VIII.13 Prices versus quantities

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Abstract

Price instruments and quantity instruments are similar market policy mechanisms to reduce pollution. Both types of instruments impose a price on each unit of emissions, creating a marginal cost of emitting, and seeking to internalise costs of pollution. Both decentralise emissions abatement decisions and devolve them to the emitters themselves, minimising adjudication. Both minimise overall abatement costs by sorting polluters by marginal abatement cost, and diverting emissions reduction efforts to those that can make reductions at lower costs. However, the instruments differ in terms of their emphases. A quantity instrument seeks to maintain some quantity of emissions, while potentially allowing the price of emissions permits – the mechanism for enforcing a quantity limit – to fluctuate. A price instruments seeks to maintain a constant price of emissions through some unitary tax – the mechanism for enforcing an emissions price – while potentially allowing the quantity of emissions to fluctuate.

Keywords

Climate change, carbon tax, emissions tax, cap and trade, market mechanisms, emissions trading

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VIII.13.1 Introduction

At the same time as a revolution was taking place in environmental law – mostly in the United States, and mostly in the 1960s and 1970s, but in other countries and times as well – environmental economists were quietly pursuing their own revolution. Most environmental laws of that era were written by lawyers, who viewed pollution as a matter of administrative law, with enforcement taking place in legal venues and at the initiation of regulatory agencies such as the newly-formed US Environmental Protection Agency (EPA). Environmental economists viewed pollution as primarily an economic matter, with government involvement limited to the setting of a single, over-arching optimal environmental standard, reflecting a trade-off of the harms of pollution against the benefits of the underlying market activity.

Within this somewhat over-simplified economic perspective, there remains the question of the nature of the single over-arching environmental standard. *Pollution, Property and Prices: an Essay in Policy-Making and Economics* by John H Dales,[1] and *The Economics of Welfare* by AC Pigou have served as guideposts for environmental economists.[2] Pigou's idea was to *tax pollution* so as to internalise the marginal social cost of that pollution. An emissions tax is a tax levied per unit of pollution emitted. A 'Pigouvian' tax is a tax on an underlying market activity that produces emissions, equal to the marginal environmental harm produced by that activity. Dales's idea was to establish a pollution permit trading system, within which polluters would trade amongst themselves to determine which firms should be able to pollute, and how much and when. Both Pigou and Dales would de-emphasise the traditional mode of regulation: regulating pollution source-by-source or emitter-class-by-emitter-class, as the legal mandates of the United States federal statutes of the 1970s tend to do. What would be left for governmental mandate was either the level of the Pigouvian tax, or the *price* of pollution, or in the alternative, the *quantity* of allowable total pollution under a pollution permit trading system. This is the question, within the economic perspective, of whether a pollution problem is best addressed by a price instrument or a quantity instrument.

Pigou's fundamental contribution was a theoretical framework by which negative externalities could be internalised. Externalities are nothing more than the divergence of private and public costs stemming from a single action.[3] By pricing external costs through a Pigouvian tax, polluters are made to include consideration of social costs in their own private abatement decision, inducing a socially optimal level of pollution in a purely private decision environment. Dales's fundamental insight was that pollution abatement costs tend to be heterogeneous across facilities, firms, and over time. Given cost heterogeneity, overall pollution abatement costs might be minimised if permits to pollute were freely traded, so that permits could flow to those firms and facilities for which the abatement cost would be the greatest. In a well-functioning market, emissions reductions would be undertaken by those for which abatement is the least expensive, who would be *net sellers* of pollution permits; those for which abatement would be most expensive could be spared the cost, and would be *net buyers* of tradable pollution permits.

Within the world of market mechanisms, the work of Pigou and Dales help frame a fundamental instrument choice question: whether to adopt a 'price instrument' through a Pigouvian tax, or a 'quantity instrument' through a Dalesian quantity instrument. Over time, these simple theoretical ideas have developed variants out of political and administrative necessity, which have blurred distinctions and sometimes detracted from the environmental and economic advantages of market mechanisms. That said, a juxtaposition of price instruments with quantity instruments is useful for comparing the administrative and welfare implications.

A Pigouvian price instrument resembles a Dalesian quantity instrument in several

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[1] Dales (1968).

[2] Pigou (1920) 131–35. Taxes that reflected the extent of negative externality thus became known as 'Pigouvian' taxes: Baumol and Oates (1988) 21–23.

[3] An externality is an effect of a decision, on a party other than the decision-maker, that the decision-maker does not consider: Hsu (2004) 341 fn 157.

ways. First, both Pigouvian taxes and emissions trading systems seek to internalise the negative externalities of polluting. In the case of Pigouvian taxation, the price paid is the tax rate, set by legislation or regulation; in the case of emissions trading, the price paid is the going market price for permits. There is no guarantee, of course, that the tax rate or the total amount of emissions allowed is socially optimal; the theoretically optimal tax rates or emissions levels are rarely achieved in practice.

Second, both a Pigouvian price instrument and a Dalesian quantity instrument theoretically achieve a *sorting* of polluters by marginal abatement cost, in the sense that they both seek to take advantage of abatement cost heterogeneity among polluters. Under a quantity instrument, market trading should produce an equilibrium such that all of the tradable permits have been purchased by polluters that have higher abatement costs. No polluter with a private abatement cost higher than the equilibrium permit price should be lacking in permits; otherwise there would still be a sale to be made by a low-cost abater to a high-cost abater. Under a Pigouvian price instrument, polluters with lower marginal abatement costs will reduce emissions, and those with higher marginal abatement costs will not. Both instruments concentrate emissions reductions among those with the lowest abatement costs.

Third, in both instruments a *price* exists, in the sense that polluters are assured of some non-administrative cost being imposed. Some have argued that regulatory mandates are prices, in the sense that they are costly. However, there is a critical difference between a *price* and a *cost.* Prices are either determined by market activity (in the form of trading), or set in advance by legislative or regulatory policy; in either case there is some transparency and predictability. By contrast, regulatory costs impose a potentially critical degree of uncertainty; even timely and efficient administrative proceedings imposing small costs introduce a level of uncertainty and delay that can disrupt private investment decisions for pollution abatement. While Pigouvian taxes state in advance the price of a unit of pollution, presumably robust markets for tradable pollution permits provide notice of the price of a permit (corresponding to a unit of pollution). At bottom, both Pigouvian price instruments and Dalesian quantity instruments involve pollution 'prices'. Such market-centred prices are *not* determined by an administrative agency, and decentralise decisions about emissions reductions so that private firms are given considerable autonomy.

Fourth, public control over emissions decisions is reduced to one central decision: in the case of emissions trading, the total quantity of permits allowed, and in the case of Pigouvian tax rate, the tax rate for emissions. Both instruments contemplate a devolution of abatement decisions, away from administrative agencies to emitters. Rather than having administrative agencies decide, through rulemaking and policy, how much polluters can emit, the polluters themselves have a considerable amount of autonomy to decide, through market decisions, how much to pollute and when.

Finally, because both instruments impose a marginal cost on polluting, they introduce an incentive to reduce emissions in innovative ways that might not have been the specific course mandated by agency regulators. The extent to which this has actually occurred, and to which innovation has been spurred by market mechanisms is the subject of some debate,[4] but it is incontrovertible that this incentive is greater than it is under the

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4 Kerr and Newell (2003).

clumsier, administratively-centred methods of regulation, if not the more flexible and enlightened modern versions.[5]

The market emphasis propounded by Dales and other economists has taken on increasingly greater prominence in environmental law and policy. Market mechanisms such as emissions trading schemes have come to be the presumptively favoured means of regulating. The Montreal Protocol to phase out ozone-depleting substances,[6] the sulphur dioxide emissions trading system under the Acid Rain reduction programme in the United States,[7] and the Kyoto Protocol to reduce greenhouse gas emissions under the United Nations Framework Convention on Climate change,[8] and the European Union (EU) Emissions Trading System (ETS), the emissions trading programme instituted by the EU to comply with Kyoto, are all examples of market mechanisms drawing inspiration from Dales's original idea. The US House of Representatives narrowly passed legislation in 2009 to institute a cap-and-trade programme for greenhouse gas emissions in the United States. Commonly referred to as 'Waxman-Markey' for its House and Senate sponsors, the bill failed to advance in the US Senate, and ultimately failed to become law.

A number of taxing instruments now exist throughout the world. Broadly speaking, some form of a carbon tax exists (or is scheduled to come into effect) in 26 countries.[9] Norway, Sweden, Denmark, and Finland all enacted national carbon taxes between 1990 and 1992, leading the way. Following the European example, several jurisdictions in the Americas have followed with carbon tax-like policies. Mexico, Costa Rica, Chile, and the Canadian province of British Columbia have instituted carbon taxes that do not necessarily conform to the Pigouvian ideal, but nevertheless succeed in placing some marginal price on carbon dioxide emissions. Taxes on pollutants other than carbon dioxide also exist. In Europe, taxes are levied on the production or consumption of a broad range of goods with negative environmental effects, such as coal and coke, natural gas, kerosene, heavy fuel oil, mineral oil and, electricity.[10] Scandinavian countries impose taxes on nitrogen oxides (NOx) and SO_2.[11] Sweden rebates NOx tax proceeds in proportion to energy output, offering at once carrots to firms that are able to reduce NOx emissions and punishing those that do not.[12] Whereas a pure Pigouvian tax is simply the tax, the Swedish NOx tax is a variant in its recycling of revenues back to producers, presumably to blunt some of the political opposition to the tax.

Roughly speaking, 25 true carbon emissions trading programmes (also known as 'cap-and-trade programmes') exist (or are planned) worldwide.[13] They range in size from the European Union Emissions Trading System (EU ETS), which applies to more than 11,000 emitters in 28 EU Member States responsible for about two gigatons (Gt)

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5 Hsu (2004).

6 Montreal Protocol on Substances that Deplete the Ozone Layer, 1522 UNTS 3, 26 ILM 1550 (1987).

7 Clean Air Act s 404 et seq., 42 USC s 7651c et seq. (1990).

8 The Kyoto Protocol to the United Nations Framework Convention on Climate Change, UN Doc FCCC/CP/1997/7/Add 1 Dec 10, 1997, 37 ILM 22 (1998).

9 World Bank and Ecofys (2018) 8.

10 ibid 4.

11 Jean-Phillppe Barde (2005) 8–11.

12 Smith (1998) 70–73.

13 World Bank and Ecofys (2018) 8.

of CO_2-eq emissions (this includes the United Kingdom, which will be exiting the EU, but may remain subject to the EU ETS),[14] to the Swiss Emission Trading System, which applies to only 55 emitters responsible for only five megatons (Mt) of emissions.[15] China has declared plans to launch a cap-and-trade system that would cover about four Gt of emissions, which would be twice as large as the EU ETS and greater than all existing carbon markets combined.[16] In the United States, the Regional Greenhouse Gas Initiative, or 'RGGI', is a cap-and-trade programme for electricity generators in nine north-eastern states.[17] The nine states effectively represent a single market for emissions permits, which electricity generators must hold in order to emit greenhouse gases. A cap-and trade programme also exists between the State of California and the Canadian province of Quebec, creating a multi-jurisdictional, multi-national (and bilingual) cap-and-trade programme.[18] The neighbouring province of Ontario, Canada's most populous, has also announced that it will join the California-Quebec programme.[19]

Pigouvian taxes and emissions trading, even as they both stand in contrast to administratively-centred regulation, are different in one important and fundamental way. Pigouvian taxes set the pollution price, and thus only indirectly set the total quantity of emissions; emissions trading sets the total pollution quantity, and thus only indirectly sets the price (Figure VIII.13.1). Pigouvian taxes are thus considered 'price instruments' and emissions trading programmes 'quantity instruments'. Whether a pollution problem is better addressed by Pigouvian taxes or emissions trading may have very significant welfare implications.

VIII.13.2 Prices versus quantities in the presence of uncertainty

In the absence of uncertainty and enforcement problems, the theoretical differences between price instruments such as taxes and quantity instruments such as emissions trading programmes are small. However, uncertainties abound in pollution problems. Regulators are likely to have imperfect information about the benefits and the costs of pollution abatement, and perhaps other factors that might affect instrument choices, such as enforcement issues.

Any comparison of price versus quantity instruments must begin with Martin Weitzman's seminal 1974 paper, 'Prices vs Quantities',[20] which examined the welfare implications of uncertainty about the marginal cost of pollution abatement. Imagine that a regulator could either set a tax (a price instrument) or a quantity restriction (quantity instrument) based upon its best knowledge of the marginal abatement cost and marginal abatement benefit (ie, avoiding environmental harm) curves, either taxing at the level or restricting quantity to the level at which the marginal benefit is equal to the marginal cost. But now imagine that the marginal cost curve is higher or lower than

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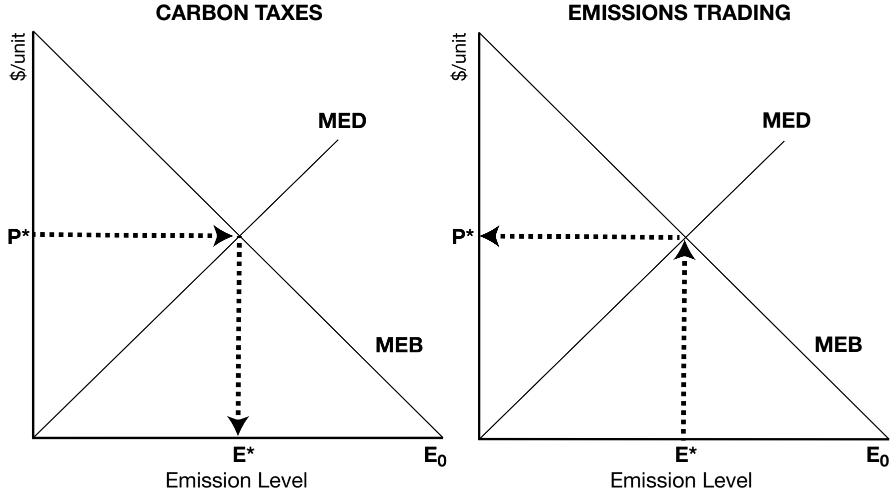
14 International Carbon Action Partnership (2015) 29.
15 ibid 31.
16 Swartz (2016) 7.
17 Regional Greenhouse Gas Initiative, 'Program Overview' (Regional Greenhouse Gas Initiative) <https://www.rggi.org/program-overview-and-design/element> accessed 13 April 2018.
18 ibid.
19 Martell and De Souza (2015).
20 Weitzman (1974).



Note: P = Price; MED = Marginal Emissions Damage to the environment; MEB = Marginal Emissions Benefit (ie, the economic value to polluters of being allowed to emit). The MEB is simply the mirror image of the Marginal Abatement Cost Curve (MACC).

Source: Conway and others (2017) 34.

Figure VIII.13.1 Carbon taxes vs ETSs

expected. Weitzman shows that when the marginal abatement cost curve is 'flat' – that is, if all of the abatement opportunities are similar in cost – then a quantity restriction (cap-and-trade) is preferable because the deadweight loss – the economic cost of a misallocation of resources – from the regulator's mistake is much larger when she sets the tax level incorrectly than when she sets the quantity incorrectly.[21] The intuition is that if the tax is set incorrectly, there could be a very large over-abatement or under-abatement, because of the ready substitutability of abatement opportunities. Put another way, if the marginal cost curve is 'flat' relative to the marginal benefit curve, that means that the marginal environmental harm is increasing rapidly, so that allowing another increment of pollution could be very harmful; under those circumstances controlling quantity could be more important. This is illustrated in Figure VIII.13.2a, in which the marginal abatement costs are lower than expected.

On the other hand, if the marginal cost curve is 'steep' – that is, if abatement opportunities are fairly heterogeneous in cost – then a price regulation (tax) is preferable. The intuition for this is that when the abatement level is mistakenly set too high, the resulting over-abatement will be very costly, requiring polluters to undertake some much more

21 A deadweight loss is the cost of having too much or too little of a market activity. In the case of too much of a market activity, a deadweight loss occurs when an increment of that activity creates less benefit than it does costs, so that a curtailment of that activity would be, on net, beneficial. In the case of too little of a market activity, a deadweight loss occurs when an increment of that activity creates more benefit than it does costs, so that an increase in that market activity gives rise to a more economically efficient state. See, eg, Tietenberg and Lewis (2018) 26.

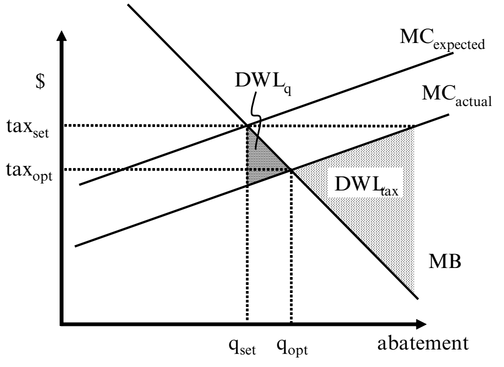


Figure VIII.13.2a Flat marginal cost, steep marginal benefit

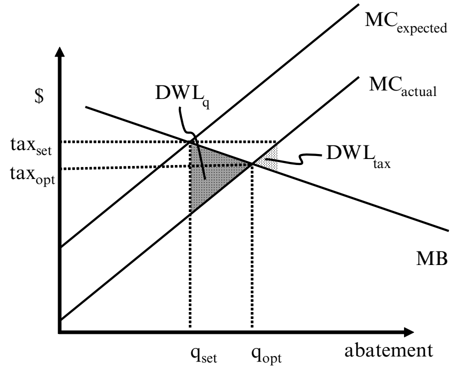


Figure VIII.13.2b Steep marginal cost, flat marginal benefit

expensive abatement measures; if the abatement level is set too low, some very valuable opportunities are missed in which the marginal abatement cost would be far below the marginal environmental benefit. Put another way, with a marginal abatement cost curve that is steep relative to the marginal benefit curve, it is less risky to set the tax incorrectly because mispricing the tax amount would not cause a very large over- or under-abatement. This is shown in Figure VIII.13.2b, again with the marginal abatement costs lower than expected.

The price versus quantity debate has taken on greater importance in light of the worsening problem of climate change. Some environmental organisations have gravitated towards quantity instruments, in the form of cap-and-trade, on the grounds that the costs should be assumed by polluters, and not individual consumers and households. However, this view generally overlooks the possibility that costs imposed on polluters may ultimately be passed on to end consumers, depending upon the elasticities of substitution.

Some environmental organisations have also supported quantity instruments on the ground that it is more important to achieve a certain amount of greenhouse gas reduction each year than it is to ensure cost-minimisation of emissions reductions. However, this overlooks the nature of capital decisions, and the interconnectedness of abatement cost and abatement behaviour. The reality is considerably more complex.

The global financial crisis of 2008 and 2009 provides an example of the interlocking cost and environmental advantages of a carbon tax over cap-and-trade. With the dramatically reduced global economic activity stemming from what has come to be known simply as the 'Financial Crisis', carbon dioxide emissions plunged globally. United States emissions alone fell 6.6 per cent.[22] Emissions in the EU fell 7.2 per cent.[23] Prices for auctioned allowances under the Regional Greenhouse Gas Initiative, a regional cap-and-trade programme for electricity generation units in an amalgam of nine North-eastern US states, dropped by 30 per cent in the three-month period between auctions, from June to September of 2009.[24] The problem with a quantity instrument is that 2009 would have been a completely missed opportunity – with, say, United States or European emissions already under any emissions cap, there would have been no incentive for any carbon dioxide polluter to reduce emissions, or to innovate in ways to reduce emissions. But with a tax – a price instrument – in place, there would have been a continuing incentive to reduce emissions and innovate.

It is also possible to make the flipside of this argument: that in times of strong economic growth, a quantity limitation would more tightly constrain emissions, and the relatively high price of emissions permits would create a *greater* incentive to innovate. A choice between prices and quantities in the presence of uncertainty thus turns, unsurprisingly, on the extent and nature of the uncertainty. Even in well-studied and highly-regulated industries, such as electricity production, the true economic environment is somewhat difficult to discern, and it is extremely difficult to estimate a range of marginal abatement costs, let alone evaluate whether the marginal abatement cost curve is 'flat' or 'steep' relative to marginal benefits. If understanding marginal abatement costs – which can at least be clearly expressed in monetary terms – is difficult, then marginal benefits, pertaining as they do to human health and ecological benefits, are even harder to estimate. Rather, the value of Weitzman's analysis lies in its juxtaposition of costs and benefits, and its illustration of the relative strengths and weaknesses of price versus quantity regulation in the presence of various forms of uncertainty. So, for example, if damages – and hence the marginal abatement benefits – are relatively 'flat', as they are in the case of a stock pollutant like carbon dioxide, with atmospheric residency times in excess of a century,[25] then a carbon tax is likely to lead to lower distortions in the case of uncertainty.[26] Emissions in any single year, affecting only a small portion of the stock of pollution, are less important. On the other hand, if one suspects that certain 'tipping points' are near, beyond which certain grave irreversibilities may result from additional emissions,[27] then a quantity instrument may be preferable.[28] These are not hard-and-fast rules, but only some principles that arise from the original Weitzman framework.

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22 United States Energy Information Administration (2013) ES-4 (Fig ES-1).
23 ClimateWire (2011).
24 Gronewald (2009).
25 United Nations Intergovernmental Panel on Climate Change (2013) 59 (fig TS-8).
26 See, eg, Pizer (2002); Newell and Pizer (2003); Karp and Zhang (2005).
27 Lenton and others (2008).
28 Goulder and Schein (2013).

VIII.13.3 Variants of price instruments and quantity instruments

As noted above, political and administrative realities, including but not limited to enforcement and monitoring issues, have intruded upon the elegance of both price and quantity instruments in their ideal implementations. This is not to say that these variants are inferior, though in many cases they are. This is to point out that comparisons between price instruments and quantity instruments can be somewhat inapposite, depending on how closely they adhere to theoretical constructs.

A 'pure' emissions trading system imposes a fixed quantity of total emissions, or a 'cap', allowing trading to take place under that cap, giving rise to the term 'cap-and-trade'. In contrast to this relatively closed system, some variants contemplate what is essentially a moving cap. In the 1970s, the EPA instituted some regulatory initiatives to introduce some flexibility for air pollution emitters. The EPA's 'netting' rule allowed firms to trade credits so that a firm could emit more as part of a change in technology. Also, as part of this 1970s initiative, the EPA's 'offsets' rule, allowed new polluting sources to begin operations only if they had obtained similar emissions reduction credits. For example, credits could be generated by a project or action that supposedly decreased emissions, such as a plant shut-down, a pollution abatement project, or, more speculatively, a programme to retire old automobiles or a transit programme to displace automobile travel.[29]

In addition to placing adjudicatory control under the EPA – the EPA was needed to approve any netting or offset transactions – these EPA initiatives did not contemplate any particular cap, but rather viewed emissions trading as an exercise in improving upon baseline emissions. That is, the EPA viewed its regulatory objective as reducing emissions at the margins, project-by-project, and not with any overarching emissions objective, and no set cap.

As another example of an emissions trading variant, the Canadian province of Alberta, the first North American jurisdiction to develop a greenhouse gas policy, instituted an emissions trading programme that allowed emitters to earn emissions credits by reducing emissions *per unit of output*. Alberta thus regulated not the absolute quantity of emissions, but the *emissions intensity* of its greenhouse gas emitters. Alberta's controversial oil sands industry has been able to dramatically increase their production efficiency over the past several decades, managing to emit less while producing more crude oil. While oil sands producers emitted more greenhouse gases, they produced *much* more crude oil, thereby staying ahead of their emissions intensity targets. By increasing production efficiency, oil sand producers were thus able to essentially raise their cap. And to underscore the artificiality of the distinction between price instruments and quantity instruments, the Alberta programme originally provided for a price 'ceiling' for emissions in the form of an opportunity to contribute, in lieu of obtaining an emissions permit, \$15 Cdn per ton of CO_2 into a provincial fund for the promotion of emissions reduction technologies. In that sense, the Alberta programme, as originally conceived, might well have been considered more of a tax than a quantity instrument.

These variants are thus not 'pure' quantity instruments, because they do not actually set the total quantity of emissions. By allowing increases in emissions in exchange for

[29] Hsu and Sperling (1994).

some other supposedly positive outcomes – reduced emissions elsewhere, or increased productivity – these variants introduce the possibility of leakage into or out of what would be, in a true cap-and-trade programme, a closed system. The problem with such programmes is that the external emissions reductions benefits may or may not truly materialise.

A closer look at offset programmes serves as an example. Offsets need not be as ad hoc as the EPA offsets rule noted above.[30] Rules can and have been developed to try and ensure that a claimed emissions reduction was truly 'additional': that the emissions were certain to occur and that the emissions reduction would not have occurred but for the granting of an emissions reduction credit, or offset.[31] The underlying problem is that there is rarely a clear counterfactual for the project, in which the emissions of an alternative world without the project could be measured and used as a baseline. Any entrepreneur can make a plausible argument for a baseline emissions level, and how even a sham project would improve upon it. Offset programmes in the past have rewarded misleading arguments for a particular baseline. For example, the emissions trading scheme contemplated by the Kyoto Protocol included an offset programme, the Clean Development Mechanism (CDM), in which emitters in developed countries could purchase credits towards emissions reductions if they sponsored some project in a developing country that *had the effect of an emission reduction*. The problem was determining whether or not claimed emissions reductions were truly 'additional'. Several studies looked at specific approved CDM projects, and raised very substantial doubts.[32] Indeed, the very structure of such programmes creates incentives to exaggerate benefits.[33] The problem is structural: offset programmes attract participants with the most generous baselines.[34]

As has been the case with emissions trading, the simple idea of a Pigouvian tax has also spawned a number of variants that achieve some, but not all, of the objectives of a true Pigouvian tax. Gasoline taxes reduce emissions from vehicle transportation, but not other activities. In the United States, federal gasoline taxes are used as a funding source for road construction and maintenance, not as a pollution tax or to discourage driving.[35] Similarly, a chemical feedstock tax under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA),[36] or the 'Superfund' law, imposed a tax on the production of petroleum and on 42 chemicals.[37] The tax, which expired and was not re-authorised, was used to fund prosecutions for violations of CERCLA and to fund

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30 Hahn and Richards (2013) 110 (noting that over 210 approved methodologies were developed for which an offset could be granted).

31 Greiner and Michaelowa (2003) 1008–1009.

32 See, eg, Wara (2008) (showing how the Clean Development Mechanism enabled entrepreneurs to cheaply manufacture carbon credits by convincing the regulatory authority that it was profitably manufacturing refrigerants); Schneider (2011).

33 Hahn and Richards (2013).

34 Millard-Ball (2013) 41.

35 It is telling that the federal gasoline tax was instituted under the Revenue Act of 1932: s 617(a), 47 Stat 169, 266.

36 Comprehensive Environmental Response, Compensation, and Liability Act of 1980, Publ L 95-510, 94 Stat 2767.

37 ibid, Subtitle A, amended Superfund Amendments and Reauthorization Act of 1986 (PL 99-499).

clean-ups of contaminated sites, rather than giving any price signal discouraging the production of chemicals. In general, variants of Pigouvian taxation do not seem to create distortions quite as readily as do variants of cap-and-trade programmes. Such variants have at least failed to draw as much scholarly attention as the former.

Variations on pure price or quantity instruments are often proposed and implemented to address problems of political or administrative feasibility.[38] Some of these variants may achieve most of the objectives of true Pigouvian taxes or emissions trading programmes, with a minimum of distortion. Necessarily, however, evaluating the relative costs and benefits of such variants introduces even more uncertainty than when comparing 'pure' price and quantity instruments. In any case, comparing the advantages of price instruments versus quantity instruments, in practice, thus requires some tolerance for imperfection, and an awareness of how variations may impact welfare analysis.

VIII.13.4 Innovation incentives

Both Pigouvian price instruments and Dalesian quantity instruments provide incentives to reduce emissions and to innovate in emissions reduction methods. A Pigouvian price instrument would represent a constant price paid for emissions, while a Dalesian quantity instrument would pose a price that would vary depending on demand for permits. Both tax levels and cap levels can be too lenient or too stringent, resulting in a suboptimal level of innovation. Depending on instrument design, however, some differences may exist.

All other things being equal, a cap-and-trade programme presents one extra source of price volatility: the fact that it is regulating a quantity, and not a price. If economic conditions, technological advances, and more mundane operational changes have the effect of reducing emissions, then the demand for permits may soften, lowering prices. Conversely, economic conditions may have the effect of increasing demand for emissions, thereby increasing prices. Price volatility could have a negative or positive impact on incentives to abate and to innovate. It is possible that risk-averse emitters would opt to innovate or reduce emissions rather than face potentially large price fluctuations. On the other hand, many emissions reductions in the industrial sector are achieved by investment in new abatement equipment or technologies, and represent some departure from current practice; to the extent the investment must be justified by the existence of a price penalty for emissions, a volatile or uncertain price penalty would tend to make the investment less attractive. If emissions reduction investments are defined by some *payback* period, then they appear less attractive if the payback is less certain.

Permit prices in cap-and-trade programmes have historically been volatile. The successful sulphur dioxide trading programme saw some significant price fluctuations, dropping from a high of $326 to a low of $65 less than two years later.[39] The EU ETS system has been perpetually plagued by low prices, falling at times to zero.[40] To contain volatility, some cap-and-trade proposals have included 'price collars' to keep trading prices within a set range. If permit trading drives prices below a set minimum price, a

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[38] Goulder and Schein (2013); Cramton and Kerr (2002) (cap and trade permits grandfathered, not auctioned).

[39] Ellerman and others (2009) 172–74.

[40] Brown and others (2012) vii–viii.

regulatory authority would buy up permits, reducing supply, and increasing the price; if permit trading drives prices above a set maximum price, then additional permits would be released, increasing supply and reducing the price.[41] Price collars can be 'hard' – in which governmental permit buying and selling maintains strict price floors and ceilings by unlimited buying and selling – or 'soft' – in which limits are placed on governmental buying and selling to stabilise prices.[42] Proposals have also allowed the 'banking' and 'borrowing' of permits, the effective transfer of a permit to another time period.[43] All of these proposals have the effect of reducing deadweight loss in the case of an errant quantity limit. On the other hand, any such flexibility has the potential to reduce effectiveness in meeting environmental goals. These mechanisms have the effect of creating some hybrid between a quantity instrument and a price instrument, revisiting the trade-offs under uncertainty outlined above.

Another difference between Pigouvian price instruments and Dalesian quantity instruments is that over time innovation will reduce the cost of abatement, reducing demand for allowances and lowering prices. Firms innovate to reduce compliance costs, but will not do so if the marginal compliance cost savings are too small to pay for the innovation. A steady stream of innovations, building on itself, would eventually reduce the cost of emission so that the cost of allowances is exceeded by the costs of innovation. Of course, both price and quantity instruments can increase in stringency over time. Proposed climate policies have contemplated increasing carbon prices over time, either through an increasing tax level or a declining cap, to track marginal damages from carbon dioxide emissions, which are expected to increase over time. However, it is only the quantity instrument that has to effectively *fight* the price-deflating effects of innovation.

The possibilities for innovation *could* be less widely spread if either a price instrument or quantity instrument failed to cover a wide enough net of actors. The EU ETS applies to only 11,500 facilities in Europe. In the failed Waxman-Markey cap-and-trade legislation, the threshold below which facilities have no responsibility to hold allowances to emit carbon dioxide was 25,000 tons per year of CO_2-eq. A study commissioned by the Nicholas Institute at Duke University reports that at such a threshold level, only 1.3 per cent of all manufacturing facilities would be covered, and over 345,000 facilities were missing.[44] Granted, these 1.3 per cent of all facilities account for over 80 per cent of the greenhouse gases emitted by the manufacturing sector. But the problem, in terms of inducing innovation, is failing to recruit these 345,000 facilities in the search for lower emissions reductions technology. The fix for this apparent shortcoming of cap-and-trade is to apply the permit requirement *upstream*, at an early point of processing, so that all potential sources of emissions are covered by a permit requirement. The fossil fuel extractors would then pass down to subsequent buyers some fraction of the cost of their permits (depending upon the own-price elasticity of the raw fossil fuel), which would cause the price signal to trickle down the transportation, processing, and distribution chains, thus incentivising all subsequent buyers to search for sources of emissions

41 Fell and others (2012) 184.
42 ibid.
43 Kling and Rubin (1997).
44 Nicholas Institute (2009) 6.

reductions. The same considerations also apply to price instruments, in so far as they fail to impose a price, directly or indirectly, on all potential emitters. As in quantity instruments, applying the price *upstream* tends to overcome problems with breadth.

VIII.13.5 Administrability

In general, price instruments, levied as they are on a discrete *transaction*, pose fewer issues with administrability. The nature of a quantity instrument is such that there is inevitably a number of administrative and regulatory moving parts that need careful definition. Defining the quantity is no more or less burdensome than defining the price in a price instrument, but, beyond that, quantity instruments beg a number of other critical programme design questions.

Quantity instruments must define the regulatory targets: who will be required to hold permits to account for their emissions? As noted above, it is quite straightforward to tax individuals for their emissions – an extra tax at the gas pump, for example – but it would be impossible to impose a permit-holding requirement on millions of individuals. The task would then be to define some regulatory point between extraction and combustion at which there is an appropriate number of regulated parties.

As discussed above, applying a quantity instrument upstream tends to overcome problems with breadth. It also serves to minimise the administrative costs of a cap-and-trade programme. The administrative cost savings are lessened, however, if other price-management policies, like price collars and banking and borrowing, are implemented in a quantity instrument.

VIII.13.6 International coordination

International cooperation on the reduction of greenhouse gas emissions to address climate change has been fraught, to say the least. Historically, developing countries such as China and India have been viewed as deeply opposed to any international measures to address climate change that would crimp their economic growth. Some of this historical reluctance can be attributed to the Kyoto Protocol, which contemplated an effective international cap-and-trade programme. The key political problem, which generated tremendous domestic pressure on international negotiators, was the intractable one of assigning a quantity of allowable emissions to each signatory country. What a quantity instrument approach to international negotiations did was to place front and centre the divisive discussion of which country was going to be entitled to emit how much. The one indispensable discussion of a quantity instrument – the quantity – was made the subject of international wrangling and finger-pointing, which unravelled any hopes of marshalling cooperation.

For this reason, a price instrument would appear to be more palatable for most global pollution problems just because of the nature of international treaty-making. An international treaty utilising a global price instrument would have to include an agreement as to the price itself. Fluctuating international currencies pose some uncertainty. But an international quantity instrument, in addition to managing currency fluctuations, would have to allocate quantities among signatories. It is true that in a global cap-and-trade system, all permits could be auctioned, avoiding the need to allocate quantities among nations. That is not a programme design that has been proposed.

It is also worth noticing that countries have cooperated extensively on tax treaties. While a pollution tax treaty is different from the kinds of reciprocity agreements that commonly characterise tax treaties, it is still a much less discordant discussion to have to agree on a tax level, especially since deciding on a price is not, as it is with deciding on a quantity, a zero-sum exercise. Assuming pollution tax proceeds are kept within the boundaries of the signatory taxing parties, there is much less of a sense of wealth or industry pouring across international borders.

Finally, there is the question of capacity. A global price instrument in the form of cap-and-trade would necessitate some global enforcement body to ensure that all emitters in all signatory countries would comply with the permit-holding mandate. By contrast, a global price instrument would likely build upon existing tax collection systems, even in developing countries, making compliance more straightforward and maintaining incentives for signatory countries to enforce treaty provisions by collecting taxes.

VIII.13.7 Conclusion

The instrument choice between a Pigouvian price instrument or a Dalesian quantity instrument is a complex matter, belying the simple theoretical similarities and necessitating careful attention to programme design. Both instruments serve a number of efficiency functions, such as concentrating emissions abatement among the lowest-cost abaters, avoiding costly and uncertain administrative procedures, and providing incentives for innovation. Several variants of these two types of instruments have emerged, many of which blur any distinctions that might be made between price and quantity instruments, while some reduce the efficiency benefits or undermine their environmental goals. But for the most part, both of these instruments have been utilised to largely achieve environmental and efficiency objectives. As between these two instruments, important differences exist.

With perfect information, price instruments and quantity instruments have identical welfare implications, as either a price or a quantity can be set to the socially optimal level. But most pollution problems are rife with uncertainty. Weitzman's 'Prices Vs Quantities' provides some guidance in terms of what kinds of uncertainties drive the instrument choice decision. Application of Weitzman's seminal article is necessarily informal, but still reveals some important policy insights for climate policy and other pollution problems.

In terms of innovation incentives, both price instruments and quantity instruments impose a price for pollution. In their pure forms, quantity instruments introduce price volatility, which might increase or decrease innovation incentives. Some quantity instrument proposals have included measures to reduce price volatility, which tend to make those instruments more like price instruments, both in terms of their welfare effects as well as their incentives for innovation. However, one difference between quantity instruments and price instruments is that in a quantity instrument, innovation will have the effect of lowering the marginal cost of abatement and therefore the cost of permits, which would in turn dull the incentives to find new ways to innovate. Incentives for innovation should also be spread as widely as possible, to the maximum number of actors. For purposes of innovation, it is not only the volume of emissions that matters, but the number of emitters that might discover new technologies, practices, and methods. Price instruments have historically cast a wider net, but some care in design can make the two instruments equivalent in terms of breadth.

Ease of administration of both price instruments and quantity instruments depend greatly on programme design. Price instruments are often implemented in the context of existing tax collection systems, such as sales taxes or fuel taxes. When that is possible, price instruments have an advantage in simplicity over quantity instruments, which necessarily involve a number of moving administrative parts for implementing and maintaining an emissions permit trading system. The administrative costs of a permit trading system can be minimised by applying the point of regulation as far upstream as possible, in order to minimise the number of regulated parties.

Price volatility is one common concern, and price collars – mandates to keep permit trading within a range of prices – have been proposed to address it. Price collars require active interventions by a regulatory authority, and so present some extra costs, above and beyond the establishment of a trading system. However, price collars also create a hybrid system of prices and quantities, which may be superior to both pure price instruments and pure quantity instruments in terms of welfare. If so, the administrative costs may well be worth incurring.

Finally, to the extent that a pollution problem requires international cooperation, a price instrument is easier to operationalise in a treaty than a quantity instrument. Aforementioned administrability issues are heightened on a global stage, on which many developing countries may lack the institutional capacity to effectively implement all of the moving administrative parts of a quantity instrument. Moreover, just the task of deciding on the parameters and terms of an international quantity instrument is likely to pose challenges to the already fraught process of treaty making.

Both quantity instruments and price instruments present advantages and disadvantages with respect to each other. Given certain practical administrative realities of environmental regulation, for most pollution problems, the relative simplicity of price instruments renders it an easier instrument to implement. However, in the presence of uncertainty, the welfare effects depend on the nature of pollution abatement and environmental benefits. Moreover, careful programme design can eliminate or reduce the differences between price and quantity instruments.

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