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Energy, Pollution Control and Economic Growth

Ross McKitrick

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ENERGY, POLLUTION CONTROL AND ECONOMIC GROWTH

Ross McKitrick

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1. Introductory summary

Growth in energy consumption is not just a by-product of economic growth, it is a causal factor. Attempts to constrain energy consumption can therefore be expected to impede economic growth. Fossil-based energy has an economic advantage but gives rise to pollution concerns. But conventional air pollution is not a necessary by-product of power production and has been successfully decoupled from it in western countries through development of scrubbers and other end-of-pipe treatments. Indirect air contaminants, such as ozone and aerosols, are not trending upwards and peak level episodes have fallen, but the complexities of the atmospheric processes in these cases make progress inherently slower. Carbon dioxide is not controllable by conventional scrubbers, instead it is tied linearly to energy consumption. CO_2 emission reductions will therefore be much more expensive to achieve under current technology. Economic reasoning provides a few basic ideas for guiding energy and pollution policy. Regulations should be focused directly on the variable of interest, not on indirect market transactions. The principle of pricing states that the most efficient outcome of well-designed regulations will match that which would have resulted from using price instruments directly applied to the emissions of concern. The pricing principle helps explain why some interventions, like the subsidy-driven expansion of the renewables sector, are inefficient.

2. Energy as a Causal Factor

2.1 Engine of Liberation

Electricity and the spread of household appliances results in increased convenience, reduced indoor air pollution and gains in population health through better food handling and indoor climate control. The availability of inexpensive electricity has truly been a miraculous source of economic growth, social progress and equality in the west. Greenwood et al. (2005) showed that, in American households, the proliferation of household appliances, made possible by the spread of electricity, reduced required average housework time from 58 hours per week to 18 hours per week between 1900 and 1975. They found that adoption of durable goods in the home (major appliances like washing machines and stoves) accounted for over half the increase in female participation in the US labour force over the 20th century. A similar finding can also be expected for other countries,, namely that increased productivity in the home leads to more time for participation in the paid workforce.

2.2 Cause or Effect?

When examining the link between energy consumption and growth we need to address the question of whether increased energy consumption causes GDP growth, or is caused by GDP growth. The distinction is important. If increased energy consumption is merely a by-product of growth, it could potentially be capped and reduced without dampening economic growth; in other words growth and energy consumption could be decoupled. But if increased energy consumption is an input to growth, the two cannot be easily decoupled and efforts to cap or limit growth of energy consumption may impede economic growth.

Detecting the direction of influence between two co-trending variables is done using a time series method called vector autoregression (VAR). Econometricians refer to an empirical causality finding as "Granger-causality," after the pioneering econometrician Clive Granger. If knowing the value of one variable x at time t permits more precise forecasts of another variable y at time t+1, but not vice-versa, x is said to "Granger-cause" y, since it is a reasonable inference that the direction of influence is only in the one direction. VAR analysis has been applied to US data (Stern 2000), Canadian data (Ghali and El-Sakka 2004) and others. The results show that energy consumption causes economic growth, and in some cases the causality runs both ways. This indicates that energy availability is a constraint on economic growth, rather than energy consumption being an unnecessary by-product of economic growth. Stern (2000, p. 281) concludes as follows:

> The multivariate analysis shows that energy Granger-causes GDP either unidirectionally as indicated by the first of the three models investigated or possibly through a mutually causative relationship... The results presented in this paper, strengthen my previous conclusions that energy is a limiting factor in economic growth. Shocks to energy supply will tend to reduce output.

The phrase "energy is a limiting factor in economic growth" is an important statement of conclusions. Energy consumption is not merely a by-product that can be decoupled from GDP growth. Deliberately reducing energy consumption will likely reduce economic growth, thereby increasing the reluctance of policy makers to attempt a reduction. For this reason we need to find out in which circumstances policy makers might be tempted to interfere with energy consumption. In the 1970s the typical explanation was a fear of energy shortages. This fear abated as supplies proved ample over the following decades and prices stayed low. Now the typical explanation is fear of pollution. So we turn to an examination of air emissions.

3. Energy and Pollution

3.1 Three Types of Air Contaminants

It is helpful to distinguish between three types of air contaminants: direct, indirect and CO_2. Direct contaminants are emitted to the air by stationary or mobile sources in the form in which they persist as contaminants. Examples include sulphur dioxide (SO_2), nitrogen oxides (NOx), particulate matter (PM), and carbon monoxide (CO). Indirect contaminants are formed in the air from other compounds. For instance, ground-level ozone (O_3) is not emitted directly, instead it is formed as a chemical reaction under intense ultraviolet light involving volatile organic compounds (VOC's) and NOx, which are themselves emitted. Likewise fine particulates, or aerosols, are formed from precursor compounds such as SO_2 and NO_2. CO_2 was not historically considered a pollutant because it is not a direct threat to human health. It has only become a focus of regulatory interest as an agent involved in climate change.

3.2 Prospects for decoupling from economic growth

The three types of air contaminants can be distinguished based on the ease with which they can be decoupled from economic growth. Briefly, the difficulty ranges from easy for the first type to difficult for CO_2. Emissions of direct air contaminants like SO_2 and particulates have been sharply reduced – to the order of 80 - 95% – in western countries despite decades of concurrent growth in energy use and output. The availability of scrubbers and other end-of-stack emission controls, more efficient fuel burning systems, higher quality fuel sources and similar technical innovations have been extremely effective in allowing western countries to increase their energy use while cutting emissions.

Plotting U.S. total particulate emissions against real income (Gross Domestic Product per capita) over the period 1945–1998 shows the relationship is clearly downward-sloping.

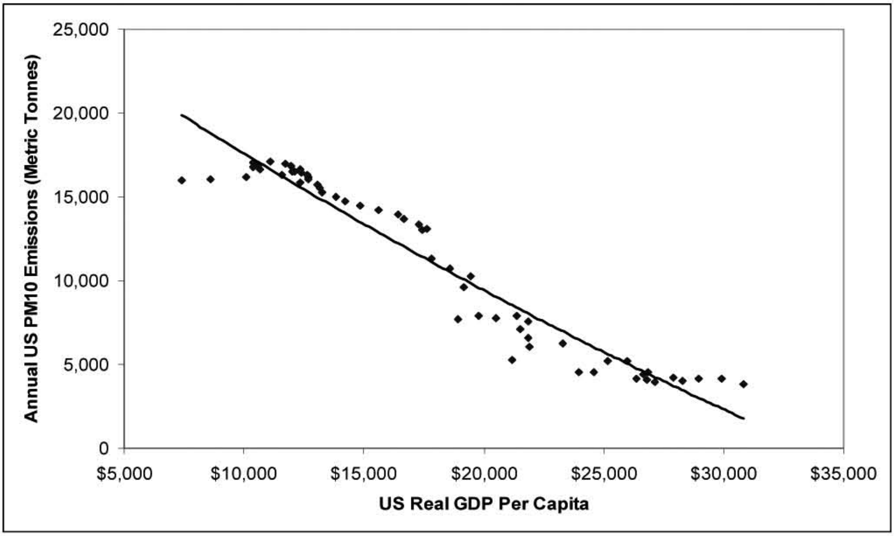

Figure 3.1: U.S. Real GDP per capita and total particulate emissions.

Source: McKitrick (2010 Fig. 1.7) using data from the US Environmental Protection Agency.

On the other hand, American carbon monoxide (CO) emissions over the same interval show an upside-down-U shaped pattern (Fig.1.8).

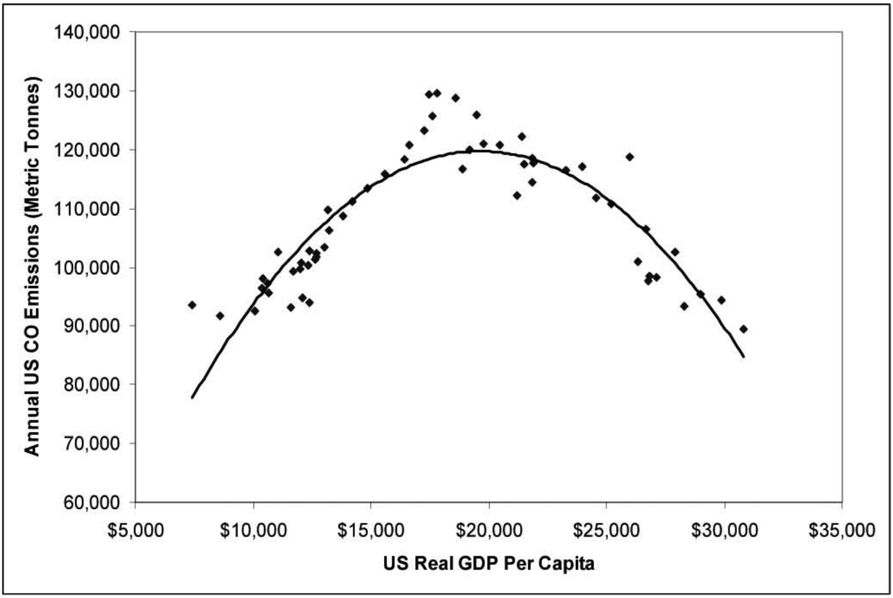

Figure 3.2: U.S. Real GDP and total carbon monoxide emissions.

Source: McKitrick (2010 Figure 1.8) using data from the US Environmental Protection Agency

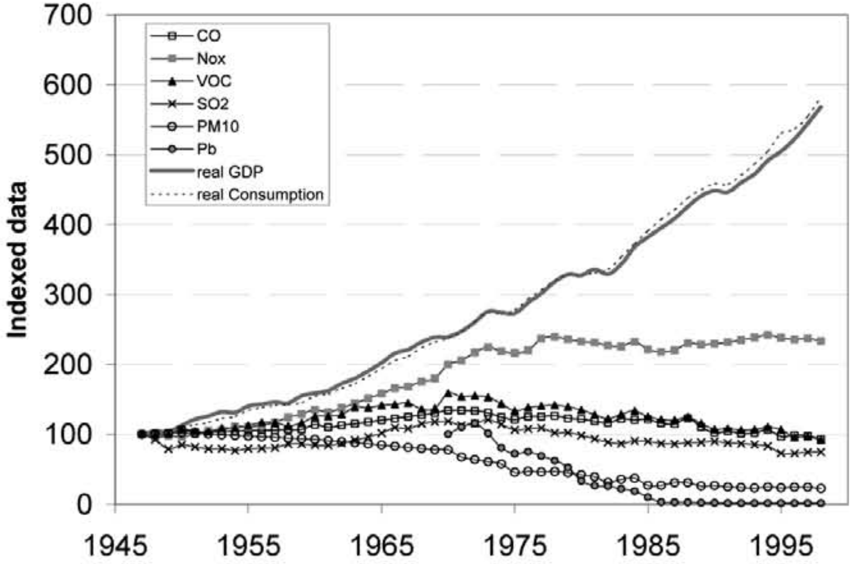

Figure 3.3: U.S. Emissions by type, 1945–1998.

Source: McKitrick (2010 Figure 1.9)

In both cases, it is clear that income and pollution are not positively correlated, and at current income levels are negatively correlated. By the end of the 1990s most direct US air contaminant emissions were at or below where they were at the end of the Second World War, and in some cases far below, as shown in this figure:

The data in Figure 3.3 have been scaled so the 1945 value equals 100 so that comparative changes are easy to visualize. NOx grew until about 1975 and leveled off thereafter, while all other air pollution emissions fell, and meanwhile real US economic growth continued accelerating. Clearly the decoupling of economic growth and conventional, direct air pollution has been proven to be technically feasible.

On the other hand, due to the complexities of the linkage between specific emission types and the formation of indirect contaminants, there has been less success dealing with ground-level ozone and aerosol pollution. For example, the rate of formation of O_3 is not a simple linear function. Under some circumstances, reductions in NOx emissions may *increase* ozone formation, rather than decrease it (Adamowicz et al. 2001), depending on the level of UV light and the abundance of VOCs. O_3 only falls if VOCs and NOx are reduced together in the correct proportions. NOx emissions themselves are controllable, though not as easily or cheaply as SO_2 or CO.

Figure 3.4 shows data from Toronto, Canada, and may be taken as typical for many North American urban locations. The monthly average ozone level shows strong seasonality, peaking in summer and reaching a minimum in winter, and there is relatively little trend over time.

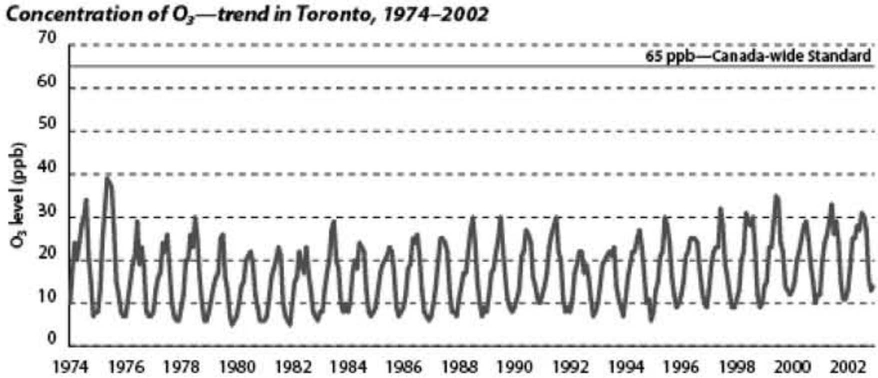

Figure 3.4: Toronto monthly average ozone concentrations 1974-2003.

Source: McKitrick et al. (2005). Data from Environment Canada NAPS archive.

However, one feature of the data not apparent in the monthly average readings is that the summer ozone spikes have tended to become less intense over time, leading to a reduction in local violations of ozone standards in North American cities. Ozone standards in North America are not based on average levels over time but on peak levels reached during episodes in which meteorological conditions favour rapid ozone and aerosol formation ("smog" episodes). These usually occur on hot, muggy days in summer. Figure 3.5 shows the reduction in monitoring site violations in US cities from 1975 to 2000. As is clear from the data, these events now occur less frequently, even though the average ozone level has not declined a great deal. Also note that, by comparison, CO violations have fallen much farther, effectively to zero by 2000.

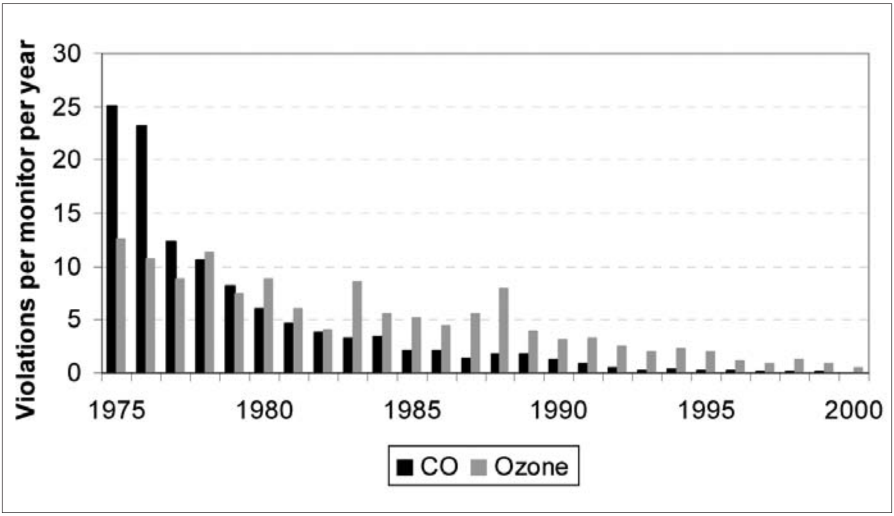

Figure 3.5: U.S. Air Monitoring Violations per station per year, CO and Ozone.

Source: McKitrick (2010) Figure 1.10.

The third type of contaminant is CO_2. In this case, there are no scrubbers, nor are emissions reducible simply by increasing the efficiency of the burn. The emissions are strictly determined by the carbon content of the fuel. Consequently, CO_2 emissions are effectively an index of fossil fuel use, with the carbon/joule content highest for coal, next for oil and least for natural gas. While it is possible to remove the CO_2 from a smokestream, it emerges as a gas and cannot be disposed of except by pumping it deep underground, which is costly both financially and in energy terms, as well as being feasible only in limited locations. So, in effect, CO_2 emissions cannot be decoupled from economic growth except by the slow process of increasing energy efficiency or switching from coal to oil or gas for electricity production. Since coal has, historically, been the cheapest form of fossil energy for electricity production, as well as the easiest to transport and the one most widely available, it has an advantage in terms of cost and convenience. Since it is also the most CO_2-intensive form of fuel, this means that CO_2-intensive power generation has a relative cost advantage over other forms. Coupled with the absence of scrubber technology we understand the reason why attempts to sharply reduce CO_2 emissions can be expected to have serious economic consequences.

4. The Energy Mix

4.1 Price and Production Trends

The reason for the long term position of coal as a leading energy source is shown by the following chart, which tracks real energy prices from 1949 to 2010. Coal is not only the cheapest energy source, but has the least price volatility. Natural gas remains relatively expensive even after its recent large drop in price.

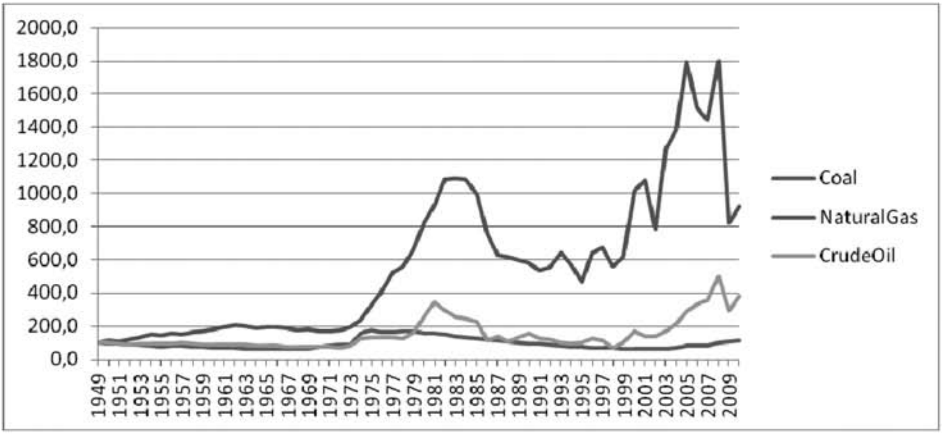

Figure 4.1: Real fossil energy process, 1949-2010. (1949=100).

Source: http://www.eia.gov/totalenergy/data/annual/index.cfm#financial.

On the production side, fossil sources continue to dominate electricity production, as shown in Figure 4.2. In 1973, 86.6% of world energy came from coal, oil and natural gas. In 2009 these sources contributed 80.9%, with nuclear now providing 5.8%. The share attributable to biofuels, waste, geothermal and other renewables went from 10.7% to 11%, in other words, it hardly changed. Even in countries that engaged in significant policy effort to increase use of renewables, they did not gain much market share. American data are shown in Figure 4.3. Up to around 2006 renewables remained at or below 5% while coal grew steadily to just over 30%, after having fallen from 40% to about 20% in the 1950s and 60s. After 2006, heavy policy intervention led to renewables growing from 5% to 7%, displacing some coal and nuclear, while natural gas grew from 30% to 33%.

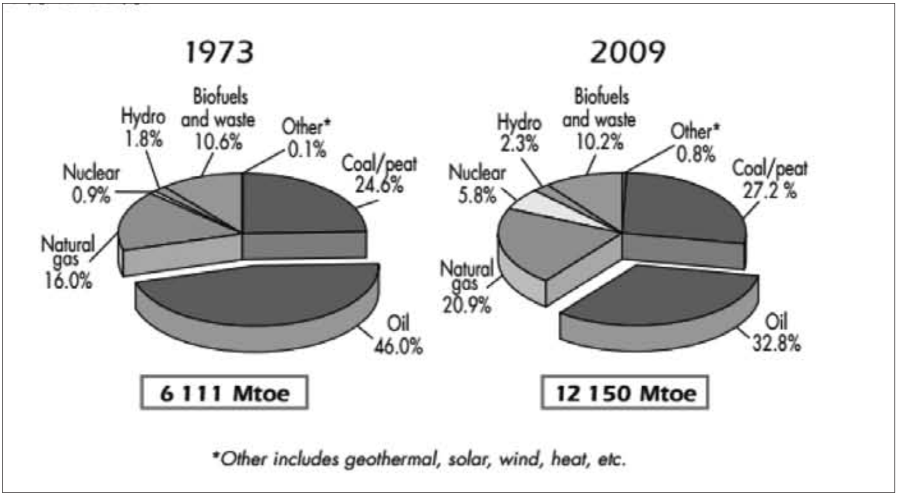

Figure 4.2: World energy production by fuel source.

Source: http://www.iea.org/publications/freepublications/publication/key_world_energy_stats-1.pdf.

Fossil sources (coal, gas and oil) accounted for 91% of US energy in 1949, and 78% in 2010. Most of the difference was made up by the introduction of nuclear, which now provides just over 10% of US energy. The continued dominance of fossil sources, and the failure of renewables to advance, are an indication that there are considerable technical and economic obstacles to their use. The economic obstacles are indicated by the fact that they only advance when subsidies are offered, and they decline when the subsidies are removed.[1]

1 See, for instance, http://www.bloomberg.com/news/print/2012-05-29/spain-ejects-clean-power-industry-with-europe-precedent-energy.html.

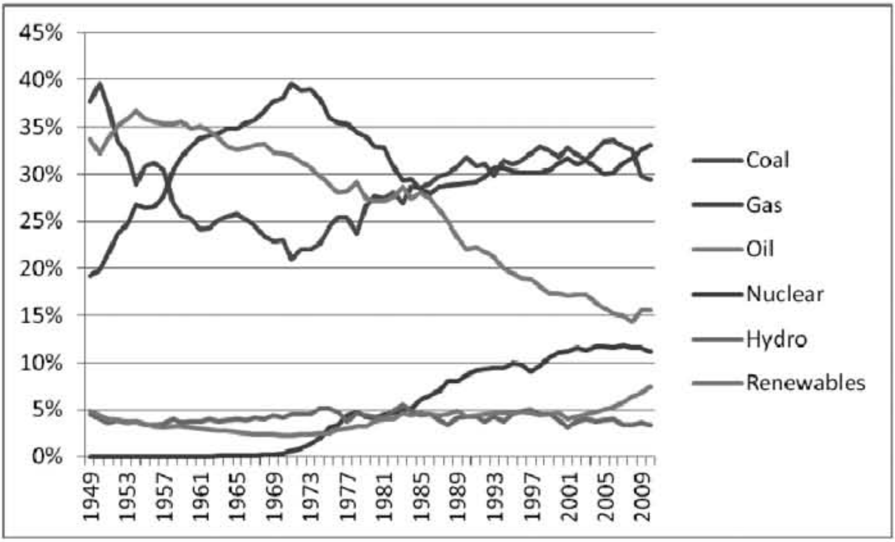

Figure 4.3: US Energy production by fuel source.

Source: http://www.eia.gov/totalenergy/data/annual/index.cfm#summary.

5. Economic principles

5.1 Using the price system

Ignoring pollution externalities and natural monopolies for a moment, if we ask what would be the best way to organize a country's electricity generation system, economists will typically turn to the price system to find the best way to proceed. The price system does not dictate how the energy will be provided, it only provides a mechanism for the market to do the job in the most efficient way possible.

On the supply side, investors need to make long term commitments to a physical capital stock and accompanying fuel sources. The price system naturally encourages the processing of large amounts of information necessary to find and select the options that minimize the long term cost of production, given the relative endowments of resources available in each location. The result is a supply schedule that presents consumers with electricity quantities and their corresponding unit prices. If the supply system is competitive, these prices will converge on the marginal value to society of the resources used to provide the electricity. Then consumers can make decisions about how much electricity to use, presumably on the basis that the value they derive from each kilowatt of consumption exceeds the cost of purchasing it.

This is standard microeconomic reasoning, and applies to any energy market, including fuels. The point to be emphasized is that there is nothing special about electricity. The price system provides incentives for efficient supply and demand decisions without the need for a central coordinator. However, two issues can arise that require modifications to the market structure. First, because electricity generation can involve large capital expenses there is a risk of natural monopolies forming. If one envisions a situation in which a market is small relative to the size of any power source, the first operator to enter the market can achieve economies of scale so quickly that any potential entrant must do so at higher supply costs than the incumbent. In this case no firm will be able to contest the market and a monopoly will result. The incumbent firm can then over-charge consumers, setting the price up above the competitive rate but just below the rate that would attract competitors. This issue is often presented in textbooks, but in practice is not a great concern. If a single monopolist emerges, it is relatively straightforward to implement price regulations to limit its power to overcharge consumers. Moreover, technology is such that continental electricity markets have formed in which suppliers must compete with each other to an extent sufficient to alleviate concerns about natural monopolies. If supply monopolies exist today it is likely that they are the result of government policy, not the rationale for them.

Second, and more relevant to this discussion, some power generating sources generate external effects in the form of air emissions. The question then becomes, how should policy makers intervene in the power sector to address this? The next section will examine this more closely using microeconomic reasoning, but the key concept can be stated simply as the principle of targeting. Whatever the matter for regulatory concern, efficiency is aided by targeting the intervention on the specific issue itself, rather than on secondary issues or matters only partly connected to it. If the issue of concern is the sulphur coming out of a smokestack, implement policies that regulate the sulphur coming out of the smokestack. Do not implement policies that tell customers hundreds of miles away from the smokestack how they should boil their eggs, in the hopes that this will affect how much electricity they use and, eventually, how much sulphur comes out of the smokestack. Any reductions in sulphur emissions achieved by rules about how people hundreds of miles away should boil their eggs will be achieved with far greater cost and inconvenience to industry and the public than a rule directly limiting sulphur emissions. It would be more effective and efficient simply to regulate the sulphur emissions themselves and leave the remaining decisions about electricity supply and demand to market participants. The idea, once grasped, is intuitively obvious, yet modern environmental policymaking seems to have completely missed it, as evidenced by the proliferation of rules about appliance standards, light bulbs, windmills, etc., all of which are done in the name of controlling emissions coming out of power plant stacks.

5.2 Taking into account externalities

5.2.1 Emission pricing

No conceptual difficulties emerge when incorporating pollution externalities into the standard microeconomic model of the market. At the theoretical level it is possible to solve the equations describing a welfare-maximizing competitive market outcome in the presence of pollution externalities.[2] It is a serious mistake to suppose that the mere existence of externalities renders the economic approach to energy markets invalid—far from it. The economic model handles externalities quite readily and provides sound guidance relating to the reasons for current policy difficulties.

If external costs were dealt with using price instruments, the basic insight of the Sandmo analysis is that, rather than subsidizing indirect control measures or regulating quantities in related markets, emitters should pay a fee per unit of emissions that reflects the marginal social cost of their actions. This is an old idea, traditionally attributed to Pigou in the 1920s, but the Sandmo analysis allows us to draw more detailed conclusions.

First, the optimal policy applies to the emissions themselves, and nothing else. Any additional price or regulatory intervention must, by necessity, make it costlier to achieve the same outcome. This goes against the instinct of policymakers, who often want a "portfolio" of measures to deal with what sounds like a complex issue. In the case of greenhouse gases, since so many sectors of the economy are involved, and the industrial processes are often very complex, policymakers have apparently taken the view that many different complex rules and procedures are needed. But this is a fallacy, and reflects a confusion in thinking. Despite the number of economic sectors and complex activities

2 Sandmo (1975) is the standard reference on this. My textbook (McKitrick 2010, chapter 8) provides a detailed derivation and explanation of Sandmo's result.

involved in greenhouse gas emissions, only one price instrument is needed, namely a price on CO_2. The rest can follow from decentralized decision-making without the need for central economic planning.

Second, the optimal policy should take the form of a price on emissions set somewhat below the estimated marginal damages, with the reduction proportional to the inverse of the marginal cost of public funds. The reason for this condition has to do with the distortions created elsewhere in the economy by the necessity of funding the government using a tax system, which inflates the cost of providing public goods, including pollution control. If the funds raised by a carbon tax are treated in a revenue-neutral way, namely to pay for reductions in other taxes, and the carbon tax is scaled to take into account the overall distortionary burden of the rest of the tax system, then the resulting emissions level will reflect the optimal tradeoff between costs and benefits of pollution control and the emission reductions will have been achieved at the minimum cost to society.

5.2.2 Pricing versus quantity targets

The integration of pollution control into general optimal policy making can be achieved naturally in a framework in which the policy targets the emissions price, rather than the quantity. In other words, economists have worked through the optimal conditions for pollution policy by thinking in terms of emission fees (prices), rather than emission standards (quantities). This is partly for convenience, since the math is easier when working in terms of prices rather than quantities. But there are deeper reasons for favouring price instruments even when it is possible to devise a policy intervention that targets quantities. Only in very simplistic frameworks is there a symmetry between regulating price and regulating quantity. Some policy analysts mistakenly assume that the two are always interchangeable. In the carbon policy world this means that policymakers are sometimes told that it makes no difference whether they opt for a carbon tax or a tradable permit (cap-and-trade) system. But this is incorrect for two reasons.

First, pricing instruments raise revenue by capturing all the scarcity rents. Any policy that limits a valuable activity (such as by imposing emission reductions) creates gaps between the cost of providing a good or service and the return on it at the regulated margin. These gaps create windfall gains, or “rents” as economists call them. A good example is the taxi industry. Cities issue a limited number of licenses for taxis, and in most cases the number of licenses, and hence competitors, is limited to such an extent that taxis can charge more than the actual cost of providing the service. Knowing that these rents are created by the licensing policy, buyers are willing to pay considerable sums to get a taxi license. The license itself costs nothing for the regulator to create, so the value of the license represents the capitalization of the expected rental flows. It is not new wealth, however, instead it is a transfer from households to license owners, and the rents transferred are always smaller than the additional costs created by the license system. The difference is referred to as the deadweight loss.

Caps on emissions also create rents, but they are hidden in layers of economic activity and accrue to industries and investors in ways that can be difficult to predict. Just as with taxi rents, they are not new wealth, instead they represent transfers of wealth from consumers to producers. If the regulator uses cap-and-trade, issuing permits and then allowing firms to trade them, the value of these rents becomes visible as firms bid for the permits.

For instance, if a regulator issues permits for 100 megatonnes of carbon emissions, and they trade on the market for $20 each, the total capitalized value of the rents created by the policy is therefore 20 x 100 million = $2 billion. The total cost of the policy to households is therefore $2 billion plus the actual cost of emissions abatement – which will be passed onto households through higher prices and reduced rates of return for labour and capital – as well as the second-order distortions resulting from applying the existing tax system to markets where prices are now higher and quantities are lower. Emission fees capture the $2 billion for the public purse. If this is treated as new revenue then households are no better off. But if the revenue is used to fund reductions in other taxes, then the social cost of the policy drops by $2 billion plus the value of the reduced excess burdens of the tax system. It is possible to capture the rents from tradable permits by auctioning them rather than giving them away free, but this practice has been rare. It is not possible to capture the rents under a system of regulatory standards. Hence quantity and price controls are not symmetric in their overall macroeconomic costs, since quantity controls typically fail to capture the rents created by the policy and this adds to the costs to households.

Second, the symmetry between price and quantity breaks down when there is uncertainty. A regulator can target the emissions price, and let the market determine the resulting quantity, or he/she can target the emissions quantity, and let the market determine the price, but he/she cannot determine both. The "price" of emissions corresponds to the marginal cost of emission reductions, or the marginal abatement cost. Having targeted the quantity of emissions, the market will determine the marginal abatement cost (MAC). If the regulator intends to target the marginal cost, the market will determine the resulting quantity of emissions.

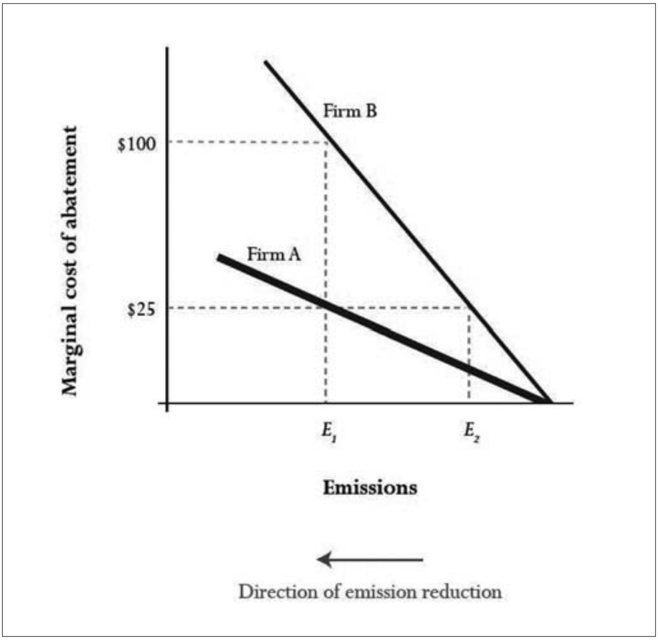

Figure 5.1.: Price regulation versus quantity regulation

Source: Taken from McKitrick 2012, fig. 4

Figure 5.1 illustrates what this means. The horizontal axis shows the quantity of emissions and the vertical axis shows the marginal abatement cost. As emissions go down, the cost of each further unit of emission reductions goes up, which is why the line slopes up as you read it from right to left. There are two firms. Firm A has a relatively shallow MAC line and firm B has a relatively steep one, meaning that it is relatively more expensive for firm B to cut emissions than for firm A. Now suppose the regulator orders each emitter to reduce emissions to the level E1. For emitter A this implies that the last unit of emission abatement costs $25, while for emitter B it costs $100. Now suppose the regulator did not intend emitters to pay more than $25 per unit to reduce emissions. By imposing a target on the emissions quantity axis (namely E1), the regulator forces the marginal costs to go above the intended level.

If the regulator instead imposed an emission fee of $25 per unit, both firms would cut emissions, since, over a limited interval, they save more in taxes by doing so than they incur in abatement costs. The point each firm would aim for is where their MAC line crosses the tax rate. Thus firm B will not reach the emissions level E1; it will reduce emissions only to the level E2. Below this point the firm's marginal abatement costs are above the cut-off.

The regulator cannot cap the marginal cost at $25 while asking both firms to cut emissions to E1. There is an inverse relation between the marginal cost cut-off and the volume of emission reductions that can be achieved. The higher the acceptable marginal cost of abatement, the lower the resulting emissions level will be. The lower the acceptable marginal cost, the higher the resulting emissions level will be. In this way the marginal abatement cost curve resembles a demand curve, since it shows the emissions level at each marginal cost level.

What happens if a regulator only intends for firms to incur a maximum cost of, say, $25 per tonne for abatement, but imposes a target that implies a marginal cost of, say $100 per tonne? Figure 5 shows that the result for firm B is a gap between the intended ($25) and the actual ($100) marginal cost. The size of this gap is a measure of the uncertainty cost arising from the policymaking error. Would it have been better for the policymaker to set a price target instead of a quantity target? The answer depends on two things.

First, if there are known danger thresholds associated with emissions, the regulator may decide that a quantity target is necessary, regardless of the costs. This may be the case with highly toxic local emissions, for instance. It is unlikely to be the case with general air pollutants that mix over large areas since emissions from any one source have relatively small effects on the overall concentration. In the case of carbon dioxide, since marginal damages of emissions do not change over the entire range of a country's emissions, this consideration does not apply.

Second, if the marginal abatement cost curve is relatively steep, it is more likely that targeting an emissions quantity will lead to relatively larger uncertainty errors than would an emissions price target. The steeper firm B's MAC in figure 5, the larger the gap will be between the intended and the actual marginal cost of emission reduction.

Since there are no scrubbers and no inexpensive abatement options, the marginal cost of reducing CO_2 emissions rises quickly. Attempting to pick a target on the quantity axis guarantees large swings and errors on the price axis. But for the same reason, when the MAC is steep, picking pretty much any emissions price will tend to yield only small errors in the resulting emissions level. Economists have shown that using price-based emission reduction policies for globally-mixed pollutants with steep MAC's – which describes the CO_2 case—leads to lower uncertainty costs, or in other words lower costs associated with errors in choosing the right level of policy intervention.

In practice it is much more common for regulators to target the emission quantity than the emissions price, or marginal cost. But this is only due to habit, and in reality there is always an implied emissions price. If the regulator picks a target like E1 and insists that it be enforced, this implies the marginal cost cut-off is at least \$100; in other words we are willing to force emitters to incur costs of \$100 per tonne in order to reduce emissions.

It is important to recognize that the "success" of a price-based instrument is not measured by whether the emission reductions achieve some arbitrary quantity target. In Figure 5, it is not the case that a \$25 tax is "successful" in reducing firm A's emissions but "unsuccessful" at reducing firm B's emissions. The tax was successful at reducing each firm's emissions up to the point where further emission reductions would be inefficient. The fact that Firm B undertook relatively little abatement is not a failure, it is the efficient outcome.

5.3 The pricing principle

Even if, for some reason, a policymaker insists on regulating the quantity of emissions rather than the price, the analysis herein can still provide guidance on how it should be done. Emission pricing works in practice, but it also works in theory. So at a simple level we can conduct an economic thought experiment along the following lines. Suppose we are concerned about particulate emissions from power plants. In line with the principle of targeting a per-tonne price is placed directly on particulate emissions. How would emitters respond? Analysts familiar with the power sector can likely offer some reasonable speculations. Some firms will have older plants that they simply close down and replace with newer more efficient units. Some will install scrubbers and other end-of-pipe treatment. Some will find all their options too expensive and will just pay the tax instead. Once these responses have been initiated, the price of electricity from power plants would probably go up slightly. Other firms might then look at whether nuclear, wind or solar energy is now cheaper to provide than coal-powered electricity. From the North American experience the answer is probably not. We can see from Figure 3.3 that US particulate emissions (PM10) had already fallen 50% by 1975 before nuclear power became a major energy source, and nuclear required heavy government subsidies to make it viable. Particulates had fallen close to 90% by 2005, after which wind energy began to grow only because it was pushed by government policy. So even after incurring the costs of heavy PM10 reductions, the private sector was still reluctant to invest in nuclear and wind sources without government subsidies. This means that even after pricing in pollution control for conventional sources, it remains relatively inexpensive compared to alternative energy sources, so the production sector would not respond to an emissions tax by, for instance, building windmills.

Likewise, we can ask how households would respond to the slight increase in electricity cost once a tax on particulate emissions was implemented. Chances are most would make only slight behavioral changes, such as reducing power consumption a little bit. There might be a few changes at the margin in appliance and light fixture choices, but it is unlikely households would make an extreme switch towards one type of lightbulb, for instance.

If the regulator wants to use quantity controls rather than pricing instruments, the pricing principle states that the best way to do so is to figure out how firms would have responded to a price, and then aim for that outcome in the quantity space. So in our thought experiment, concerns about particulate emissions would mainly lead to adoption of scrubbers and accelerated turnover of old plants, but not to investment in wind energy or complete rejection of existing household appliances and light bulbs. The contrast with actual experience then becomes evident. Regulators concerned about air pollution have required installation of scrubbers but also offer lavish subsidies for wind and solar energy and have issued bans and directives on various household appliances. These are wasteful and unjustified.

In the same way, we can ask how firms would respond to a levy on carbon dioxide emissions? Many power generating firms would simply pay it and only slightly adjust their fuel consumption, because of the steepness of their marginal abatement cost curves. Others would act more aggressively, perhaps by replacing coal plants with natural gas ones. But under any reasonable carbon price it is unlikely German power producers would have invested much, if anything, in solar farms or wind turbines. Hence the push to develop these industries is not justified as a CO_2 emissions policy, since a policy targeted on efficient control of emissions would not have led to them being developed.

6. Concluding remarks

Growth in energy consumption is not just a by-product of economic growth, it is a causal factor. Attempts to constrain energy consumption can therefore be expected to impede economic growth. Fossil-based energy, especially coal, has a stable long-term economic advantage as a fuel source. Concerns about pollution have led to considerable policy intervention in the energy sector over the past decade, but much of it has been based on misunderstandings of the relevant pollution issues. Conventional air pollution is not a necessary by-product of power production and has been successfully decoupled from it in western countries through development of scrubbers and other end-of-pipe treatments. Indirect air contaminants, such as ozone and aerosols, are not trending upwards and peak level episodes have fallen, but the complexities of the atmospheric processes in these cases make progress inherently slower. Carbon dioxide is not controllable by conventional scrubbers, instead it is tied linearly to energy consumption. CO_2 emission reductions will therefore be much more expensive to achieve under current technology.

Economic reasoning has led to a few basic ideas for guiding energy and pollution policy. The principle of targeting states that regulations should be focused directly on the variable of interest. If we are concerned about air pollution coming from power plant smokestacks, then we should regulate the emissions coming from the smokestacks, not kitchen appliances in households hundreds of miles away who buy their electricity from the power plant. The principle of pricing states that the most efficient outcome of well-designed regulations will match that which would have resulted from using price instruments directly applied to the emissions of concern. In practice, achieving that outcome is easiest simply by using price instruments. But if this is not feasible, the pricing principle can still be used as an analytic tool to understand why some interventions, like the subsidy-driven expansion of the renewables sector, is inefficient.

7. References

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