Pigovian fee. Even evaluating W' at these two extremes fails to yield definitive conclusions. The bottom line seems to be that the two terms in brackets in Eqn. 17 are pulling in opposite directions. The first involves the elasticity of supply of foreign goods with respect to an emission fee and the second is how marginal environmental damage changes with the emission fee.

C. Tradeable Permits.

The cases examined here involved an emissions fee rather than a tradeable permit system. We know these are generally equivalent so can infer how a tradeable permits system would work. For the case of an emission fee alone, we concluded that the optimal emission fee should be set below marginal damage, resulting in more emissions than the Pigovian level. This is equivalent to auctioning more permits than is efficient, resulting in a market price that is below marginal pollution damage.

The case of emissions rebated in proportion to output is a natural for a tradeable permit system. Either the permits can be freely allocated based on output or if auctioned, the receipts from the auction can be rebated in whole based on output to producers.

D. Environmental Damage from Foreign Production

TBD….

IV. CONCLUSIONS

The problem treated by this paper is a very real one in environmental regulation: how to achieve the proper balance between environmental objectives and standard economic wellbeing. The issue is particularly sharp for a global public good such as carbon, particularly considering how controlling carbon is developing. Individual countries or jurisdictions are unilaterally regulating carbon emissions. Not surprisingly, a big issue is how to shape regulations so that emissions are reduced, though at the same time avoiding leakage which can injure the domestic economy and the jobs and income that everyone depends upon.

We have shown that if one is using an emissions tax or a tradeable permit system, with no subsidies to output, then it is desirable to set an emission fee lower than the marginal damage from pollution; with a tradeable permit system, it is optimal to release more permits than otherwise might be desirable, in order to drive the market price of tradeable permits below marginal environmental damage.

Although policy makers are seeking clear guidance regarding how to structure regulations which take into account these dual and usually conflicting goals. This paper has not be able to satisfactorily offer at guidebook for regulating a pollution such as carbon. What this paper has sought to provide is a framework for analyzing the problem. For empirical implementation, the theoretical models presented here must be estimated or calibrated.

One issue that remains is measuring the strength of the opposing goals of environmental protection and economic security. We have seen that the extent to which an emission fee encourages leakage vs. reduces emissions can play a major role in determining the optimal balance between these goals. Better and intuitive quantification of this sensitivity would be a useful addition to the literature.

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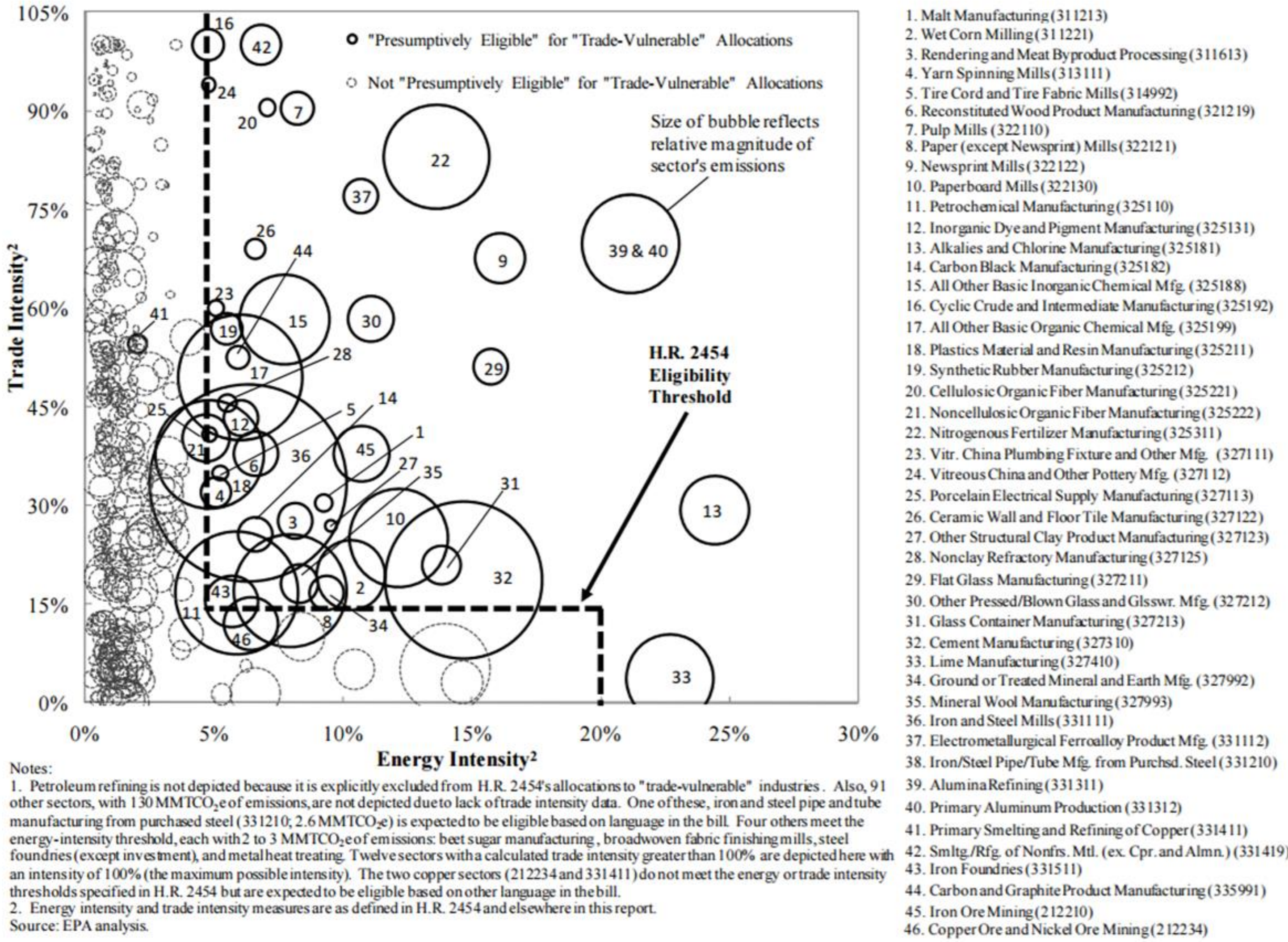

Figure 1: Energy Intensity and Trade Intensity in Waxman-Markey Bill

Source: EPA (2009), Figure 2.

Figure 2: California Determination of Leakage Risk

Source: Table K-7 from Air Resources Board Staff Report on AB32, dated Oct. 28, 2010.

NB: TE = Trade Exposure

Leakage Risk	ARB Classification	NAICS code	Emissions Intensity	TE
High	Oil and gas extraction	211111 211112	Medium	High
	Soda ash and mining mfg	212391	Medium	High
	Reconstituted wood product mfg	321219	Medium	High
	Paper manufacturing	322121	Medium	High
	Paperboard manufacturing	322130	Medium	High
	All other basic inorganic chemical mfg	325188	Medium	High
	Flat glass manufacturing	327211	Medium	High
	Container glass manufacturing	327213	Medium	High
	Cement manufacturing	327310	High	Medium
	Lime manufacturing	327410	Very high	Low
	Iron and steel mill	331111	Medium	High
Medium	Food manufacturing	311	Low	Medium
	Breweries	312120	Low	Medium
	Cut and saw apparel mfg	3151	Very low	Very high
	Sawmills	321113	Low	High
	Petroleum product manufacturing	324	Medium	Medium
	Pesticide and agricultural chemical mfg	325230	Low	High
	Polystyrene foam product mfg	326140	Low	Medium
	Gypsum product manufacturing	327420	Medium	Low
	Mineral wool manufacturing	327993	Medium	Medium
	Metal processing	331X	Low	High
	Turbine and turbine generator set units mfg	333611	Low	High
Low	Pharmaceutical and medicine mfg	325412	Very low	High
	Aircraft manufacturing	336411	Very low	High