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An analysis of the effects of policies: the case of coal

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An analysis of the effects of policies: the case of coal

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Abstract: The shift to more sustainable energy regimes requires the implementation of the right mix of policy options to internalise fossil fuel externalities. This paper focuses on coal. Coal is the main fossil fuel for energy production and also the key driver in emerging economies (China, India). On the other end of the scale, coal has also been the driver of developed economies (EU, US), and a systematic review of policy options offers several insights on the path to sustainability. Whereas coal combustion externalities (mainly CO2) are well regulated, policies for coal mining externalities are generally neglected. Policy options present multiple characteristics, and this paper engages in a formal discussion of the externality and efficiency nexus and presents the results of a systematic web search for coal mining externalities. The strength of this search is the review it provides of several national and international reports/papers on coal mining effects. Policies dealing with environmental and societal externalities are also reviewed. Results show that command-and-control is still the most common mechanism. However, mature economies (e.g. the US) have successfully shifted in the direction of voluntary agreements. These mechanisms promote efficiency and minimise distributional effects. It also emerges that landscape and biodiversity losses are not well regulated.

Key words: Externalities, Redistributive Effects, Valuation of Environmental Effects,

Valuation of Environmental Policies;

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Dedicated to the 301 coal miners
killed in Soma, Turkey, May 2014

1. Introduction

All production processes cause 'external' effects in one form or another. In fact, the maximisation of private profits or the directives of bureaucratic planning act as strong incentives to individual cost reduction at the expense of third parties. Fossil fuel production is no exception and externalities from fossil fuels have been attracting attention since the early 1990s. Fossil fuels produce externalities in several stages of their life cycle: extraction, transport, processing and combustion. Currently the social costs of fossil fuels are not well accounted for and several policy options have been designed to internalise externalities. Therefore, interest in designing effective policy options is still very much alive and a unique example is the great attention dedicated to CO2. CO2 is an external cost in fossil fuel consumption and a number of policy options (trading schemes, regulations, etc.) have been implemented to minimise its effects on environment and society.

The focus of this work is rather on the policy options available for neglected externalities such as those of coal mining. This choice is motivated by the risk that coal production will continue to increase massively. In the down slope of the oil consumption peak the possibility that governments/industries may create petroleum substitutes from coal is emerging. Many states are still rich in coal and new technologies and competitive prices are creating the ideal environment for an increase in the demand for coal in the near future.

Coal extraction has evolved rapidly over recent decades. In Europe, for example, coal extraction was initially subsidised and publicly supported and policy mechanisms were used to encourage coal industries. In the mid-1990s growing concern about the environmental impact of coal emerged in Western and Central Europe and decision-makers implemented a combination of reforms to minimise these (Steenblik & Coroyannakis 1995). Some countries closed down their mines and started importing coal from abroad. The UK closed down more than 900 mines during the 1947-2008 period (Jardine et al. 2008). This de-localisation increased coal transport effects by 2% and the net global effects of these policies was not fully determined (Steenblik & Coroyannakis 1995). Reductions in subsidies to coal industries in Europe certainly benefitted the environment but coal industries continue to evolve globally. US and Russian coal extraction has remained constant but the newly industrialised countries of China and India have recently started extracting coal. Coal has many advantages for newly industrialised countries: it can be extracted without advanced technology, is relatively cheap to extract and often available locally. This implies that while policy tools in Europe and US policy mechanisms mainly target reductions in coal mining externalities, elsewhere they are used to promote coal industries.

In this paper the focus is on coal mining externalities and policy mechanisms aimed at internalising them. Coal mining is still a growing industry in many developed and developing countries and the growing attention paid to the social and environmental impact calls for a systematic review of policy options. This paper presents a review of policy options for coal mining externalities based on advanced Google search engines. The link between the economic concept of externality and efficiency is presented in order to highlight what is actually involved in the phenomenon of external effects connected to fossil fuels. The three main characteristics of a policy option - efficiency, efficacy and distributional effects - are discussed and assessed by means of a review of the literature. The research follows a hierarchical structure and starts with a description of coal mining externalities. Epstein et al. (2011) quantify coal mining externalities and suggest a hierarchy of impact severity which is reflected in our findings. The intention of this paper is not to provide a definitive conclusion on the best policy option. Defining 'best' can be controversial and is highly influenced by socio-economic, political and country-specific factors. The paper reviews policy options on coal mining in a number of countries and explores the limitations and potential of the main policy mechanisms. The results show that policy options (mainly command-and-control or voluntary programs) are popular tools in internalising coal extraction externalities but a variety of policy mechanisms has been implemented in the various local contexts.

2. Background

In 1995 an International Conference held at Ladenburg (Germany) on 'Social Costs and Sustainability' discussed fossil fuel externalities, energy and transport costs and reviewed the results of the EU ExternE project. ExternE was the first comprehensive attempt to use a consistent "bottom-up" approach to evaluate the external costs of various fossil fuels. Some commentators have, however, highlighted that the €1.5 million external cost of coal plants in the EU estimate underestimated the true costs of coal use. The ExternE project completely overlooked other stages in the coal life cycle - such as mining. Furthermore, the ExternE steering group did not identify possible action aimed at internalising external coal costs. Hohmeyer et al. (1991, 1997) filled this gap, discussing the main policy options available and their market effects. Detailed results on the coal production and environment and society cause-effect nexus have been published in recent decades (e.g. Galetovic-Munoz 2013) but world energy consumption is still coal reliant. Fig. 1 shows that coal energy use did not increase in the 1990-2000 period but over the last fifteen years it has significantly escalated (IEA, 2012) and forecasts are scary.

According to the US Energy Information Administration (US EIA) coal will continue to play an important role in meeting global energy demands in the foreseeable future and world coal consumption is expected to increase by 56% from 2007 to 2035 (US EIA 2010). Coal is considered an important source of energy for various reasons. Firstly its market price is still very low and highly competitive (Fig. 2). Secondly, the Kyoto Protocol imposed no penalties on exporting products made with coal thus giving countries using coal to make export goods such as China and India a competitive advantage. Finally, many nations are still rich in coal and many plants are still coal based. This projection and coal's long lasting success ignores the huge costs of coal production for society and the environment.

The IPCC (2007) has estimated that methane emission in coal mining costs 0.11/KWh (2008$). Epstein et al. (2011) has estimated that coal extraction costs are roughly three times this figure and coal production impacts in other ways as well. Governments should balance higher coal production demands with better society and environment safeguards. In this respect, policy options will play a crucial role.

3. Externalities, economic efficiency and policy options

A policy to reduce environmental damage (a typical example of negative externality) is often referred to as a cost. In principle, if an externality is corrected - in order to eliminate inefficiency and achieve efficient allocation – no costs are incurred and the result is clear-cut gain. It is the purpose of this section to clarify this statement.

The traditional economic approach is set and efficiency is both the benchmark with which an economic system's performance is evaluated and a policy making goal.

When two parties are involved, efficient allocation ensures that one party cannot be made better off without making the other worse off. Therefore if an arrangement can be found whereby one or both parties are better off it follows that the previous allocation was not efficient. When externalities occur a system is not efficient and several solutions can be implemented. The main policy mechanisms can be summarised into three macro-categories (Fig. 3): i) traditional mechanisms, ii) market-based mechanisms, iii) innovative mechanisms.

'Command-and-control' is a traditional tool with which to internalise externalities. Such tools set uniform standards for all firms irrespective of their production costs. Standards can be technology or performance based. The former dictate the method or equipment that that firms must use to minimise environmental impact. The latter define a target which firms can achieve using a range of strategies. These mechanisms were first introduced in the 1970s and were used widely for several years.

Market-based tools were introduced in the 1980s and are believed to encourage environmental friendly behaviour by means of market signals such as tradable permits or pollution charges. If such mechanisms are well designed and implemented they encourage firms (and/or individuals) to attempt pollution control, satisfying their own interests alongside collective interests set by the political agenda.

In the early 1990s several countries implemented 'green tax reform' and in this context innovative policy options such as voluntary agreements or environmental bonds were introduced. Since then several new policy tools have been introduced and the OECD (2001) reviewed several green taxes and their chief effects. Policy mechanisms each have advantages and disadvantages and commonly used parameters are:

- static and Dynamic efficiency;
- distributional effects.

Static efficiency refers to the current costs of implementing environmental friendly behavior. Command-and-control sets uniform standards and this creates static inefficiency. Firms are far from uniform and even if they produce the same goods they may use different technologies and processes to do so and vary in size, scale, location and hence, overall efficiency. In this context regulators need information on which to base their standards and bear implementation monitoring costs. Furthermore, ratcheting up standards over time is costly and creates antagonism between regulators and firms. Market-based and innovative mechanisms, on the other hand, are chosen or designed by firms and create incentives for ongoing improvements. Such tools can evolve rapidly to satisfy new environmental requirements and are considered cost-effective.

Dynamic efficiency relates to the future costs involved in achieving environmentally friendly behaviour. Command-and-control tools do not create innovation incentives for industries who tend to invest to meet standards and then call a halt to them. The other mechanisms generate ongoing incentives to evolve and are dynamically efficient.

A simple description of distributional effects is not sufficient and the issue will be discussed in a formal debate on the externality-efficiency nexus. Let us start from the simplest possible case of two parties, a mining company and a farm.

The mining company pours waste into the river nearby during its production process with the result that the farm's water is polluted. This is a typical example of (negative) externality present whenever an individual relationship encompasses real variables whose values are chosen by others without the individual concerned being involved.

If, like Pigou in his *magnum opus* (1932: Part II, chapter I), we look at the economic system as a whole and, in other words, take a social perspective, it is evident that the damage (in our case to the farm) is a real cost which ought to be evaluated in any assessment of the efficiency of the real allocation. The fact that this real cost is not borne by the mining company does not mean that is not real. It inflicts real damage to the value of the farm's activities at given market prices. In other words social cost assessment and private calculations diverge. Certain costs are left unaccounted for in private calculations: the marginal cost curve that the mining company faces does not reflect all costs. In this way actual allocation differs from that which would be achieved if costs were properly calculated and, more specifically, resources are allocated in such a way that they do not reflect the

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true costs and are thus inefficient. As it is not required to pay the costs of the damage to the farm the mining company is encouraged to mine more coal at given market prices.

Two separate questions arise. What can the two parties to such a situation do? Can a third party with efficiency goals design an efficient policy?

As far as the first question is concerned one option is for the two firms to merge. This would eliminate negative externalities and therefore inefficiency (provided that the markets remain competitive). This solution is likely to be implemented only if the two parties would be better off afterwards. In turn, this entails at least one party gaining and the other either not losing out or being compensated if it does. If such a merger does not actually occur it may mean, for example, that the farm does not have enough to offer to convince the owners of the mining company to merge. One is tempted to conclude that, unless we resort to the social point of view drawn up by Pigou, no inefficiency follows from the negative externality in this given institutional situation (which cannot be changed by the parties concerned). In this specific example, in which only two agents are involved, as Baumol & Oates (1988) note, taxes or subsidies are out of question. But there is another option, put forward by Coase (1960) on the basis of his innovative approach. This presents itself when property rights are well defined and clearly allocated. Two cases arise in our specific example in a perfect competition context: either the farm has the right to clean water or the mining company has the right to mine and pollute. In this situation the two can voluntarily agree to sell and buy property rights. Under certain conditions such agreements may take place and, it is argued, efficiency will thus be achieved. This is often summed up by the observation that markets are remedy to the externality. Market-based economic systems (better, competitive markets) are thus inefficient only in so far as markets are not universal. It would be more accurate to state that the inefficiency associated with an externality manifests itself, as Pigou (1932: Part II, chapter IX) has already noted, when, for various reasons, bargaining between the individuals concerned is not possible.

The most significant conditions in which Coase's results are valid are twofold: transaction costs are negligible, which is likely to happen when only a few participants are involved (Baumol & Oates 1988: chapter 2), and neither party undertakes strategic action.[1]

If these conditions are met Coase's solution can be illustrated in a diagram (Fig.4)

The PMC curve represents the mining company's private marginal costs, the MD curve represents the marginal damage done to the farm and finally the SMC represents the social or true marginal cost as the sum of the previous two. On the other hand the MSB curve is the marginal (private and social) benefit that is represented in a competitive environment by the price consumers are willing to pay for coal. The producer's surplus when the firm is producing *0B* is *W+X+Y* whereas the damage to the farm is measured by *X+Y+Z*. Therefore the overall surplus is given by the difference between the two magnitudes, namely *W-Z*. It is apparent that if the mining company could be induced to produce *0A* its surplus would be *W+X* and the farm's *Z* hence overall it would be *W*, with *Z* measuring the overall loss for society when the mining company is producing according to its private convenience. Note that all these magnitudes are value magnitudes which depend on prices that are not within either party's power to modify.

Let us now look at the farm's right to clean water case study. In this situation the mining company can produce only if it can compensate the farm. The maximum amount the company can offer is the value of the extra-product profit whereas the minimum amount the farm can accept is the value of the damage done to it. If the first is higher than the second it is thus probable that an agreement will be reached.

How can an efficient solution be achieved? Note that when the mining company is producing *0A* its surplus is *W+X* whereas the damage inflicted to the farm is *X*. So that an agreement can follow to produce *0A* where the social marginal cost equals the social marginal benefit, if we are willing to assume that these monetary values also represent utility levels. On the other hand if the mining company produced *0B* it would not have enough money to pay the minimum sum required by the farm, the extra profit *Y* being less than *Y+Z*, the extra damage.

Let us now move on to the case study in which the mining company has the right to mine and pollute. It is now the farm that has to induce the mining company to produce less. The maximum amount it can offer equals the marginal damage that could be avoided if the mining company produced less. The minimum sum that the mining company would be willing to accept would be equal to the profit lost following a reduction in the amount produced. Again an agreement is probable if the former exceeds the latter. If the mining company produces *0B* the farm will have damage measured by *Y+Z* whereas the mining company's extra profit is only *Y*: an agreement not to produce that quantity can be reached. However the farm does not have enough money to induce the mining company to produce less than *0A*: in this case the profit lost is *W+X* whereas the damage equals *X*. As a result *0A* is the level that can be reached if the same considerations as before regarding utility levels are valid.

The intention of this brief description of Coase's analysis is simply to highlight that the specific distribution of property rights, although immaterial to the solution to the efficiency problem, has intrinsically distributive effects. The bargaining which takes place, even in absence of transaction costs, necessarily involves a redistribution of income away from one party and in favour of the other. In one case it is the mining company which pays out to the farm, in the other is the latter that pays out to the former. This can be reconciled with the characterisation of the end point as an efficient allocation at the social level if, as stressed, a few conditions are met. One party's gains are in absolute value greater than the losses suffered by the other. In our specific example this is easily assessed by the two parties involved. It is more challenging in more general cases unless one assumes that the gain in utility from one more euro for those who have been advantaged is in absolute value equal to the loss of utility from one euro less suffered by the disadvantaged. Whether or not this is empirically valid depends on actual circumstances. It is theoretically valid only in a very restricted set of cases: agents have the same incomes and tastes or the same tastes and homogenous indifference curves or, lastly, the same incomes and homogenous indifference curves. But, it has to be stressed time and again that an actual loss does take place for one of the parties involved unless compensation is paid (and in an undistorted way). In other words at best we are dealing with a potential efficiency gain.

This situation is akin to that in the evaluation of free trade in the Heckscher-Ohlin approach context. The shift from autarky to free trade in a capital abundant country intrinsically involves redistribution away from workers in favour of capital owners. The argument that free trade is in any case to be preferred to autarky rests on the assumptions mentioned above and on the (often implicit) argument that there is no difference between potential and actual gain: what are in actual fact potential gains are considered real gains. The possibility of constructing a social indifference curve rests on an assumption about distribution

In our specific example, therefore, bargaining will take place if participants' utility calculations are such as to lead to an actual gain for both or at least one of them. It would indeed be surprising if a party willingly entered a non-beneficial transaction. Nor is Coase's argument that his analysis demonstrates that when transactions costs are non-negligible a specifically favourable allocation of property rights occurs, namely one which involves the lowest level of cost, relevant.

It is important to stress that efficiency incurs costs and these are actual, distributive costs caused to one of the parties. If this is the case it is not surprising that losers if no compensation is paid to them, tend to oppose a reallocation that is potentially superior. Hence Coase' solution is less pertinent in practice. As an aside, note that exploiting Coase's argument could lead to the conclusion that if the relevant market does not exist is because overall benefits are less than overall costs. We might be tempted to argue, then, that inefficiency would simply disappear, a result which is not socially acceptable at least if other methods for an efficient allocation exist. And this takes us on to the second issue. It is more useful to go beyond the specific case we started with and think in terms of a whole sector, e.g. the coal industry, inflicting externalities on another, or possibly, on the whole economic system.

In such cases Coase's direct bargaining solution is practically impossible but the implementation of a tax is now feasible. Taxes on coal industry emissions will lead to higher marginal costs and prompt output reductions. Is this the whole story? Obviously not. What happens to the resulting newly unemployed workers? And the resulting drop in demand for other resources? This was overlooked in the initial case as the effect was negligible but in the present example the issue necessarily arises. Another issue is what these tax revenues are used for. Leaving aside the latter let us deal with the former.

To this end we will start by reconsidering the third part of the efficiency conditions characterising a Pareto optimum. As is well known the latter is made up of three parts: consumption, production and product mix efficiency. In the case of two goods, two individuals, two factors, the first requires that the two individuals concerned place the same relative value (at the margin) on the two goods; the second requires that the marginal rate of substitution between two factors must be the same in the two sectors; the third that the marginal rate of substitution between the two goods must be equal to the marginal rate of transformation of the two goods. These conditions must be valid for the economic system as a whole and it is argued that this is true of a competitive market price system. More precisely a set of universal competitive markets must exist.

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The third condition is sometimes interpreted as identifying the composition of the two goods needing to be produced for efficiency. A relative price level, identified by the tangency point between the community indifference curve and the production possibility curve, which also equals the marginal rate of substitution in consumption and the marginal rate of transformation in production, must exist.

A point which is often not made crystal clear is that postulating a given community indifference curve requires (save in exceptional cases) a known distribution of income. Therefore an efficiency point is only efficient in relation to that specific distribution. Unless this is done there will an infinite number of relative output points on the production possibility frontier.

A social welfare function can be useful for the purposes of identifying a social welfare function as it potentially enables a point on the utility possibility frontier to be identified which is in turn derived from the locus of all possible tangency points between the production possibility curve and the set of indifference curves. But if the latter can be built only knowing the income distribution, the social welfare function amounts exactly to choose a particular distribution of income, as shown long ago by Little in his criticism to Samuelson.

This brief recap highlights a profound difference between the second (and first) efficiency condition and the third. The second can be analised in physical terms without recourse to prices and utilising an efficiency definition according to which an allocation is inefficient if the welfare of one agent can be increased without reducing the welfare of the other(s).

The third condition has a different nature. Once we have leveled the marginal productivities of the factors in all the sectors we have just noted, a whole range of product mix that can satisfy this condition emerge: all those that lie on the production possibility curve. Choosing one point on this, namely evaluating which mix of heterogeneous goods is better, requires a way of comparing them, namely prices. Introducing goods prices (and therefore factors that are somehow connected) is tantamount to introducing income distribution.

The practical implications of this observation are as follows. It is not possible to argue that because a superior allocation to the current one exists (where the third condition is not satisfied), any move towards that allocation will be unambiguously better. Moving means changing the product mix and therefore prices and income distribution unless, of course, we are prepared to eliminate income effects on demand by postulating very restrictive assumptions.

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Suppose that the production mix is not in line with consumer preferences. In particular too much food and too few hi-tech goods are produced at given prices for a given demand. Resources are transferred from the food production to the hi-tech sector leading to an increase in the price of food and a fall in the price of hi-tech goods. If the poor consume food 'alone' they will experience a reduction in their real income which may outweigh the gain experienced by the rich buying 'only' hi-tech goods. Hence to pass judgment on the new allocation we need a different definition of (in)efficiency no longer based on values (and utility) rather than physical requirements.

Indeed this is what we have already done in analyzing the case of the farm and the mining company.

In other words, it is one thing to move from an allocation within the production possibility frontier to a point on it and an entirely different matter to move along it.

This argument is implicit in the definition of inefficiency following an externality which we introduced at the outset. Since correcting an externality requires a different product mix this in turn involves changes in income distribution. This will make some better off and some worse off. Even if we can show that there is an overall social gain under certain conditions someone somewhere will lose out or incur costs: these are precisely the costs that are being referred to when it is argued that costs are always involved in correcting externalities, even in the most favourable cases.

There is one way out from the theoretical viewpoint, namely assuming that all individuals have the same tastes and homothetic indifference curves. In this case income distribution is irrelevant as the mix of consumer goods is no longer income dependent and everybody consumes the same mix.

The upshot of this is that distributive effects cannot be ruled out in the actual implementation of policies designed to correct externalities such as those related to fossil fuels. This could be one of the reasons behind the actual specific policy tools chosen by policy makers.

4. Coal extraction and the classification of externalities

Coal extraction follows two main techniques: underground and surface mining. Underground mining includes: horizontal hill access, vertical shaft from the surface of the coal and slope mines which usually begin in a valley bottom with a tunnel sloping down to the coal to be mined. There are various types of underground coal mining and recovery rates range from 60 to 75% (coal left in the ground to support the roof of mine). Improvements in mining technologies have generated more efficient coal extraction but production efficiency potentially results in quality inefficiencies in the surrounding environment and society. Surface mining includes: area, contour, mountain top removal and auger mining. Area mines are surface mines which remove shallow coal over a broad area where the land is flat. Rocks overlying coal are temporarily removed for coal extraction. Contour mines are surface mines that mine steep, hilly or mountainous terrain. A wedge of overlying rocks is temporarily removed along the coal outcrop on the hill or mountain side. Rocks are put back when coal has been extracted. Mountain top removal mines are now a major form of mining in the US and the main driver of land-use change in several regions. This technique uses explosives to break up rocks and access buried coal and requires fewer workers. However the external impact of surface mining is wide ranging.

Epstein et al. (2011) presented a life cycle analysis of coal production and estimated the external costs of the US industry. Fig. 5 shows that the principal external costs are in combustion (blue rectangle) but extraction costs (red rectangle) are significant too. This justifies intense research into minimising coal combustion externalities (e.g. the EU trading scheme) but does not rationalise the disregarded effects of mining activities. The main mining costs are health and methane emission related. Table 1 presents a full classification of external coal impacts as in Epstein et al. (2011). This work focuses on the policies used to correct social and environmental coal mining externalities and we would anticipate that given the scarce attention paid to certain external mining effects (such as biodiversity loss or landscape damage) few or no papers will have been written about them. The Tab.1 classification and Fig.3 policy options set out the keywords for our web search analysis.

5. Literature review using advanced web search engines

A web search routine to review the literature on coal extraction externalities and policy options was set up. Google and Google scholar were used to review published articles and grey literature. It was established that the following criteria should be present:

- use of English;
- quantitative assessment (physical or monetary measures) of the problem researched;
- keyword driven search;

- web page domain search.

Web domains were chosen to collect information from the most relevant organisations such as the World Bank, Resource for the Future, EPA etc. Search terms were used in various combinations (Table 2). In total 126 key term combinations were web-searched and more than 300,000 documents found (see Appendix II for details). The first 10 relevant studies for each individual combination were extracted and analysed using the abstract. Only relevant studies were retained and thoroughly analysed and over 50 studies were ultimately summarised.

There are a number of important limitations to this review. Firstly, although the search for empirical/quantitative studies of coal extraction externalities and policy options was systematic and comprehensive, it is possible that some articles were missed. For example, international agencies rarely report facts on Indian coal mining. This might indicate that no internalising coal mining externalities policies are being implemented in India or that Indian cases are not of interest to international agencies. Secondly, given the tendency to publication bias (studies with statistically significant findings are more likely to be published) we may have overestimated coal externality effects or policy options with significant impact or study areas in which coal effects have been researched to a greater extent. Thirdly, Google research algorithms generate different results if research is repeated: this limits the potential for re-testing findings.

6. Results

The review used a two-fold approach. Firstly the quantification of impact for each externality was web-search related (Table 3). Secondly if one or more policy options have been implemented results are summarised with a focus on efficiency, efficacy and distributional effects. Web searches came up with no documents at all for some of externalities (see Appendix I for details) and these are not discussed here. Social and environmental externalities will be presented separately but it is clear that some policy mechanisms set up for safety reasons (e.g. methane ventilation in underground mines) can also promote environmental quality (e.g. capture of methane to reduce air pollution).

6.1 Social externalities in coal mining

A brief description of all the social effects reported in Table 3 is presented at the beginning of this section. However the policy options reviewed only refer to morbidity and mortality in coal mining communities. Table 4 reports the number of studies and reviewed policies found.

Although too often ignored, the coal mining occupational injury burden is still globally significant. "Historically no other occupation has been as dangerous as mining coal. Since 1900, over 100,000 miners have met death on the job. To this figure could be added the hundreds of thousands of miners who were permanently injured or died a 'slow death' from 'black lung'" (Lewis-Beck and Alford 1980: p.746).

Leigh et al. (1996) conservatively estimated that 3 percent of the annual global burden of illness is directly attributable to occupational conditions. UNDP (2000) confirms this reporting that occupational mortality rates for miners are up to 20 times the average for all occupations. They estimated 6,500 to 16,000 deaths annually worldwide. Harris et al. (2014) attempted an inventory of coal mining fatalities in Australia, China, India, South Africa and the US. The comparison is not a straightforward one for many country-specific difference reasons (i.e. definition of fatalities, regulation and control systems and technologies). However the authors apply a consistent definition of fatalities and their findings are shown in Table 5. Australia has the lowest number of injuries and China the highest. A critical distinction in this table is the mining system used. In general, whilst surface mining is still dangerous underground mines are more so. Hazards specific to underground mines are: coal dust, which can cause 'coal workers' pneumoconiosis often combined with silicosis. Coal dust is explosive and explosions are one of the main causes of death. Weeks (1998) reviews coal extraction and reports several toxic gases such as: carbon monoxide, carbon dioxide and methane. Carbon monoxide is extremely toxic because it binds to hemoglobin in the blood, blocking oxygen transport and causing chemical suffocation (Bascom et al., 1996). Another health hazard comes from the diesel engines used in underground machinery and transport vehicles. This exhaust contains very fine particles, nitrogen oxides and carbon monoxide all of which pose serious health hazards such as lung cancer (Bascom et al., 1996). Surface coal mining avoids some of the hazards of working underground. But it still involves risk of injury from machinery, falls and falling rocks. The machinery used is also noisy and hearing loss is a common problem. Another health hazard is the often squalid conditions under which many coal workers and their families live in developing countries leading to higher risk of poverty-related diseases. Coal mining community risks can be summed up as follows (Colagiuri et al. 2012):

- higher rates of mortality from lung cancer, chronic heart, respiratory and kidney diseases;
- higher rates of cardiopulmonary disease, chronic obstructive pulmonary disease (COPD) and other lung diseases, hypertension, kidney disease, heart attack and stroke and asthma;
- increased likelihood of hospitalisation for COPD (1% for each 1,462 tons of coal mined) and for hypertension (1% for each 1,873 tons of coal mined);
- poorer self-rated health and reduced quality of life;
- increased respiratory symptoms especially in children including wheezing, coughing and absence from school;
- high blood levels of heavy metals such as lead and cadmium;
- higher incidence of neural tube deficits, a high prevalence rate of all birth defects and a greater chance of low birth weight (a risk factor for future obesity, diabetes and heart disease).

For underground mines we reviewed 11 studies on US mines and 2 for China and Australia. For surface mines we reviewed 9 studies from the US only.

<u>US: Underground mines</u>

In 1910 the federal 'Bureau of Mines' agency was established to research and investigate mine safety. In 1941 Congress authorised Bureau of Mines inspectors to enter mines. In 1969 the Federal Coal Mine Health and Safety Act (Coal Act) sought to strengthen protection and introduced penalties and health standards. The 1977 Surface Mining Control and Reclamation Act consolidated all federal health and safety regulations. In the 1910-1969 period the number of injuries dropped significantly (Fig. 6). Adjusting for the number of workers, the fatality rate dropped from 48/10,000 deaths in 1907 to 12/10,000 in 1949. 1952, 1969, 1977 and 2001 US governments legislated to improve the health and safety of underground miners. Regulations were effective and a significant decrease in fatalities can be observed. Boden (1977) tested the 1969 coal mine regulation and proved that the benefits of regulation are greater than costs. Beck and Alford (1980) demonstrated this trend statistically and confirmed that governments can successfully regulate coal mines regardless of owner profit issues. Weeks and Fox (1983) confirmed these results.
Critics have observed that the free market would eventually have led to a similar downward trend. However, Lofaso (2011) highlighted significant differences in the pre and post

regulatory periods and Lewis-Beck and Alford (1980) confirmed the success of US coal mining regulations. Darmstadter (1997)'s results are inconclusive on the positive effects of regulation on coal mining accidents although he points out that the legislation was designed not only to reduce injuries and fatalities in the short term but also to create long term benefits. Therefore while the profit loss associated with improving health benefits is borne in the short term the benefits last for several decades. Lofaso (2011) observed that it is not only the number of fatalities which decreases but the number of accidents is also more predictable after regulation. This stability in coal mine fatality rates allows businesses to properly assess risk and workers to make more rational workplace choices. However, while preventing deaths regulations also reduce industry profits (Fig. 7). The supporters of the free market's role in preventing coal mine accidents are not contending that there would be fewer accidents without regulations but that there would be an efficient number of fatalities.

Darmstandter (1997) established that coal mining safety regulation forced firms to spend more money on labour and other safety inputs. 40% of these costs increased in the 1969-1979 period due to US mine regulation. Fullerton (1996) reports that taxes on coal mined in 1995 were \$1.10/ton in underground mines and \$0.50/t in surface mines. These taxes were designed to collect money for a trust fund to deal with one specific pollution problem (i.e. the Black Lung disability trust fund). Success was achieved in term of compensation but policies did not discourage externalities. Fullerton (1996) presented an input-output analysis to check the economic impact of environmental taxes. Coal taxes mainly impact on energy and metal producers but the overall burden for the coal sector is minimal. Hendrix and Ahern (2009) examined the number of deaths in the Appalachian region and demonstrated that the value of statistical life lost in the region is worth more than the overall economic contribution of coal.

<u>US: Surface mines</u>

The surface mining process involves removing vegetation and topsoil from ridges and peaks, using explosives to remove up to hundreds of feet of rock above and between coal seams and disposing of excess rock in adjacent valleys. Surface mining is currently very popular in the US coal regions. The main reason for this success is reduced labour costs. Surface coal mines require fewer employee hours per ton of coal and the number of deaths is consequently less. On the other hand, there is strong evidence that surface mining is highly polluting with serious health consequences (Hendryx et al., 2008; Baumann et al.

2011, Ahern et al. 2011, Rockett 2011, Hendryx 2011, Hendryx et al. 2012). These threats are further exacerbated by the poor socio-economic conditions in which coal mining communities live. In several papers Hendryx and his colleagues have pointed out the need for policies to create healthier coal mining communities. Four federal statutes play a significant role in regulating and enforcing surface mining standards:

- the SMCRA regulation issued in 1977 for all coal mining processes;
- the Clean Water Act;
- the National Environmental Policy Act;
- the Administrative Procedure Act.

The first two regulations provide substantive standards for surface mining regulation whereas the last two acts are procedural statutes guiding enforcement of the law. Kaneva (2011) has reviewed these regulations in detail but her main conclusion is a lack of stringent enforcement. Kaneva reports that in 1997 75% of the active surface mines in West Virginia were violating state and federal laws. This finding confirms the ineffectiveness of the legislation.

In conclusion, US health and safety regulation was effective for underground mines with growing benefits for miners and a significant decrease in mortality. On the other hand, morbidity is still a serious threat for miners. Mine owners (and final users) bear the brunt of increased regulation costs.

<u>China</u>

Chinese coal mining is growing rapidly and according to a 2003 government report coal mining deaths per one million of the population were about 37 times that of the US. Prior to 2000 coal mining fatality reports were inaccurate and only recent statistics are available. Ming-Xiao et al. (2011) analysed coal mining accidents in China from 2001 to 2008 and reported a significant decrease in injuries and fatalities since 2006. The Chinese government has implemented a comprehensive, sophisticated and complex legal regime dealing with coal mine safety. The government also channelled $36 million into technological coal mining safety and gas management upgrading for major state mines. In China the majority of mines are state owned and in 2008 12,209 unsafe small coal mines were closed.

China still lags far behind developed countries in terms of coal mining safety and therefore efficacy, efficiency and general assessment of its regulation system is still limited.

Australia

Coal mining legislation takes the form of a set of different regulations issued and managed by each Australian state and territory. Early in the 1990s reforms in mining legislation began across Australia promoting a shift from compliance to self-management. The idea was that the balance between 'prescriptive' and 'goal-setting' legislation needed to shift towards the latter. Legislation on duty of care, risk management principles and workforce representation were the key elements in change. In recent years the federal government has developed a model of legislation with the aim of harmonising job health and safety. Furthermore in 2002 the Ministerial Council on Mineral and Petroleum Resources developed a specific National Mine Safety Framework (NMSF) for health and safety in the Australian mining industry. Remarkably, it is the greater use of innovative policy mechanisms and the degree of workforce unionisation which may explain positive Australian performance as compared to other countries. A comparison between Australia and the US with the same interest in job safety, mining methods and technological development might indicate that prescriptive policies are less successful than self-regulation.

6.2 Environmental externalities

The coal mining process impacts on the environment in many ways (Tab. 3) but methane emissions are the only one of these which is highly regulated. Methane is one of the most significant coal extraction externalities for both surface and underground mines. Methane emissions from surface mines are usually ten times lower than those from underground mines. The emission potential for each type of mine is determined by the coal's gas content. Some of the gases remain in the coal but roughly 70% is released during extraction. Methane (CH_4) is a dangerous greenhouse gas with a much higher radiative efficiency than CO_2. The studies reviewed in this section are summarised in Tab. 6 and several authors attribute 8-12% of global methane emissions to mining methane emissions (Cheng et al. 2011, Bracmort et al. 2011, Dessus et al. 2009, Badarch et al. 2009, IEA 2009, WB Group 2007, Zhi et al. 2006, OECD & IEA 2008, EPA 1999). Underground mines account for 90% of coal methane emissions (OECD & IEA, 2008). Abandoned mines are also responsible for methane emissions and these account for nearly 5% of national methane emissions (US EPA 2004).

Methane has always been considered one of the dangers of underground coal mining with the potential to create serious threats for workers and productivity. Methane concentrations of 5-15% in the air are an explosion hazard in coal mines. Governments initially regulated methane concentrations for health reasons and only recently has regulation dealt with its environmental consequences. The potential of capturing and using this methane as an alternative fossil fuel has recently been explored with the aim of increasing air quality. Two types of methane can be used as fossil fuel: coal mine methane and coal bed methane. Coal mine methane (CMM) is the gas extracted with coal while coal bed methane is associated with pre-mine drainage activity and if it is not exploited it is not ready available. The former type of methane is discussed in this paper.

CMM can come from abandoned or active mines and in both cases it must be dealt with. In the past abandoned mines were not specifically regulated and if the top of the mine shaft was sealed for safety reasons and the gas in it built up there was a serious risk of gas escape or explosion. Nowadays, active and abandoned mines are regulated for safety reasons. In active mines CMM needs to be dealt with before mines can be considered safe and several systems can be used for this. Chief among these are:

- large-scale ventilation systems which aim to dilute the gas with massive quantities of air and release the mixture into the atmosphere;
- the degasification or pre-drainage system which absorbs methane from mines before work starts.

For both systems innovative technologies can be used to capture and use methane for energy production or local energy uses (Banks, 2012).

From an economic point of view, methane can be either an externality or joint production. As an externality it needs to be internalised into coal mining production costs; as a complementary fossil fuel methane should have its own market value. CMM is emitted around the world and the largest emitters are countries with the largest numbers of underground mines. Currently the top two producers are China and the US. Other large producers are Russia, Australia, Ukraine and India (Fig. 8).

According to Banks (2012) the majority of the methane currently extracted with coal is not used economically and represents an externality. Tab. 7 reports the percentage of CMM ventilated and recovered in the main coal producing countries. The OECD (2000) has estimated that methane capture technology costs vary from $100 to $350/ ton of methane and this can be a disincentive to methane capture. Other limitations on the economic use of CMM are ambiguous property rights definition. In many countries a coal leaseholder does not automatically obtain rights to recovery and use CMM. For example in the US, coal lessees can capture and discharge methane without holding a supplementary gas lease. If the captured gas is released into the atmosphere there is no need to pay royalties. If, however, a mining company wants to use the CMM extracted it must follow federal leasing procedures and pay royalties to the government. This system is an incentive to treat CMM as an externality.
In Australia and Canada each state has its own CMM legislation. In Ukraine and the UK CMM is considered a mineral or petroleum resource and standard licensing procedures apply.

In total we reviewed seventeen studies CMM policy options worldwide.

US

Methane emission was initially regulated for health and safety reasons. It was only in 1994 that the US started regulating coal methane emissions for environmental reasons. In that year the US EPA promoted the 'Coalbed Methane Outreach Program' in which mining companies signed up to this voluntary methane emission reduction program. State administrations could also offer income tax incentives to attract investment and stimulate CMM recovery and use. EPA (2011) established that in the 1994-2009 period the coal mining industry captured and used 81% of methane emissions which is equivalent to removing more than 51 million passenger vehicles from the roads for a whole year. This success was worth $150-350 million in revenues. In 2004 the U.S. Environmental Protection Agency (EPA) launched and started administering the 'Methane-to-Markets Partnership' or 'Global Methane Initiative'. This is an international voluntary initiative which draws up guidelines and supports innovative technologies and projects to promote the capture and reuse of methane around the world. Currently 41 countries plus the European Commission are contributing to the 'Global Methane Initiative'.

US methane regulation depends mainly on voluntary agreements and this strategy seems to be successful. However, a significant quantity of methane from mines is still released into the atmosphere.

Australia

The Australian government recently reported that coal emissions significantly increased between 1990 and 2011. Fossil fuel methane emissions account for 30% of all methane emissions and coal mining accounts for 83% of this (AU report, 2013). A successful initiative in Australia is the '13% Queensland Gas Scheme' launched in 2005 and valid for 15 years. This scheme forces energy producers to source 13% of electricity from gases (one of these can be CMM). The scheme promotes CMM by paying higher prices for it. The scheme has produced successful results and the current electricity from gas percentage is 18%, 5% more than the target set. Another initiative is the 'Coal Sector Assistance Package' which encourages the coal industry and miners to explore opportunities to reduce methane emissions. The government supports the scheme to the tune of around $38.5 million for innovation projects.

Australia promotes innovation and has been particularly active in deploying power generation and oxidation systems using CMM for energy production.

Europe

In Europe CMM emissions account for 5% of total EU methane emissions. In absolute terms, CMMs are declining in the EU since coal mining has been on a downward trend for many decades. AEAT (1998) reports that Germany produces the most methane from coal (42% of total EU methane) followed by Spain (27%), the UK (17%) and France (11%). The EU has tackled methane emissions in the so-called 'Climate and Energy Package' together with other GHG missions. However, CMM is not covered by any specific EU legislation for methane emissions, and national legislation to reduce methane loss is in place. UK and Germany started to capture methane from coal mining in the 1990s, but Germany currently captures more than 70% of its methane whereas the UK only captures 30%. The high rate of capture in Germany is accounted for by its feed-in-tariff which promotes renewable energy use. This policy was introduced in 1990 and reviewed in 2004 and 2006. CMM is considered a renewable energy and the goal of the feed-in tariff is to offer cost-based compensation to CMM producers. The policy provides long-term price reductions and promotes investment in CMM capture and use projects. In the UK the emphasis is on methane control and flaring rather than energy recovery. Whilst this policy is successful in reducing methane emissions in a cost-effective way, it does not generate the environmental benefits of gas capture. The UK has also activated an Emission Trading Scheme for methane from active coal mines assuming that methane from abandoned mines is minimal and will reduce over time through natural processes, a highly contentious statement. Since April 2002 the electricity generated from CMM has been exempt from the Climate Change Levy (CCL) but this does not provide a sufficient economic driver for investment in electricity generation technologies.

Russia

Russian mines are particularly gassy as compared to other world mines. However few mines have installed cutting edge technologies for CMM recovery. The key driver of Russian methane regulation is underground mine safety improving labour and mine productivity.

As compared to other states, Russia has a very thoroughgoing set of regulations for coal mining and its environmental and social impact. In 1995 Russia regulated exploration, use and protection of subsoil in coal mining production but failed to regulate the legal status of recovered CMM. In the subsequent two years, Russia regulated coal mining for safety reasons and in 2000 it was still far behind other states on methane recovery and use (and experienced many coal fatalities). Addressing CMM was increasingly important for improving mining productivity and competitiveness and in 2003 methane limits in mine air ventilation were defined together with monitoring procedures.

The 2003 Decree 'On Payments for Emissions of Pollutants into the Atmosphere from Stationary and Mobile Sources, Pollutant Discharge into Surface and Underground Water and Disposal of Production and Consumption Waste and Mobile Sources, Pollutant Discharge into Surface and Underground Water and Disposal of Production and Consumption Waste' recognised methane as a pollutant. It also defined limits and payments that companies were charged annually on pollutant emission. Payments for methane emissions within emission limits increased 1000-fold in 2005-2006 and coal companies paid 44% of all Russian environmental payments (roughly $37 million).

Notwithstanding these environmental fines (minor compared to coal revenues) coal companies had few incentives to install emission-abating equipment. The 2006 'Guidelines on Coal Mine Degasification' defined the design, construction and exploitation of coal mine degasification systems. The guidelines were compulsory for all organisations and defined achievable CMM recovery targets. Regional administrations could also use financial incentives to stimulate and promote CMM use. In 2008 methane emissions in Russia were still several millions of cubic meters and the IEA (2009) estimated that the recovery and use of 1.9 billion m^3 of methane would be worth 130 million USD in 2008 regulated Russian wholesale natural gas prices.

This failure to monetise methane emissions and international experiences with CMM recovery and use have captured the attention of the Russian government. At the federal and regional levels several legislative initiatives have recently been set up to encourage CMM recovery and useisation. Legislative initiatives are based on mandatory degasification of coal seams prior to mining requirements and are performance-based. They define CMM as a new type of product and establish zero taxation for recovery and use. Several further changes to current legislation were discussed in 2008 to facilitate CMM recovery. In 2009 a Russian Government Decree on 'Main State Policy Areas to Increase Electricity Supply from Renewable Power Generation by 2020' included CMM in the list of resources for energy supply. Few details are currently available on the implementation of this Decree.

<u>China</u>

CMM is regulated in several laws mainly for safety reasons and China is seriously committed to recovering and using CMM in the short term. Nowadays, China is the largest emitter of CMM. The 'Mineral Resource Law' (revised in 1996) made important changes in the management of coal resources mainly to monitor coal supply. China has several small mines with sub-standard safety and environmental conditions. This distorts the coal market and exploits coal reserves which are not efficiently used. In the late 90s the Chinese government launched an aggressive program to close down small (mostly illegal) mines and several hundreds have recently been shut. In China CMM is considered an associated coal mineral and several regulations and financial incentives promote its recovery and use. In 2005 the 'Five year Plan 2006-2010' aimed to capture 5 billion cubic meters of methane (40% capture efficiency) utilising 3 billion cubic meters (60% efficiency) by 2010. Cheng et al. (2010) have presented the results of this program and report that captured CMM levels successfully reached targets but that utilisation rates have not significantly increased as compared to previous years. To address coal mine safety, in June 2006 the State Council issued 'Opinions on Speeding up CBM/CMM Extraction and Utilisation' which clarified the guiding principles of gas extraction prior to coal mining. Key aspects of this policy are:

- CMM capture is compulsory in coal mining;
- CMM measurement and monitoring activities must be implemented;
- coal production is not allowed without a CMM capture system and the event of significant problems mining activity must be suspended;
- coal mine owners and operators have legal responsibilities to ensure that these standards are met.

These regulations have been successful and several mines have installed CMM capture systems (IEA 2009, Info). In support of the 'Five year Plan 2006-2010' initiative, in 2007 the Chinese government issued a 'Notice on CBM/CMM Price Management'. The price of CMM can be freely negotiated. If CMM is distributed via city pipeline networks the price will be equivalent to its heating value. CMM power plans also take priority with grid operators. At the same time, the Ministry of Finance issued 'Executing Opinions on Subsidising CBM/CMM Development and Utilisation Enterprises' whereby any enterprise engaged in CBM/CMM extraction within China is entitled to financial subsidies if it is used on site, marketed for residential use or used as chemical feedstock.

In 2008 the Ministry of Environmental Protection issued a 'CBM/CMM Emission Standard'. This new standard dictates rules for CMM capture systems, methane dilution and transport of lower concentrations. Details about the effects of the recent Chinese regulations are still not available but Cheng et al. (2010)'s results suggest potential effective CMM recovery action.

7. Conclusions

Coal mining is responsible for multiple environmental and social externalities and governments have tried to internalise these effects in a number of policy decisions.

Command-and-control is the most popular policy option with good efficacy results (at least in developed countries, whilst in developing countries inadequate application of standards is still an issue).

In the US the equity effect of policies has been a government concern since 1977 when the Federal Mine Safety & Health Act was implemented. This act aimed to establish "interim mandatory health and safety standards [..] for the nation's coal or other mines; (2) to require that each operator of a coal or other mine and every miner in such a mine complies with such standards; (3) to cooperate with, and provide assistance to, the States in the development and enforcement of effective State coal". This law standardised state legislation on mines which had created inequities in the competitiveness, safety and miners' health spheres. The Australian government has recently shifted from prescriptive to "goal-setting" legislation. This minimises control costs and distributional effects. On the other hand it promotes ongoing research for efficiency solutions. Another popular mechanism is voluntary agreement, principally used for methane emissions. The methane question, however, is a complex one which can take the form either of an externality or a new petroleum product. Furthermore, in some cases property rights are not clearly defined and the use of methane is not efficient. The Global Methane Initiative, a voluntary agreement supervised by the US, has generated satisfactory results across the world and related administrative costs and distributional effects are assumed to be lower.

In general, it can be observed that policy mechanisms for coal mining are changing quickly, especially in developing countries, and possibly for this reason few studies have assessed the impact of these polices.

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[1] Note that although Coase's analysis is considered to be a major theoretical finding, it has been strongly criticised by some: for example, Dixit and Olson (2000) argue that costless agreements do not automatically lead to efficient outcomes.

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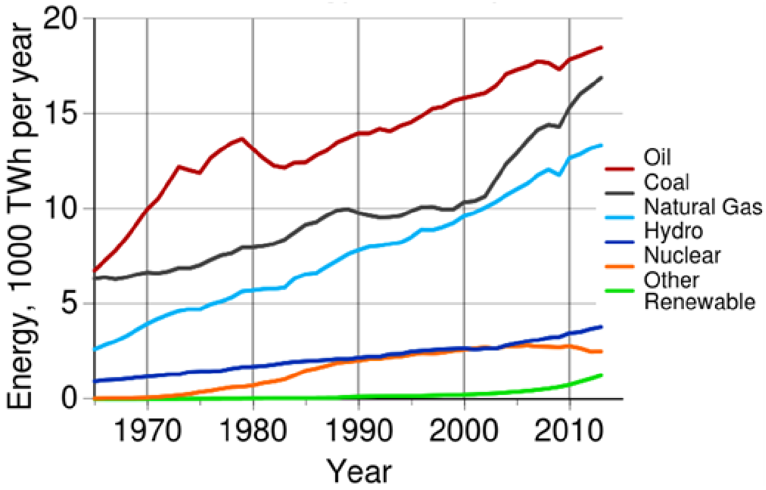
Figure 1. World energy consumption



Source: BP (2013)

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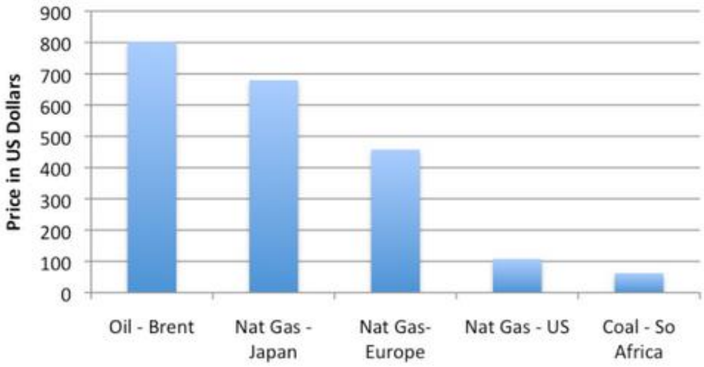
Figure 2. Price of fossil fuels (MT of oil equivalent)



Source: World Bank

Figure 3. Policy options classification

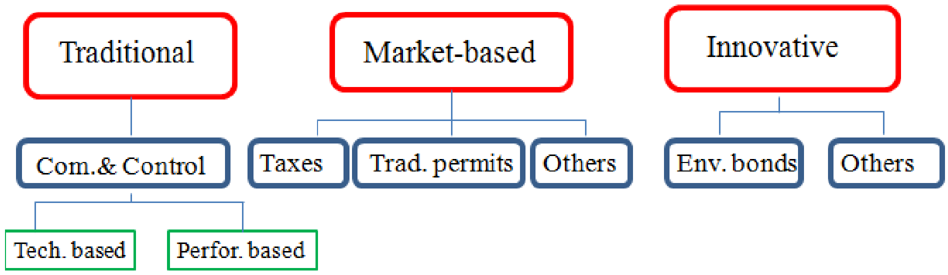


Figure 4. Coase's solution

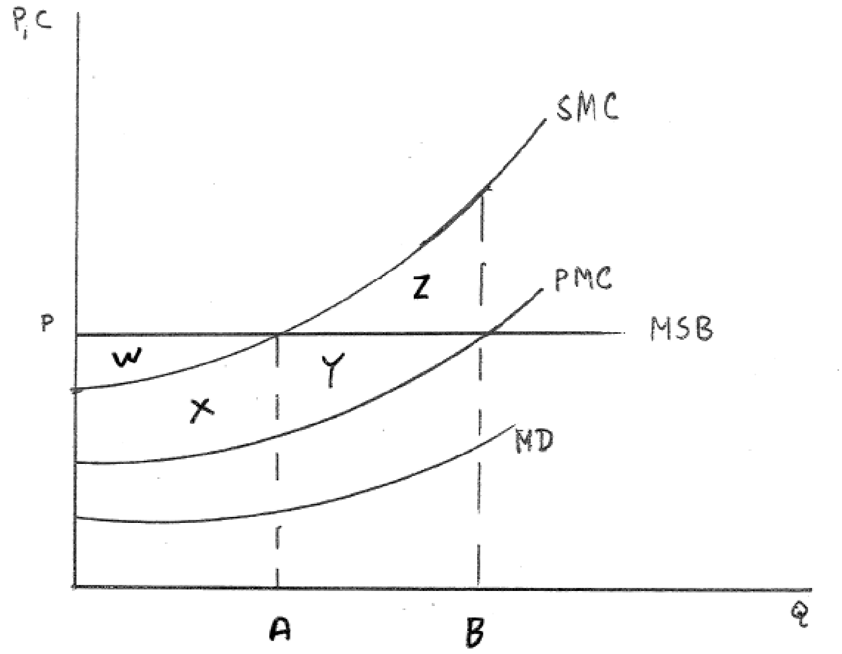


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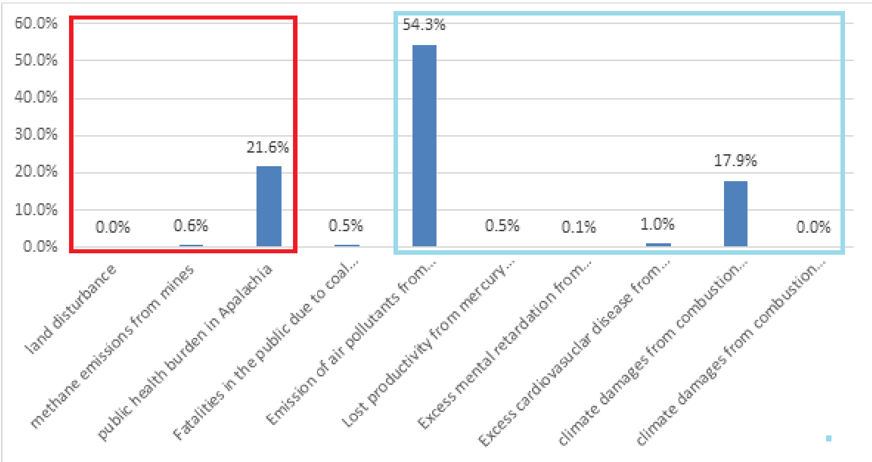
Figure 5. Impact of the cost of externalities on coal costs (derived from Epstein et al. 2011 p. 91)



Commented [LBox1]: Nella figura: climate damage from combustion, Appalachia

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Table 1. The classification of coal extraction externalities

Mining	Social externalities	Environmental externalities
Underground	Mortality and morbidity in coal communities	Methane emissions
	Health risks from abandoned mines	Abandoned mines
Surface	Mortality and morbidity in coal mining communities	Biodiversity loss
	Health risks due to water and air contamination	Contamination of rivers, streams and ponds
	Occupational hazards in mining	Air contamination
		Methane emissions
		Acid rain
	Health risks from abandoned mines	Impact of abandoned mines on the landscape

Table 2. Key Search Terms Used in the Google and Google scholar Literature Search

Key word string	*Policy options	@ Externalities	Web domain
Quantitative assessment of effects of (*) to damages from coal surface mines/underground mines/ abandoned mines to (@);	Pigouvian taxation, charges, subsidies, tradable permits, voluntary actions, command and control policies, regulation, environmental bonds, insurance workers	biodiversity loss; methane emissions; emissions fires; water contamination; particulate emissions; sludge slurry ponds; mortality morbidity health coal communities miners	.org; .gov; .ue; gov.uk; gov.au; .cn; .ch

Table 3. The physical impacts of coal extraction externalities

Impact	Description	Quantitative measures
Social	Mortality and morbidity in coal communities	6,500 to 16,500 deaths annually (UNDP 2000)
	Occupational hazards in mining	30% more risk of hypertension, 64% increase in the risk of chronic obstructive pulmonary disease, 70% increase in the risk of kidney disease
Environmental	Methane emissions	8-12% of global methane emissions
	Abandoned mines	5-9% of national methane emissions
	Biodiversity loss	45%-90% biodiversity loss (surface mines)
	Contamination of rivers, streams and ponds	6% river loss (surface mines)
	Air contamination	na
	Acid rain	na
	Impact of abandoned mines on the landscape	20% loss of forests (surface mines)

Table 4. The social externalities and policy options

Impact	References	Policies
Social	11 US studies 2 AU studies 2 CH studies	Command and control, Taxes

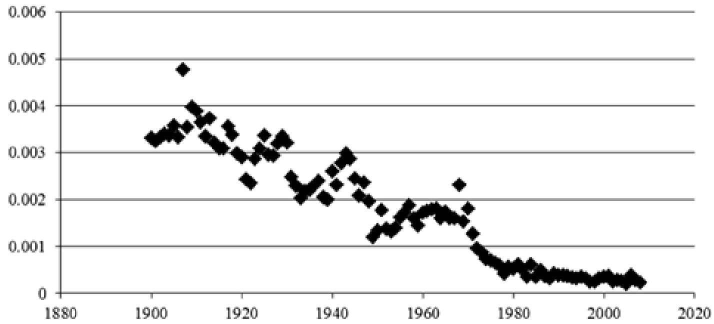
Table 5. Coal mining fatalities between 2006-2010

	underground hazards			open cut hazards			
Country	Explosions	Strata fall	Explosions and Strata	Explosives	Ground fall	Explosives and Ground	All coal mining fatalities
Australia	0	0	0	0	0	0	8
China	2145 (60.7%)	188 (5.3%)	2333 (66.1%)	17 (.5%)	35 (1%)	52 (1.5%)	3532
India	74 (14.3%)	114 (22%)	188 (36.2%)	0	5 (1%)	5 (1%)	519
South Africa	3 (3.5%)	21 (24.7%)	24 (28.2%)	0	0	0	85
USA	49 (27.7%)	26 (14.7%)	75 (42.4%)	0	4 (2.3%)	4 (2.3%)	177

Note: percentages represent the number of fatalities caused by that hazard relative to the total number of fatalities in that country

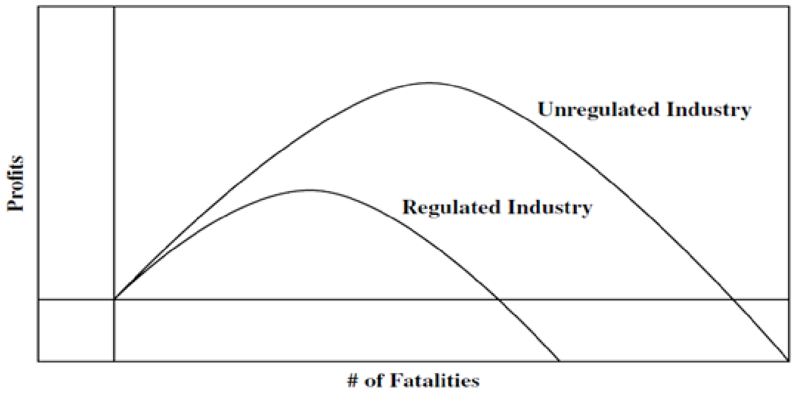
Fonte: Harris et al. (2014)

Figure 6. Percentage of coal mining fatalities per working mine (1990-2008)



Source: Lofaso (2011)

Figure 7. Percentage of coal mining fatalities per working mine (1990-2008)



Source: Lofaso(2011)

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Table 6. The social externalities and policy options

Impact	References	Policies
Social	4 US studies 2 AU studies 6 CH studies 1 Russia 6 EU	International voluntary program (GMI), command and control, mix mechanisms

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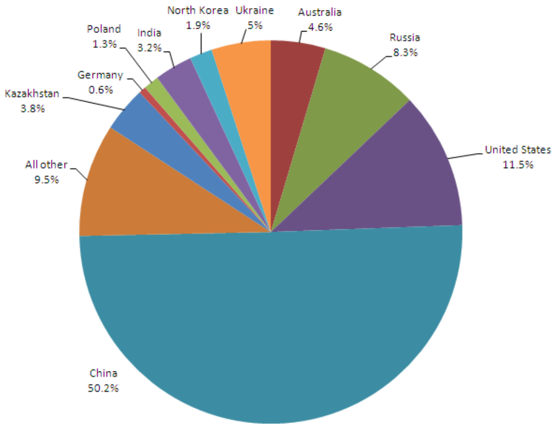
Figure 8. CMM emissions



Source: EPA (2006)

Table 7. Amount of CMM emitted, ventilated and recovered in recent years

	Coal Mine Methane (m3)	Ventilated	Drained and recovered
China	20 billion	60-70%	2 billion
US	3.1 billion	94%*	280 million*
Ukraine	2 billion	86%	179 million
Russia	1.9 billion	na	31.7 million
India	na	na	na
Australia	na	64%	na

*These values presented by Banks are not in line with published EPA values

Source: adapted from Banks (2012)

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Appendix I

The following table summarises the quantitative estimates of damages to the environment and society from coal mining. Despite their relevance, the advanced web search yielded no policies addressing these externalities.

Externality	**Description**	**Geographical region**	**Quantitative Estimates**
Abandoned mines	Abandoned mines pose a threat to the environment and society (i.e. methane)	Mongolia	9% of methane emissions
		US	5% of methane emissions
		UK	The annual methane emission ranges from 0.02-0.3 Mt. (UK, 2008)
Water contamination	Water quality deteriorates, threatening the landscape (risk of flooding) and society (health risks)	US	Water consumption for coal mining ranges from 11 to 200 l/MWH (2010)
			For the central Appalachian region costs for water contamination were estimated to be $1,048 million (USD 1976)
			6% of the West Virgina rivers in the valley fills (2012)
			2000 km of rivers have disappeared in Central Appalachia (2011)
		China	Between 1996 and 2003 the damages to local water services, water ecosystems and flooding were estimated to be 5.54 million (2011)
Biodiversity loss	Forest depletion, landscape loss and other environmental impacts	Czech republic	2276 km^2 of landscape are seriously damaged; 2382 km^2 irrevocably damaged 45%-90% biodiversity loss 20% loss of forests Wetland replacement costs 7000 Euro/ha, Forest replacement costs 45000 Euro/ha Two-fold increase in the average daily temperature due to mining activities

Commented [LBox2]: Euros? Dollars?

		US Appalachia	Mountain Top: loss of 1.1 million hectares of forest

Appendix II: Details of the web search: example for methane

The details of the advanced Google search are reported in this section with the number of documents found in each domain. A total of 11,270 documents were shortlisted.

Details of the string of key words	Domain	Results
Quantitative assessment of effects of Pigouvian taxation on methane emissions from underground coal mines	.org	472 (9 with "methane emissions")
	.gov	6
	.eu	0
	gov.uk	0
	gov.au	0
	.cn	0
	.ch	6
Quantitative assessment of effects of chargers on methane emissions from underground coal mines	.org	8040 (4)
	.gov	1490 (8)
	.eu	1
	gov.uk	0
	gov.au	0
	.cn	0
	.ch	1
Quantitative assessment of effects of subsidies on methane emissions from underground coal mines	.org	38900 (5880)
	.gov	4880 (227000)
	.eu	260 (54)
	gov.uk	4
	gov.au	146 (6)
	.cn	1
	.ch	6
Quantitative assessment of effects of tradable permits on methane emissions from underground coal mines	.org	3520 (954)
	.gov	592 (7)
	.eu	6
	gov.uk	1
	gov.au	7
	.cn	7
	.ch	5
Quantitative assessment of effects of voluntary actions on	.org	5930 (748)
	.gov	1060 (164)

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methane emissions from underground coal mines	.eu	8
	gov.uk	10
	gov.au	223 (44)
	.cn	44
	.ch	5
Quantitative assessment of effects of command and control policies on methane emissions from underground coal mines	.org	5110 (1160)
	.gov	2470 (10)
	.eu	9
	gov.uk	1
	gov.au	8
	.cn	7
	.ch	5
Quantitative assessment of effects of regulation on methane emissions from underground coal mines	.org	114000 (13400)
	.gov	24100 (229000)
	.eu	647 (9)
	gov.uk	586 (9)
	gov.au	625 (106)
	.cn	269 (8)
	.ch	9
Quantitative assessment of effects of environmental bonds on methane emissions from underground coal mines	.org	77000 (69200)
	.gov	16300 (975)
	.eu	8
	gov.uk	10
	gov.au	147 (8)
	.cn	148 (84)
	.ch	6
Quantitative assessment of effects of insurance workers on methane emissions from underground coal mines	.org	57000 (6570)
	.gov	8710 (10)
	.eu	8
	gov.uk	74 (9)
	gov.au	85 (17)
	.cn	36
	.ch	6

A total of 373,015 papers were found.

Advanced Google Scholar search

String of key words	Results

Quantitative assessment of effects of Pigouvian taxation on methane emissions from underground coal mines	42 (11 with "methane emissions" i)
Quantitative assessment of effects of chargers on methane emissions from underground coal mines	42 (11 with "methane emissions")
Quantitative assessment of effects of subsidies on methane emissions from underground coal mines	1400 (257 with "methane emissions")
Quantitative assessment of effects of tradable permits on methane emissions from underground coal mines	651 (134 with "methane emissions")
Quantitative assessment of effects of voluntary actions on methane emissions from underground coal mines	1290 (232 with "methane emissions")
Quantitative assessment of effects of command and control policies on methane emissions from underground coal mines	675 (102 with "methane emissions")
Quantitative assessment of effects of regulation on methane emissions from underground coal mines	4310 (584 with "methane emissions")
Quantitative assessment of effects of environmental bonds on methane emissions from underground coal mines	1690 (155 with "methane emissions")
Quantitative assessment of effects of insurance workers on methane emissions from underground coal mines	1170 (180 with "methane emissions")

Health and safety regulations in coal mining

EU	**US**	**Russia**	**China**	**AU**
1950 European Coal and Steel Community – research and dissemination programmes	1910 Organic Act established the US Bureau of Mines	1993 Federal Mining and Industrial Safety Inspection of Russia	1992 Mine Safety Law	Historically, each state and territory in Australia has managed OHS separately
1957 Safety and Health commission for the Mining and Other Extractive Industries – supportive research in preparation of laws	1966 Federal Metal and Non-metallic Mine Safety Act: demanded annual inspections of underground mines	1996 The Federal Law on State Regulation in the Field of Extraction and Use of Coal, and on Social Protection of Workers in Coal Industry Enterprises	2000 Coal Mine Inspection Ordinance	[2002 National Mine Safety Framework is to improve the safety of workers through greater consistency and efficiency of occupational health and safety regulation.]
1980 D. 80/1107 protection of workers against chemical, physical and biological agents at work	1969 Federal Coal Mine Health and Safety Act: established the mining enforcement and safety administration	1997 The Federal Law of the Russian Federation on Industrial Safety of Hazardous Industrial Facilities	2002 Work Safety Law	2008 "National Mine Safety Framework – Harmonisation of national laws
1982 D 82/605 workers protection against exposure to metallic lead	1970 Federal Occupational Safety and Health Act: created the national institute for occupational safety and health and responsible for	2003 Mine Safety Regulations (ПБ 05-618-03) (RosTechNadzor, 2003): These detailed regulations, obligatory for all organisations working		

	developing and enforcing health and safety regulations in the workplace	in mines, sets out requirements to ensure the safety of all aspects of mining.		
1983 D 83/477 workers protection against exposure to asbestos	1977 Federal Mine Safety and Health Act: combined coal, metal and non-metallic mining underground under one legislation instrument.	2008 Several legislative initiatives have been started at the federal level		
1986 D 86/188 worker protection against exposure to noise	2007 Mine Improvement and New Emergency Response Act: requires operators of underground coal mines to improve accident preparedness.			
1987 Directive adopted under Article 118A of the single European Act lay down minimum requirements concerning health and safety at work				
1990 D 90/269 the minimum safety and health requirements for the manual handling of loads where there is a particular risk of back injury to workers				

1992 D 92/91 the minimum requirements for improving the safety and health protection of workers involved in mineral-extraction through drilling				
1992 D92/104 the minimum requirements for improving the safety and health protection of workers in surface and underground mineral-extraction industries				
1997 D97/42 The protection of workers from risks related to exposure to carcinogens at work				
2002 D02/44 the minimum health and safety requirements for workers exposed to risks from physical agents (vibration)				

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Environmental acts and regulations

Environmental protection legislation is generally more recent than health and safety legislation. However, it is evolving quickly under national and international frameworks.

EU	US	Russia	China	AU
	1970 Clean Air Act		1988 Land reclamation Provision- actions to prevent damage to waters and the environment	1997 Protection of the Environmental Operations Act
	1977 Clean Water Act		1989 Environmental Protection Law (revision of the 1979 Law)	1999 Environmental Protection and Biodiversity Conservation Act –Commonwealth Law
	1977 Surface Mining Control and Reclamation Act		1991 Water and Soil Conservation Law	
	1990 Amendments to the Clear Air Act (1970)		1995 Solid Waste Pollution Prevention and Control Law	

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THE ABSTRACT OF THE PROJECT IS:

The research programme will integrate diverse levels, methods and disciplinary traditions with the aim of developing a comprehensive policy agenda for changing the role of the financial system to help achieve a future which is sustainable in environmental, social and economic terms. The programme involves an integrated and balanced consortium involving partners from 14 countries that has unsurpassed experience in deploying diverse perspectives both within economics and across disciplines inclusive of economics. The programme is distinctively pluralistic and aims to forge alliances across the social sciences so as to understand how finance can better serve economic, social and environmental needs. The central issues addressed are the ways in which the growth and performance of economies in the last 30 years have been dependent on the characteristics of the processes of financialisation; how financialisation has impacted on the achievement of specific economic, social, and environmental objectives; the nature of the relationship between financialisation and the sustainability of the financial system, economic development and the environment; the lessons to be drawn from the crisis about the nature and impacts of financialisation; what requisites of a financial system are able to support a process of sustainable development that is broadly conceived.

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3	School of Oriental and African Studies	UK
4	Fondation Nationale des Sciences Politiques	France
5	Pour la Solidarite, Brussels	Belgium
6	Poznan University of Economics	Poland
7	Tallin University of Technology	Estonia
8	Berlin School of Economics and Law	Germany
9	Centre for Social Studies, University of Coimbra	Portugal
10	University of Pannonia, Veszprem	Hungary
11	National and Kapodistrian University of Athens	Greece
12	Middle East Technical University, Ankara	Turkey
13	Lund University	Sweden
14	University of Witwatersrand	South Africa
15	University of the Basque Country, Bilbao	Spain

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