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GLOBAL ENERGY SUBSIDIES: AN ANALYTICAL TAXONOMY

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Abstract: Governments around the world have pledged to eliminate or sharply reduce subsidies to energy firms in order to increase economic efficiency and reduce environmental externalities. Yet definitions of subsidies vary widely and, as a result, estimates of their global magnitude vary by orders of magnitude. I review why energy subsidies are so difficult to define and measure. I show why some non-standard measures are very poor proxies for subsidy costs and in fact may vary inversely with them. In particular, recent attempts to treat unpriced externalities as subsidies yield especially misleading results. In general, energy subsidies as conventionally understood do exist but only comprise a small portion of some very large recently-reported estimates, the bulk of which are indirect measures that may have little connection with actual costs to governments or allocational inefficiencies.

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1 INTRODUCTION

Energy subsidies have become a major topic of discussion among policymakers, due to a combination of concerns about costs to governments, market distortions and environmental externalities. Regarding the latter, the 2009 declaration by G20 leaders[1] asserted that removal of such subsidies would eliminate ten percent of global greenhouse gas emissions, and they called on international agencies to direct their attention to ascertaining their global scope. Estimates of the size of such subsidies have long been subject to considerable uncertainty. The OECD (2015) estimated subsidies from 2010 to 2014 within its member states plus six large partner economies (including China and India) and put the total at between US$150 and US$200 billion annually. The International Energy Agency (IEA 2014) put the global total at a comparable US$550 billion in 2013, but a team of International Monetary Fund (IMF) economists estimated it to be ten times larger at US$5.6 trillion (Coady et al. 2015).

There is an extensive academic and grey literature estimating energy subsidies at the national level: see survey in Lin and Li (2012) as well as the country-specific studies at the Global Subsidies Initiative (https://www.iisd.org/gsi/fossil-fuel-subsidies, June 7, 2016). The elusive nature of the quest shows up at this level as well. Koplow and Dernback (2001) examined ten estimates of US

[1] See http://www.g20.utoronto.ca/2009/2009communique0925.html#energy (June 7, 2016).

energy subsidies over the preceding two decades and found a range from $200 million to $1.7 trillion annually, thus spanning three orders of magnitude. The large range is entirely due to conflicting definitions of what constitutes a subsidy. Kojima and Koplow (2015) provide a review of the methodologies for national and global subsidy estimations with an emphasis on the difficulties of achieving a single workable definition. Country-specific studies can yield surprisingly ambiguous results as to whether domestic subsidies even exist (for example, Nwachukwu and Chike 2011), or how to define and measure them (contrast Sawyer and Siebert (2010) and McKenzie and Mintz (2011) in the Canadian case).

Conventional subsidies, namely direct transfers to firms or consumers, definitely exist and can be highly distortionary. The IEA (2014 Chapter 9) points out, for example, that the price of motor fuel in Saudi Arabia is only one-tenth that in the EU, and that many Middle Eastern countries have capped market prices for fuels well below market levels, requiring large ongoing subsidies to producers to cover their losses. But many researchers believe that such direct fiscal transfers are only a part of the picture, so the definition of subsidies has been widened at times to include indirect measures, such as subsidies to complementary goods and the absence of charges for pollution externalities. These are, in some cases, easier to measure, but as will be shown here, they may be a poor proxy for the social welfare costs of the alleged market distortions. They are open to considerable ambiguity in interpretation, and in some cases they are not only uncorrelated with what we are trying to measure, but they may even vary inversely with it.

This paper attempts to put the discussion into a clear theoretical framework that allows a comparison of the various definitions and a deeper understanding of why they span such wide ranges. While numerous authors have surveyed the different methodologies using qualitative concepts (e.g. Kojima and Koplow 2015), there has been little use of microeconomic tools to provide theoretical clarity. The discussion herein will rely on relatively simple graphical models to illustrate the different cost concepts and to explain why indirect approaches can sometimes fail to correlate with what we are trying to measure.

2 Transfers and Tax Expenditures

The most common way of measuring subsidies is the price gap approach (Koplow and Dernbach 2001), which involves comparison of an actual net-of-tax price to a reference net price, multiplied by a quantity. Deviations from the reference price can arise due to direct, or simple transfers, or by reducing a tax rate below the level that ought to be charged. The difficulty of defining the reference price will be a recurring theme in this analysis.

2.1 Simple Transfers

Figure 1 shows a supply and demand diagram for fossil energy with a simple subsidy in the form of a transfer to the purchaser of s per unit. The incidence of the subsidy is not affected by whether the transfer is to the buyer or the seller. In the absence of the subsidy the market price would be P_1 and the quantity would be Q_1. The subsidy introduces a gap of s per unit between the buyer's price and the seller's marginal revenue, resulting in a new market equilibrium at Q_2 units. If demand is inelastic the change in quantity will be relatively small, and vice versa. The magnitude of unpriced externalities will depend on the size of the quantity shift, so in this case, market conditions that make the effect of the conventional subsidy larger (for example, elastic demand) will also make the unpriced externality magnitude larger, in other words subsidies and induced externalities are correlated and one can serve as a proxy for another. However, as we shall see, this is not always the case.

There are two appropriate cost measures for the simple case: the cost to the government (denoted herein S_G) and the social welfare cost (denoted herein S_W). The cost to the government is $S_G = sQ_2$. This is the amount that should appear in the government's spending accounts, and it is the amount the government would save if it cancelled the subsidy. In this case if s is known the price gap does not need to be computed.

The social welfare cost is somewhat different. S_G itself is just a transfer but the cost to society of raising it includes the marginal excess burden of taxation, denoted MEB_T (per dollar). The Harberger triangle associated with Q_2 is c, which represents the resource misallocation of fuel production costs that exceed consumption benefits. Hence the social welfare cost of the subsidy is $S_W = c + (sQ_2 \times MEB_T)$. An economist estimating the size of the subsidies would try to ascertain S_G while an economist estimating the social welfare costs of the subsidies would be trying to estimate S_W. The more elastic the demand, the larger will be both S_W and S_G.

Subsidies in this form are relatively rare, and surveys of international subsidy magnitudes yield estimates of S_G that only account for a small fraction of the reported totals. Koplow and Dernbach (2001) reported that, in US studies, transfers were typically under $10 billion (1999$) annually, and in the few studies which quantified more general categories of subsidies this contributed only one or two percent of the reported total.

The IEA (2015) reports that a particularly common form of subsidy in developing countries is a regulatory cap on the selling price of fuel coupled with a producer subsidy to cover losses. This situation can also be represented in Figure 1. If the price cap is imposed at z and the producer is indemnified against losses, the market quantity will be Q_2 and the losses to the producer will be s per unit. The rest of the analysis would be the same.

2.2 TAX EXPENDITURES

Figure 2 illustrates a situation in which fossil energy is subsidized by applying to it a tax rate lower than some reference rate. The reference tax rate is denoted t_R, and the associated market quantity is Q_3. Suppose the tax rate on fossil fuels is reduced to t_F. This in turn yields a market outcome of Q_4 per unit. What is the subsidy in this case?

If an analyst were to compute the tax differential times the market quantity, $Q_4 \times (t_R - t_F)$, this would overstate the size of the subsidy since at t_R we would not observe the quantity Q_4, so the government would not save that amount if the policy were canceled. The proper estimate of the cost to the government is the net increase in revenues if the policy were canceled, which is

$$S_G = t_R Q_3 - t_F Q_4.$$

In principle this may be a positive or negative number but because fuel demand is relatively inelastic it is probably a positive number, i.e. a net cost. In contrast to the simple case, therefore, the more elastic the demand, the lower is S_G and indeed the higher the likelihood that the net cost is negative. If demand is inelastic the subsidy cost will be relatively larger but the effect on the market quantity will be smaller, which implies a smaller effect on pollution externalities. So in this case there is an inverse relationship between the subsidy costs S_G and the potential magnitude of unpriced externalities: the conditions that yield a larger subsidy magnitude yield a smaller effect on pollution.

Another challenge arises when computing the social welfare cost. There is a reduction in deadweight loss from reducing the tax on fuels which is shown in Figure 2 as area a+b+c. We assume that the policy must be revenue-neutral, so if the net effect is to reduce government revenues the difference must be made up by raising another tax, which we will assume has a marginal excess burden of MEB_x. So the net social welfare cost of the tax expenditure is

$$S_W = MEB_x \times (t_R Q_3 - t_F Q_4) - a - b - c.$$

Even if the first term is positive the whole expression may yield a positive or negative amount. However, the inelastic nature of fuel demand implies that the MEB of an alternative tax is likely higher than that on fuels, so MEB_x is probably somewhat large and a+b+c is probably somewhat small, so S_w is probably (though not unambiguously) positive.

Since low demand elasticity implies subsidy costs vary inversely with induced externalities, the magnitude of unpriced externalities is a poor proxy for the social welfare cost of the tax expenditure. This creates a problem for some indirect estimation methods. Stefanski (2016) exploits an empirical regularity in the time path of per capita carbon dioxide (CO_2) emissions across countries to estimate a canonical, or reference, case, then uses departures above that path to infer the magnitude of the likely fossil fuel subsidies in each country. The motivation of this approach is that the subsidy policies themselves cannot be observed nor their costs measured directly, whereas CO_2 emissions per capita can. The problem, however, is that whether a deviation in the quantity of CO_2 emissions correlates with the cost of a subsidy depends on the form of the policy. In the case of simple consumption subsidies the two vary together, but as we have just seen, in the case of tax expenditures they vary inversely. Hence the conclusion by Stefanski that removal of global subsidies would both reduce CO_2 emissions by 36 percent and save governments $1.8 trillion in subsidy costs is not valid. It assumes all the subsidies take a specific form that they are already known not to take.

A further measurement problem is that the reference tax rate t_R needs to be defined. If there was a pre-existing tax on fuels and it was recently lowered, the previous rate would be the obvious candidate, unless the reduction was part of a more general change in tax policy. Otherwise another candidate might be the tax rate on other consumption goods. But in many economies, fossil fuels are subject to relatively high excise taxes, so it may be the case that even with favourable treatment, $t_F > t_R$. Economic theory would suggest, as an alternative, the notionally optimal tax rate on fuel, which will be relatively high due to the low elasticity of demand. This, of course, would be difficult to compute, and there is no guarantee that this is the basis from which revenue-neutrality ought to be computed since other tax rates are also likely not set at optimal levels. Finally, the reference tax rate might be based on the Sandmo (1975) rule, which combines a second-best optimal revenue-raising component with marginal environmental damages deflated by the marginal cost of public funds. The latter component ties in to the subject of unpriced externalities, which will be discussed below. The Sandmo analysis assumes there are no other emission controls in place, which creates problems for constructing the appropriate social welfare measure when emissions are controlled by quantity caps.

Two more complications arise in the tax expenditure case: (a) treatment of resource royalties, and (b) non-marginal subsidies. They will be considered in turn.

(a) Royalties for oil and gas extraction typically consist of two parts: an upfront payment at auction for a lease that confers the right to develop the asset, and a per-unit charge paid out of net or gross revenues. The amounts that are bid at lease auctions are based on expected net earnings, therefore there is a tradeoff between the two types of revenue (e.g. Kalter et al. 1975, Opaluch and Grigalunas 1984). Suppose that a jurisdiction reduces the per-unit royalty rate on the operation of oil wells in its jurisdiction. An economist applying the price gap approach might conclude that a tax expenditure subsidy has been introduced, and indeed this would be a valid observation, but only for existing wells. Subsequent lease auctions would be expected to yield higher bids, which would recover the expected profits of the reduced royalty stream. The risk-adjusted discounted royalty payments should be equivalent between the two cases. In effect the change in one royalty parameter merely changes the allocation of risk between the firm and the state. This may amount to a positive or negative income effect overall for firms, but the price gap approach will not provide a valid measure of the value of the change because the reduction in the royalty rate on new wells will be at least partly offset by higher lease bids.

(b) As noted by McKenzie and Mintz (2011), not all subsidies have impacts at the margin. Some forms of royalty relief, for example, are granted only up to $\$X$ per well, or only on the first Q_5 units of production. For firms operating below the threshold, the analysis would be as described above. But as shown in Figure 3, if a firm receives a subsidy of s per unit up to quantity Q_5 but it operates at a market equilibrium above the threshold at Q_1, the subsidy is essentially a lump sum transfer of $s \times Q_1$ and it does not affect marginal decisions by the firm. The cost to the treasury is still real, but it has no allocational effect on the marginal quantity. This is an important point when considering secondary effects of subsidies on pollution externalities.

Finally, tax expenditures may take the form of accelerated capital cost allowances in which the rate itself is not reduced, but faster depreciation allows for earlier receipt of some benefits that would otherwise accrue later. The value of this benefit will then be sensitive to the discount rate chosen. Treatment of input costs will be discussed in the next section.

To summarize this section, in the simplest case of a classic per-unit subsidy, the cost of the policy and its social welfare implications are relatively straightforward. Higher subsidy costs correlate with higher effects on pollution externalities. But while this type of subsidy yields a clear picture of distortion and inefficiency, it is relatively rare and is not what lies behind the very large estimates of recent years, which are mostly driven by estimates of unpriced externalities. Adding tax expenditures into the discussion takes account of some potentially larger distortions, but also opens up substantial measurement challenges, and these vary inversely with the magnitude of externalities.

3 INTERMEDIATE INPUT SUBSIDIES

Figure 4 illustrates the effect of subsidies to intermediate inputs. These might include any measures that reduce the costs of inputs, labour or capital in the production and sale of fossil fuels, or that shift investor risk onto the state. The effect is to shift the supply curve S down to S', increase the equilibrium quantity to Q_6 and create a Harberger triangle of area c. Since the subsidy is paid to an intermediate input the amount is not shown directly in Figure 4, but suppose it works out to s per unit sold, on average. The cost to the government can be measured as the amount the government would save if the program were terminated, which implies $S_G = s \times Q_6$. The social welfare cost is $S_W = s \times Q_6 \times MEB_T + c$.

There are many examples of these kinds of subsidies, especially because governments seem to consider large capital investments in energy infrastructure to be attractive uses for public money.

In the 1980s, provincial and federal governments in Canada spent hundreds of millions of dollars on the development of two heavy oil upgraders in western Canada. The government of Saskatchewan was especially keen to see the construction and operation of the upgraders, since both would be located within the province. Neither one was commercially viable at the time the projects were proposed so provincial governments in Saskatchewan and Alberta, as well as the government of Canada, agreed to subsidize them through direct lending, grants and loan guarantees. The subsidies thus included not only direct transfers but also the assumption of default risk through the provision of loan guarantees which reduced financing costs for the firms involved. The size of the loan guarantees eventually trapped Saskatchewan into covering ongoing operating losses or risk a credit default that could have bankrupted the province (Stobbe 2014). Many more such examples could be canvassed from around the world, at the risk of depressing the reader.

A more controversial question is whether security costs should be considered subsidies, in particular the cost of a military or naval presence in the Persian Gulf. In their review of US energy subsidy estimates Koplow and Dernbach (2001) show that attributing a share of US military spending to security operations in the Persian Gulf for oil transport expands the estimate of the subsidy cost by between six and 82 percent, depending on certain assumptions. A difficulty arises in deciding whether the military costs would be incurred anyway, for instance as part of international efforts to control piracy, or (especially post-2001) as part of anti-terrorism efforts. Where an increment in military costs can definitely be attributed to the need to secure oil production and transportation, the question then arises more generally as to whether police and military services constitute a special subsidy or are simply part of the portfolio of public goods paid for through the tax system. Any store owner, for instance, benefits to some extent by the reduction in crime due to a local police presence. This is not normally thought of as a subsidy, but as a public good for which the shop owner pays through taxes. Likewise a nation's marine traffic depends on military protection, which is a public good that benefits all shippers equally, and to which they contribute at least in part through taxation. It would be difficult to identify a particular increment of military expenditures assignable solely to oil tanker traffic, which is why the numbers vary so widely.

4 COMPLEMENTARY GOODS SUBSIDIES

This case arises when, rather than subsidizing the energy commodity itself, the government subsidizes an essential complementary good. A typical example in discussion of energy subsidies is road construction. Figure 5 provides a simple graphic model of this situation. Consider a setting in which all roads are toll roads, therefore households have to pay for each use as well as the fuel costs associated with car trips. Fuel costs are on the vertical axis and road use is on the horizontal axis. The downward-sloping line B_1 indicates the budget constraint connecting the two, and optimization of perfectly-complementary preferences (the dashed right-angles) yields the initial pair (R_1, C_1). Now suppose that the government subsidizes road availability by covering the cost of construction and maintenance. This will swing the budget constraint out to B_2 and will lead to a new optimum at (R_2, C_2). If the government completely covers the cost of the roads at s per unit then the cost to the public sector is $s \times R_2$. Adjustments to get a social welfare cost would need to include the usual marginal excess burden adjustment, a Harberger triangle, and also congestion costs from increased road usage.

As with military security, roads are typically considered public goods that can be justified on the usual Samuelsonian grounds. It clouds the subsidy discussion if we arbitrarily select one type of public good and call it a subsidy, without applying the same reasoning to all other public goods. In principle, the users of public goods pay for them through taxation, and the question of how extensive public provision should be is determined by comparison of the marginal costs and the summed private marginal benefits. Any particular public good may be over-provided because the marginal signals are lost, which is intrinsic to the nature of public goods. This is a general problem, not a specific one for complements to energy consumption. In principle, the citizens of a town benefit from the whole range of its public services, and pay for them through taxes. Singling out non-toll roads and calling their provision a subsidy is an arbitrary redefinition. It is true that users do not pay at the margin, but that is true by nature of all public goods: users pay average costs rather than marginal costs.

Furthermore, road subsidies are often financed through excise taxes on gasoline. To graph this case, note that a gasoline tax forces up the cost of car trips and the budget constraint must swing inwards to B_3 as shown in Figure 6. The new solution will be at (R_3, C_3), somewhere to the left of R_2. If the gasoline tax is t_g the total net subsidy will be $s \times R_3 - t_g \times C_3$, which may be positive or negative.

5 UNPRICED EXTERNALITIES

The examples described above all yield sizeable variations in the estimated magnitude of subsidies, but the largest changes occur with the inclusion of so-called unpriced externalities. Coady et al. (2015, herein C15) estimate global energy subsidies to be a $5.6 trillion annually, or nearly 7 percent of global GDP. Disbursements from governments to fossil fuel companies are only one-sixteenth that amount, or $333 billion. The remaining $5.3 trillion is dominated by uncollected externality taxes which C15 propose should be considered a subsidy. These estimates have attracted considerable international attention, including an article in the *Financial Times* (Martin Wolf, October 28 2015) and a subsequent series of letters to the Editor from prominent economists debating their validity.

What C15 call subsidies would better be described as scarcity rents associated with a regulated quantity. Since they are mere transfers there are no allocational inefficiencies if they accrue to private agents rather than to the government. Moreover, any quantity regulation gives rise to such rents: the logic does not just apply to pollution emissions. The main problem with the C15 analysis is that the size of these rents, whether captured by the government or not, is not a measure of the welfare cost of the underlying externality.

C15 uses a Pigovian-style diagram to illustrate externalities in the product quantity-price space. This makes it difficult to see the inherent problem, so Figure 7 re-draws the externality model in emissions-price space, as is customary in environmental economics textbooks. The downward-sloping line labeled *MAC* is the marginal abatement cost curve, showing the marginal profits to polluters of increasing emissions, or equivalently, the marginal cost of reducing emissions. The upward-sloping line labeled *MD* shows the marginal damages of emissions. The unregulated emissions level is $\bar{e}$ and the optimal emissions level is e^*. The corresponding shadow prices are $\bar{p}$ and p^* respectively. The entire analysis of unpriced externalities begins with the assumption that pollution emissions are not already subject to Pigovian-type taxes. The net social welfare cost of the uncontrolled externality is shown as area *c*. At this emissions level if the social cost of the externality were valued at marginal damages, the amount would be be $\bar{p} \times \bar{e}$. It is immediately apparent that this does not equal *c*. Moreover, it could never be collected as a pollution tax because if the charge $\bar{p}$ were imposed the emissions level would fall according to the MAC (which, in this context can be interpreted as a demand curve), meaning emissions would go to zero. The tax rate corresponding to the unregulated emissions level, meaning the rate that, if charged, would yield emissions $\bar{e}$, is zero by definition. So there are no foregone emission tax revenues corresponding to emissions level $\bar{e}$.

Now suppose pollution is reduced via a regulatory cap. As emissions go down the foregone pollution tax revenue rises as the rectangle bounded at its upper right corner climbs up the MAC. At e* the revenues would be $p^* \times e^*$. But along the way c steadily shrinks as emissions fall, and at the optimum there is no longer any resource misallocation and c goes to zero. Hence the uncollected emission tax revenues vary inversely with the size of the net welfare loss associated with the emissions. In other words, higher estimates of uncollected pollution taxes correlate with lower externality costs, making the former a very poor proxy for the latter.

In this example an efficiency improvement comes about by reducing emissions to e*. The fact that nothing is remitted to the government in the process does not mean that no efficiency gain took place. The rectangle $p^* \times e^*$ now represents a scarcity rent created by the restriction on emissions, and the form of the policy will determine whether the rents accrue to the government, such as through taxes or quota auctions, or to the emitters via freely-distributed emission permits, or are dissipated through inefficient regulatory policy. The disposition of the rents does not matter in this case.[2] To call the uncollected rents a subsidy would, if we applied the same reasoning to any other regulated market, lead to the absurd idea that any quantity subject to statutory limitation (such as prostitution or narcotics) is publicly "subsidized."

To explore further the problem of equating uncollected externality taxes to the welfare cost of pollution, from the unregulated point $\bar{e}$ we might consider $p^* \times e^*$ to be the implicit subsidy, since it is potential optimal tax revenue uncollected by the government. But that rectangle does not equate to the magnitude of the net social welfare costs at $\bar{e}$, which equal area *c*, nor does it correspond to the net social welfare costs of the externality at e^*, which equal zero. It is simply a measure of uncollected rents associated with a quantity regulation. The distinction being drawn here is exactly analogous to that between *pecuniary* and *technological* externalities as explained in Baumol and Oates (1988, pp. 29-31). Pecuniary externalities redistribute income but do not change the underlying production functions, nor do they imply allocative inefficiencies.

Another problem with the C15 analysis is that it ignores the presence of other regulations, chiefly non-price ones. It is an obvious error to assume that if a policy does not require agents to remit fees to the government it is therefore non-existent or ineffective. Yet the C15 analysis does this by assuming that the absence of an explicit emissions tax implies the presence of uncorrected externalities (and furthermore, erroneously, that one is a proxy for the size of the other). Yet countries around the world have longstanding air pollution regulations in place, most of which take

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[2] Failure to collect the rents does have the general equilibrium implication that funds are not available for revenue recycling to reduce other taxes and thereby reduce the tax interaction effect (Parry, Williams and Goulder 1999). However this potential loss is not the basis of the subsidy calculation in C15.

the form of quantity caps, the results of which are that conventional air pollutants have fallen considerably in the past 50 years, at least in OECD countries. Moreover, while CO_2 is rarely subject to direct regulation or pricing, many countries have enacted energy efficiency rules and electricity sector interventions in the name of controlling CO_2 emissions, which translate (albeit inefficiently) into quantity restrictions. Considering how low conventional air pollution levels are in developed economies, and how low some mainstream estimates of the social cost of carbon are (Tol 2009, Dayaratna et al 2015), it may be the case that some current air emission levels are below their optimal levels. Figure 8 shows a case in which emissions are controlled by quantity restriction to e_1, which is below the optimum at e^*. The C15 methodology would define $p_1 \times e_1$ as a "subsidy," even though the policy imposes a welfare loss (shown as the area *d*) through excessive emissions reduction. Relaxing the emissions standard by one unit would unambiguously reduce the welfare loss from over-regulation, but the C15 subsidy estimate might go up, implying a larger welfare loss. In other words, variations in the C15 subsidy measure cannot be shown to correlate with variations in the welfare cost of an overly-restrictive pollution regulation.

The unpriced externality case might alternatively be framed as a tax expenditure, by invoking Sandmo (1975) which extends the optimal tax analysis to an economy with externalities and yields a pricing rule in which the second-best optimal tax rate on a commodity is supplemented by an additive term representing the external disutility from consumption externalities. The absence of this additive term could then be considered a subsidy in the form of a tax expenditure. However, the application is not so simple, since the Sandmo analysis assumes there are no other emission control policies in place. If the externality is already optimally controlled by a quantity limit then the situation is as described here: there is no resource misallocation requiring a tax, though there might be a welfare cost due to the policy costing more than it needs to. If non-optimal emission control policies are in place then there is no guarantee the Sandmo rule still applies, and a term consisting of emissions times marginal damages will not typically correlate with the size of the social damages needing to be corrected.

6 CONCLUSION AND POLICY IMPLICATIONS

The economic case against subsidies for energy production or consumption is well-established and sound, and there are many examples in which public money has unquestionably been wasted. But policy makers wanting to address the problem need to be very cautious about some of the numbers being touted. Discovering and quantifying the extent of subsidies to energy firms has proven to be extremely difficult. Direct payments by government are relatively rare, and researchers have instead looked at a range of indirect measures, including tax expenditures, intermediate input subsidies, complementary goods subsidies and unpriced externalities. These additional categories are themselves subject to measurement challenges, and may not even correlate with the quantities being sought. Tax expenditures may have a positive or negative effect on government expenditures, and the case in which they are most likely to be a net cost to the government coincides with the smallest effect on pollution externalities. Complementary goods subsidies should not be conflated with public goods which are provided as part of a general package of revenues and expenditures, and in the particular case of roads and fuel taxes, may be a net contributor to the government budget. Unpriced pollution emissions do not measure the underlying social welfare cost of the externality and in fact can easily vary inversely with its magnitude, so estimates of uncollected pollution tax revenue cannot reasonably be interpreted as subsidies.

For the purpose of determining the actual size of subsidies to fossil fuels it would appear that conventional subsidies, that is actual payments to consumers and firms, are at the low end of the range of past estimates and are only a small percentage of the large numbers that have sometimes been put forward. To the extent we include indirect or notional concepts the numbers get dramatically higher but they also become meaningless and potentially misleading.

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8 FIGURES

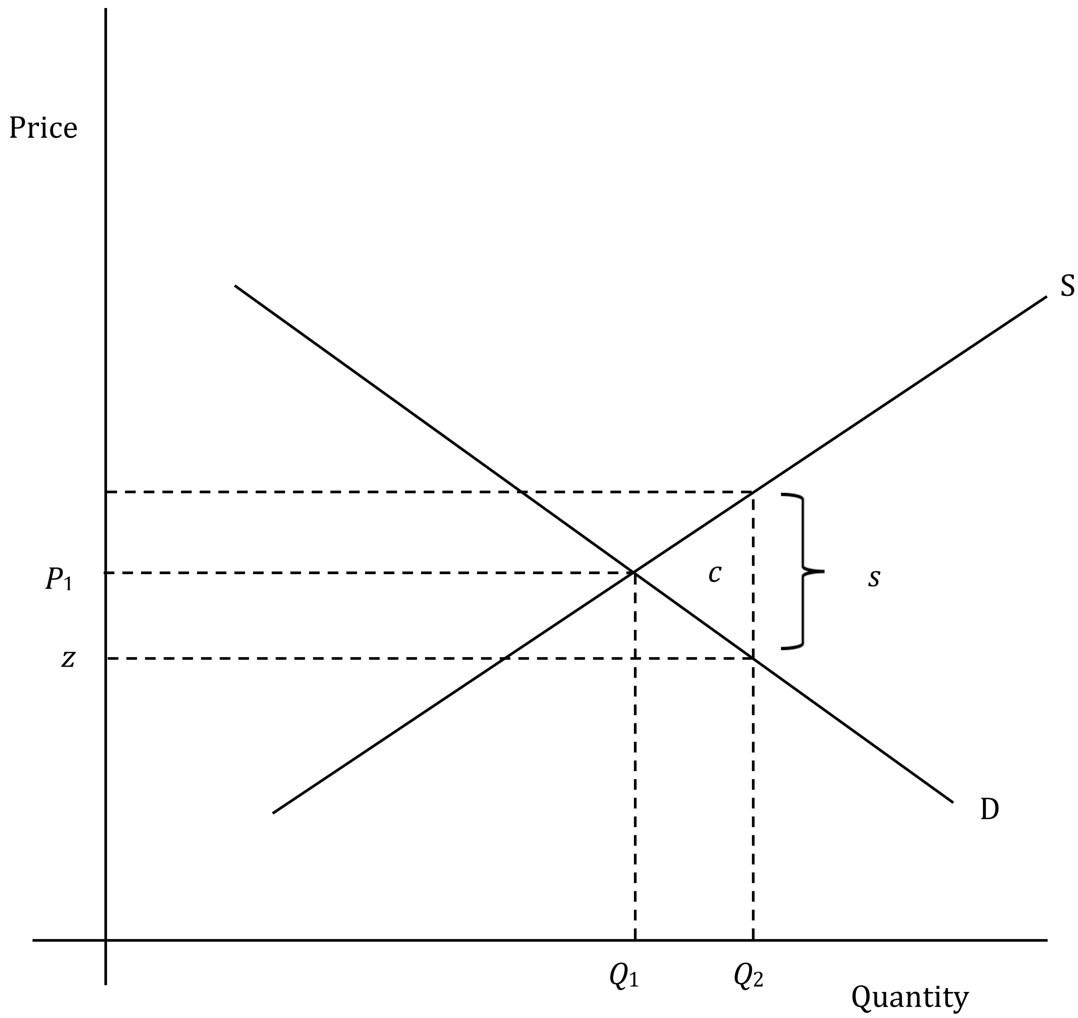

Figure 1: Simple unit subsidies.

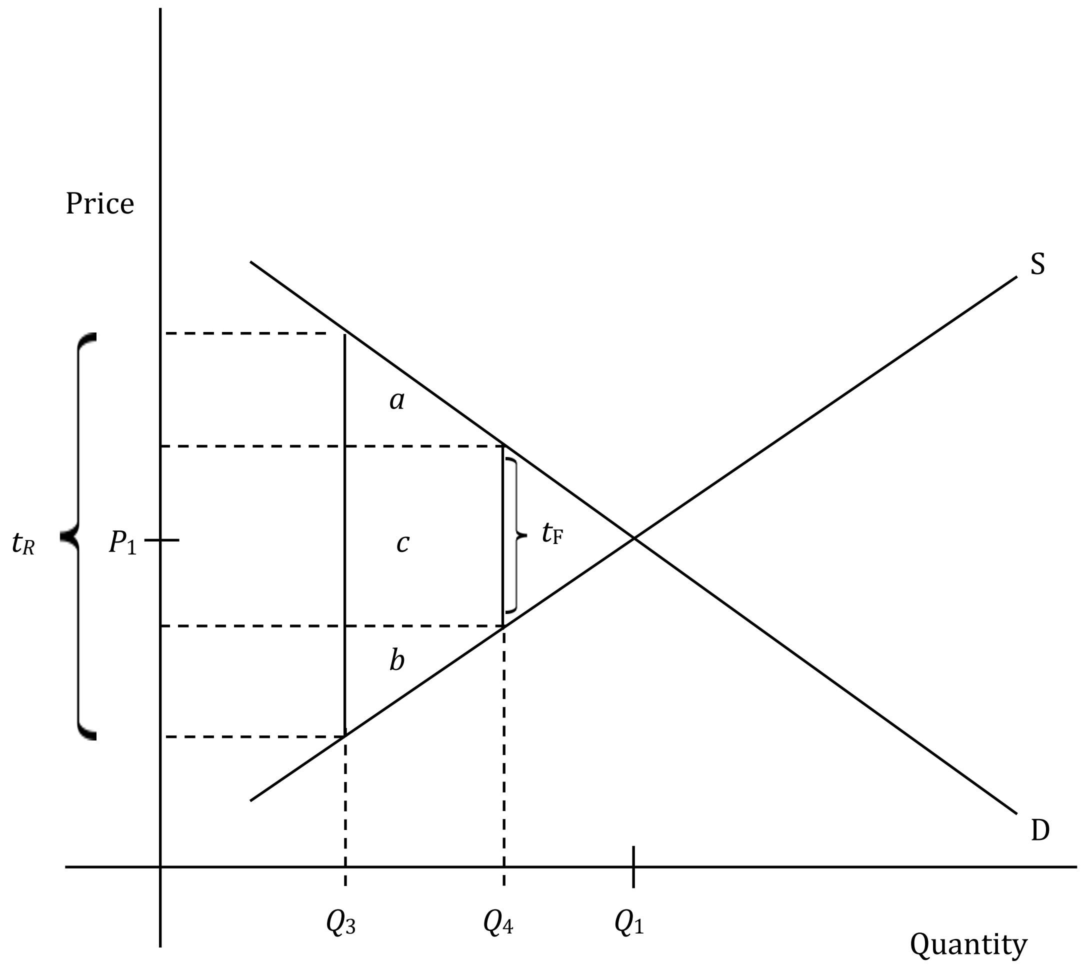

Figure 2: Tax expenditures.

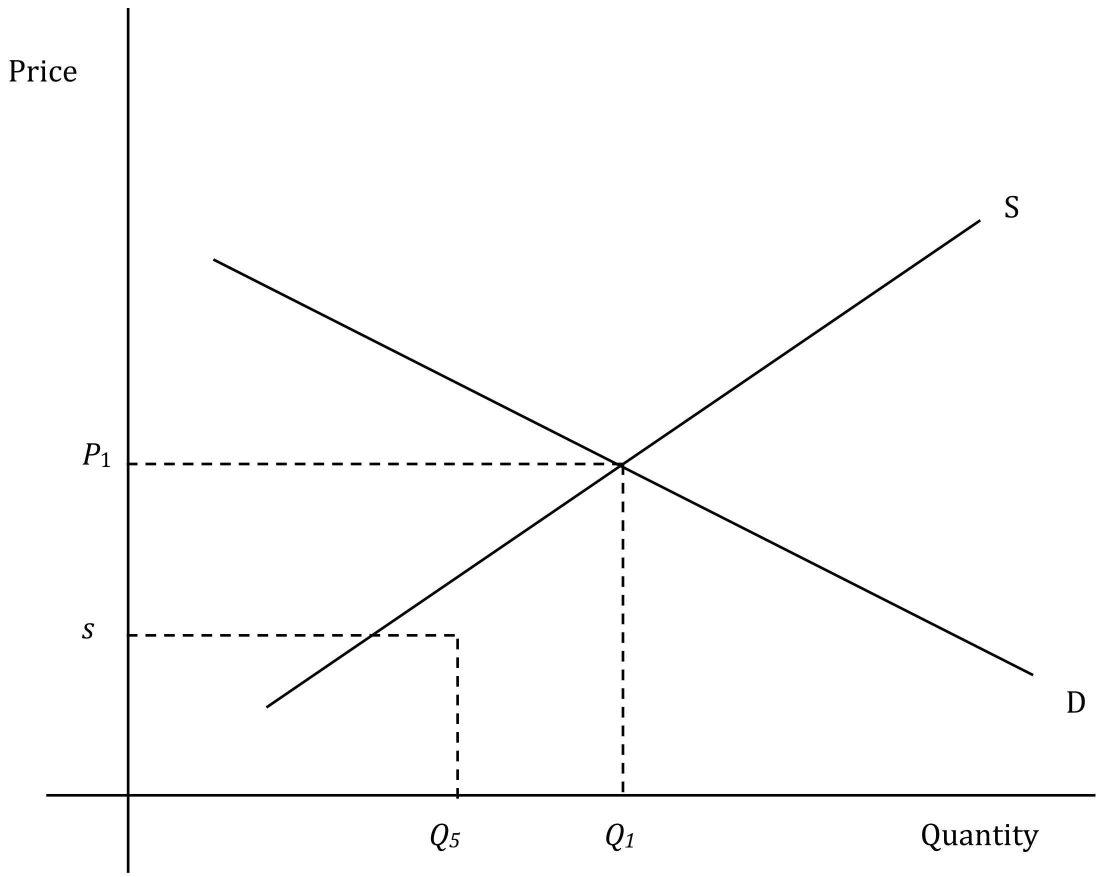

Figure 3: Non-marginal subsidy.

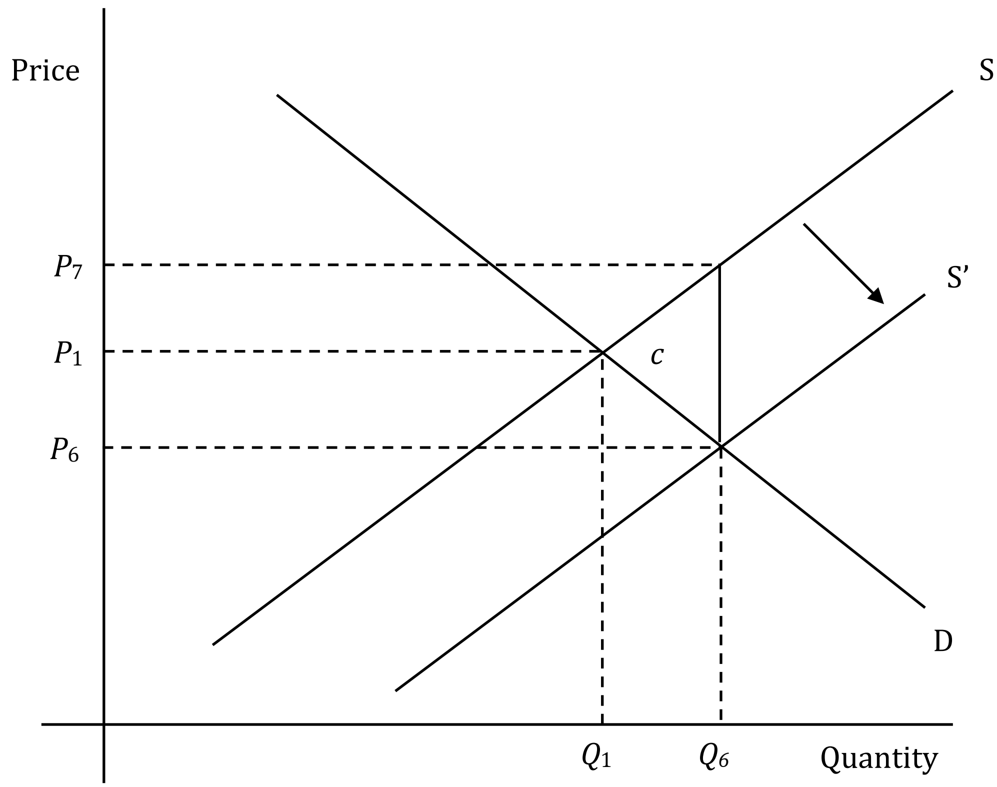

Figure 4: Intermediate input subsidy

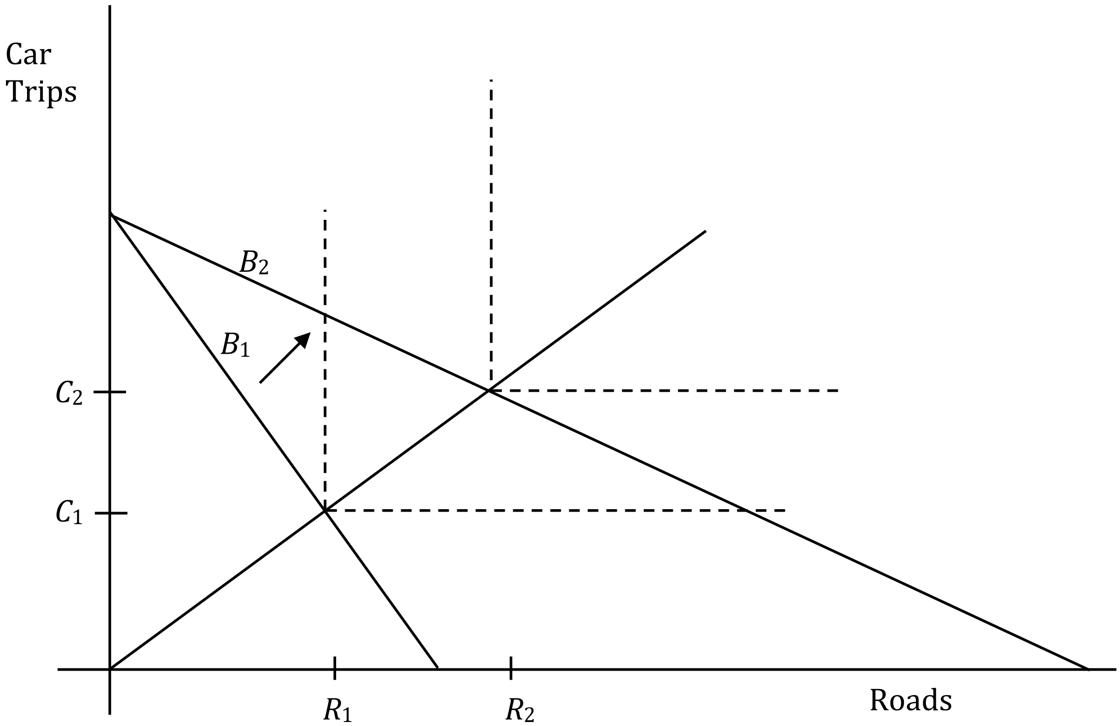

Figure 5: Complementary goods subsidy

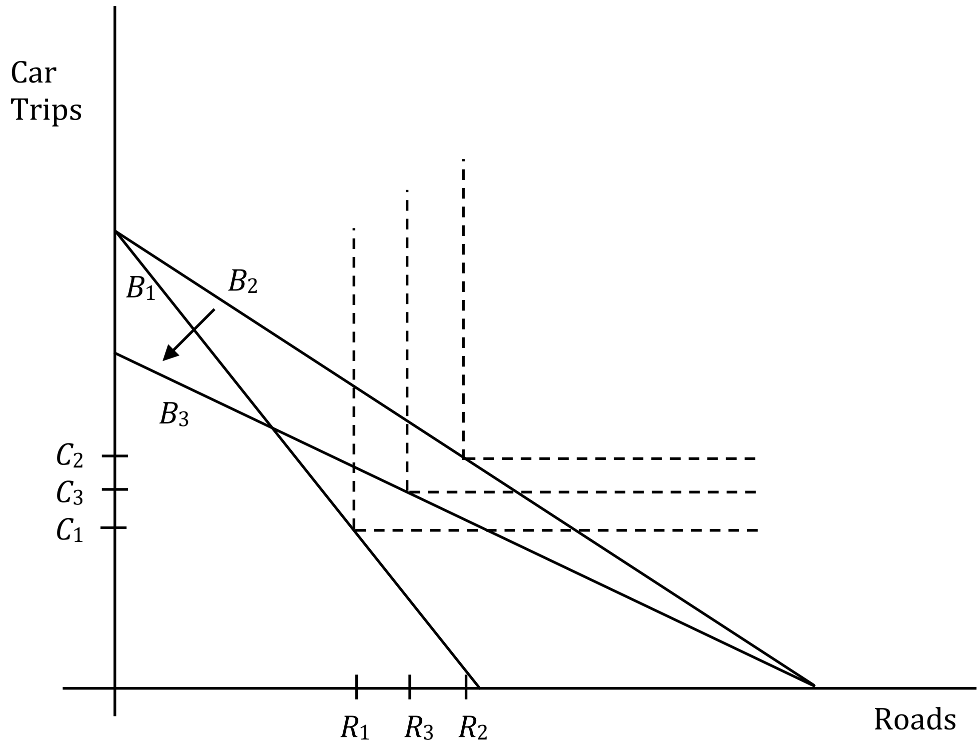

Figure 6: Complementary goods subsidy with excise tax

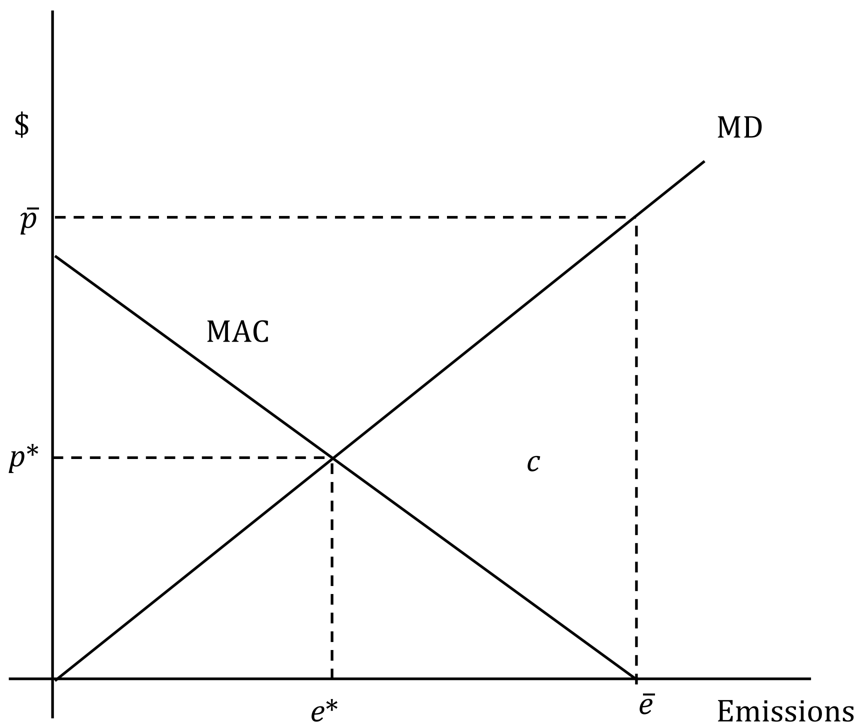

Figure 7: Environmental externality

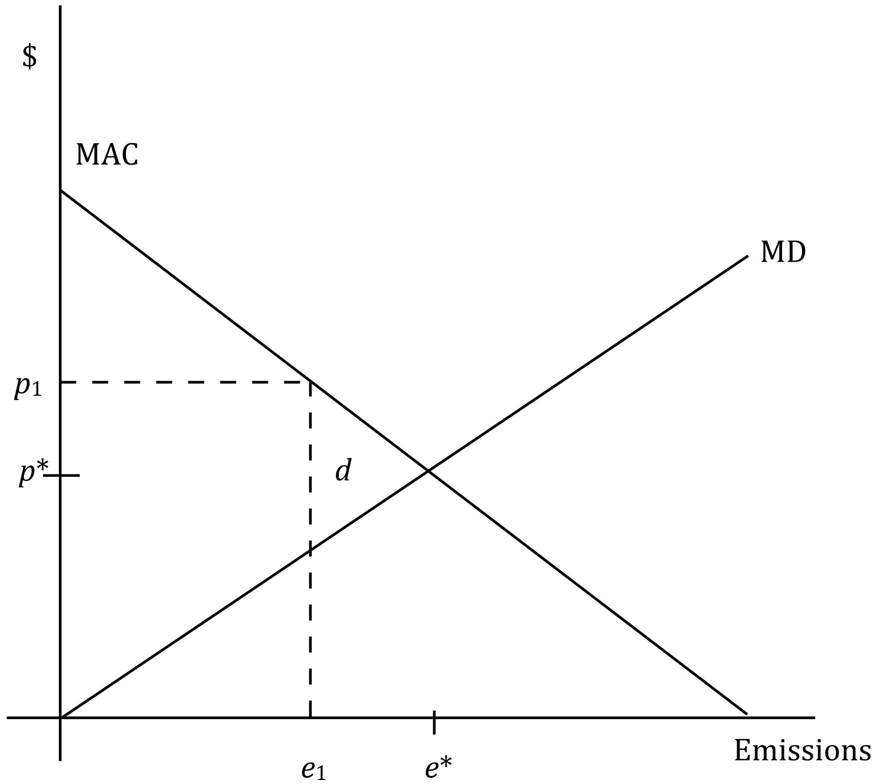

Figure 8: Environmental externality with overly-stringent regulation