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Economic growth, liberalization, and the environment

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GLOSSARY

Comparative advantage. A country has a comparative advantage in a particular good if the ratio of costs to produce this good, relative to the cost to produce another good, is lower than the same cost ratio in other countries. Comparative advantage is the basis for trade: countries gain if they export the good they produce relatively most efficient.

Economic growth. Steady increases in GDP.

Energy intensity. Energy supply divided by GDP.

Externality. A situation in which market transactions affect persons who are not involved in the transaction directly (i.e. not through market prices).

GDP Gross domestic product. The sum of all output produced by economic activity within a country. GNP (gross national product) includes net income from abroad, e.g. rent, profits.

General equilibrium. A situation in which all markets in the economy are in equilibrium.

Market equilibrium. A situation, characterized by a certain volume of trade and a price of a certain good, such that no market party wants to change behavior: no seller of the good wants to increase or decrease supply, no consumers wants reduce or increase demand.

OECD countries. Organization for Economic Cooperation and Development. The Northern American and Western European countries, Greece, Turkey, and Mexico.

Real price. Relative price of a commodity in terms of another (basket of) commodities. GDP is often measured in real prices (also labeled "at constant prices") to eliminate the effects of inflation (where inflation is the upward trend common in all prices, leading to a downward trend in the purchasing power of money).

Total factor productivity (also: Multifactor productivity). Outputs per unit of input. Changes in total factor productivity measure technological change, by accounting how much of the increase in production is due to other factors than changes in inputs.

DEFINITION

Economic growth is the steady increase in output produced by economic activity within a country (GDP). A central question is whether economic growth is compatible with a non-deteriorating environment and whether the environmental consequences of economic growth have a major impact on welfare levels derived from growing output of marketed goods. International trade has grown even faster than national income. It has been asked whether increased trade has been bad for the environment and whether it has caused rich countries to relocate their polluting industries to developing countries. Another important question is how large are the costs associated with environmental regulation in terms of competitiveness, productivity and employment This article deals with these questions by reviewing empirical evidence and economic theory on resource use and economic growth.

I. INTERACTIONS BETWEEN THE ECONOMY AND THE ENVIRONMENT

A. Economic growth and resource use

Statistics on national production levels and indicators of environmental pressure have been collected the last decades (and reconstructed for the more distant past) to document the link between economic growth and the environment. The theory of economic growth and economic theories of natural resources provide explanations and interpretations of the trends, as well as methods to assess future developments. The basic approach in most statistical and theoretical analyses is the decomposition of aggregate production of a nation into, on the one hand, the current state of technology and, on the other hand, the inputs into the national production process. The main inputs are labor (hours worked), capital (produced means of production that can be used over a certain time period), and natural resources.

Natural resources comprise energy inputs and material inputs. An important distinction is between renewable and non-renewable resources. Renewable resources are biotic populations, flora and fauna, which have the potential to grow by means of natural reproduction. For example, the theory of renewable resources studies fishery and forestry. Non-renewable resources are minerals of which physical supplies do not grow on a for humans relevant time scale. Examples are metals (like aluminum, copper, gold) and fossil fuels (like oil, coal, natural gas).

The basic characteristic of natural resources is that they cannot be produced, but they serve as an essential input in production. A higher rate of resource usage implies faster depletion of the available stock of the resource. In this sense resource inputs differ in a fundamental way from other inputs used in production such as labor and capital: labor is not used up and man-made capital can be accumulated. Another important difference is that the available resource stock itself may directly affect welfare as an amenity (non-use value). Resource economics studies the trade-off between extraction of the resource for current consumption and conservation for later dates. Environmental quality can also be considered as an input in the aggregate production process. Pollution is an inevitable by-product of production. Pollution can be seen as a degradation of environmental resources, like clean air and soil.

B. Externalities, markets, and incentives

Economic growth is the result of growth in inputs and increases in the productivity of the inputs – that is, changes in technology. Economics further explains why inputs and technology change over time. Inputs like materials, labor and capital are traded in factor markets. Prices match demand and supply and provide consumers and suppliers with information and incentives. Population growth, for example, raises the potential working force and the supply of labor inputs in the economy rises. This fuels growth if wages adjust so that the growing working force is employed in production. With more labor in production, capital can be operated at a higher productivity level. This increase in the return to capital induces fuels investment in new capital so that also growth in capital inputs fuels output growth. Similarly, the demand for materials and energy increases. If these are available in limited supply, their prices rise, which provides incentives to develop technologies that save on their use. Thus while growing scarcity of inputs may itself impose a drag on growth, it may also induce technological change which fuels economic growth.

Markets provide a powerful coordination mechanism. In sectors of the economy where the demand for resources like materials or labor is high, prices rise and this attracts resources to these sectors, away from other sectors. Thus resources tend to be allocated in those sectors where they are in largest demand. The high demand reflects a high willingness to pay for the resources and implies that their value is considered to be large. This explains why the market mechanism in principle can enhance efficiency and welfare in the economy.

The market can only coordinate social preferences (demand for certain goods or services) and (technical) possibilities and resource endowments in a welfare-maximizing way, if prices reflect these preferences and possibilities. This requires, first, that the owners of production factors (the inputs like labor, capital and materials) can charge a price that reflects their production cost, and, second, that consumers can express their willingness to pay. For many environmental goods, these preconditions are not met. In the absence of environmental regulation, there are no markets for clean air or climate. Pollution entails a cost to society, but not a cost to the polluting producers. Waste can be disposed freely, but imposes a cost on society. When economic activity – that is, a market transactions – imposes costs or benefits on persons who are not involved in the transaction directly, *externalities* are said to be present. Externalities cause markets to function imperfectly and welfare to be impaired. This is why environmental policies may improve welfare. These policies have to correct environmental externalities, for example by making firms pay for the pollution costs they impose on society.

We can now be more precise to define the cost of pollution for society. From an economic perspective, pollution (and, similarly, environmental degradation or resource depletion) is costly to the degree that it causes externalities. Because the value of environmental quality is not reflected in the prices in the economy, the economic decisions that are based on these prices give rise to more pollution than society finds optimal.

The ideal (optimal) environmental regulation imposes measures to eliminate all external costs of pollution, that is, it makes all parties in society internalize all social costs of pollution. In such a situation, welfare is maximal, but pollution is not necessarily (and very unlikely) at the technical minimum. Although depletion of natural resources and polluting consequences of production are by definition bad for the environment, they are not necessarily bad for welfare. They provide the inputs for production of valuable things. As long as the benefits from increases in production outweigh the costs of environmental degradation, economic growth enhances welfare.

In the remaining sections of this article, we study how economic growth, international trade, and environmental regulation affect the environment and welfare. To examine the impact on aggregate welfare, changes in the physical state of the environment have to be made comparable to changes in economic production, which requires a valuation method to put values on environmental improvements. Since this is not only a hard, but also subjective task, we also look at the physical effects, by which I mean the impact on pollution, pollution concentration and resource stocks measured in physical terms. This is the conservationist perspective, to be contrasted with the economic approach that deals with welfare effects.

II. TRENDS IN ECONOMIC GROWTH AND RESOURCE USE

A. Trends in economic growth

In the period between 1820 and 1995, total world production (GDP) has grown on average at an annual rate of 2.2 per cent, which amounts to a more than 40 fold increase over a mere 175 years. This rate of change is unprecedented: in the 1800 years before this period world GDP increased less than 7 fold. Per capita economic growth has been enormous also the last century. With current world population at about 5.5 billion, 5 times as big as in 1820, per capita GDP is now almost 8 times bigger than it was 175 years ago.

Differences among countries are large. In 1988, output per worker in the US was more than 30 times higher than output in Subsahara Africa. Developing countries often have per capita income levels that are less than 10 per cent of US levels (e.g. India 9 per cent, China 6 per cent, in 1988). Per capita income in Western Europe is on average 30 per cent lower than in North America, but income gaps are now smaller than four decades ago. Typically, among the richer countries, there is convergence in income levels, while the gap between the poorest and richest countries still grows.

B. Trends in energy and materials

Economic growth directly translates into growing demand for energy resources and materials, since they are necessary inputs in production. However, in the process of growth, some energy resources or materials may be substituted for others so that not all of them are used at an increasing rate. Technological change has allowed many sectors of the economy or even entire economies to produce at a lower overall energy intensity.

Primary energy supply in the OECD countries was roughly 50 percent higher in 1999 than in 1971, but GDP rose faster. Indeed, from 1960-2000, energy use is decoupled from economic growth, at least in the EU, Japan and the US (at annual rates of 0.4, 0.2 and 1.4 per cent, respectively). The oil shortages in the 1970s induced energy conservation programs. Also the growing relative importance of services relative to manufacturing caused energy efficiency to rise. In recent years, growth in energy use has accelerated due to increased transport and electricity use in service sectors. Trends in materials use vary considerably over different materials. Iron and steel have grown slower than GDP, paper use has grown in line with GDP, but plastics and aluminum have grown faster than GDP.

The concern is that growing energy and materials use results in scarcity of resources and imposes a threat to future growth. Stocks of virgin ores decline. The stock of materials embedded in products grows, leaving less available for recycling. If growth fuels demand for resources and supply becomes smaller, prices can be expected to rise. Yet, most price indicators do not reflect growing scarcity. The prices of most commodities have declined since 1960. Here, prices are measured in *real* terms, i.e. relative to the prices of a representative basket of produced goods. Most economists have concluded that resource scarcity will not limit growth, at least not during the coming decades and not if we consider scarcity of those resources that are traded in well-developed global markets, like most minerals and energy resources.

Falling prices may reflect technological progress, which allows mining at lower cost, or exploration of new resource deposits. According to most economic theories, this is likely to be a temporary phenomenon and in the long run prices of non-renewable resources are expected to rise over time. This does not necessarily imply, however, that future growth will no longer be fuelled by lower costs of energy and materials, since technological change, as well as exploration and development of new economically useful resources, may overcome scarcity limits.

The growing use of certain energy resources and materials has severe impacts on the natural environment. In general, economists agree that free market forces do not serve very well society's demand for environmental amenities or conservation of natural resources for which markets are illegal, incomplete, or do not exist (like water and air quality, rare species, biodiversity, ecosystem services). Emissions of CO_2 from fossil fuel combustion pose major threats to air pollution and climate. Despite the decoupling of energy use from economic growth in the developed economies and despite the decline in the carbon content per unit of energy used, total CO_2 emissions have risen in almost all countries in the last decades. In large developing countries like India, China and Brazil, absolute CO_2 emissions have risen very rapidly. In contrast to the OECD experience, their CO_2 emissions per unit of GDP have risen at fast rates (up to 2.6 percent per year, in India 1971-1998).

Other major threats to the environment come from the use of hazardous industrial waste, emissions and toxic chemicals, which are used in the production process and discarded as some form of industrial waste. As a result of environmental regulation, emissions from production activities (industry) have actually declined. However, waste and emissions from consumption activities are growing. Municipal waste and hazardous waste have increased in recent decades in developed countries, at a rate faster than population and faster than GDP.

C. Cross country differences in resource intensities

Differences in energy used per unit of GDP are large. In Northern America per capita energy use is more than twice per capita energy use in Japan, France or UK and about 1.5 times that in Germany and Australia. The differences mainly arise because of differences in per capita income and differences in energy used per unit of output. Differences in the structure of production (in terms of the relative importance of industrial production sectors) are hardly responsible for the differences in per capita energy use.

III. EXPLANING THE LINK BETWEEN GROWTH AND RESOURCE USE

A. The environment – income relationship

Economists have tried to identify underlying mechanisms in resource use and growth trends. A central question is how environmental pressure changes with economic growth. One hypothesis is the so-called *Environmental Kuznets Curve* (EKC) hypothesis, according to which environmental pressure or resource use first increases with GDP, but – after a certain threshold income level – declines with per capita GDP. The hypothesis has been tested for several resources, energy sources and emissions. The evidence is mixed: the EKC shows up, but only for some pollutants and not in all countries.

In the typical approach, pollution in the major cities (or other measurement stations) of a set of countries is compared and related to the level of income in these cities. If pollution rises with the level of income but also declines with the square of the level of income, the EKC holds.

The EKC is found for water pollutants and for air pollutants like SO_2, suspended particulate matter (dark matter as well as heavy particles), NO_x and CO. These pollutants cause health problems close to the place where they are emitted (i.e. these are *local* pollutants), while their impact occurs simultaneous with emissions (i.e. these are short-lived or *flow* pollutants). The EKC is generally rejected for municipal waste, CO_2 and aggregate energy consumption: these variables monotonically increase with the level of income in a cross-section of countries. Since it is the accumulation of municipal waste in landfills – rather than the annual flow – that imposes environmental pressure, it is a *stock* pollutant. CO_2 is partly a local flow pollutant, but its main impact is through concentration of CO_2 in the atmosphere on the global climate (i.e. it is a *global* pollutant as well as a *stock* pollutant). Other evidence on the main global stock pollutants and environmental indicators is only indirect. For example, wilderness land is monotonically declining with the level of income, which is a crude measure of the negative relation between income and biodiversity loss.

B. The role of environmental regulation

Thus, the common pattern is that local pollutants and flow pollutants are more likely to first rise and then fall with income than global pollutants or stock pollutants.

The main driving force behind the lower pollution levels in richer countries decline is policies to reduce pollution. In richer countries, citizens are willing to pay more for improvements in environmental quality and succeed in convincing their local and national governments to impose the necessary regulation to reduce urgent pollution problems. Since the effect of reducing local flow pollutants has the most visible effects for the constituencies of the local authorities, regulation mainly aims at these rather than at global or stock pollutants. The latter affect other regions or future generations, respectively, but not so much the authorities' electorate. In this interpretation, environmental improvement only occurs when environmental regulation becomes more stringent in richer economies. That is, environmental problems are not solved "automatically" by economic growth. Growth will be accompanied by reductions in pollution only if a number of conditions is fulfilled.

First, when becoming richer, people must care more about environmental quality. There is no strong evidence in favor of this claim. For example, in developing countries, environmental quality and availability of natural resources is often much more crucial for households than in developed countries. Yet, within developed countries, willingness to pay for improvements in health rise with income. As a result, richer citizens may be more in favor of costly measures to reduce pollutants with direct health impacts.

Second, only if the costs of reducing pollution do not rise too much with national income, citizens vote for pollution reduction. Technological change is important in this respect. On the one hand, cleaner production processes have been developed, which mitigates the cost of pollution reduction. On the other hand, some new production processes and the production of new goods require more energy and resource use. For example, the rapid spread of computers and the growing demand for transport makes the economies heavily dependent on electricity and fossil fuels so that reductions in energy use have a big cost in terms of loss of production. This may explain why electricity and fossil fuels use does not decline with income, despite concern about the environment.

Third, actual environmental policies need to reflect societies preferences for environmental quality. Indeed, in countries with relatively high degree of political and civil freedom, environmental problems decline more rapidly with income. In countries with high indicators of corruption, natural resource depletion is faster.

Pollutants differ in terms of their (health) impact, the degree to which they are local and short-lived, and the cost of reduction. As a result, when comparing emissions of different pollutants in a particular country, some may rise and others may fall with income. That is, the Kuznets curves – if they exist at all for the pollutants at hand – overlap. It implies that while environmental quality improves on account of the reduction in one pollutant, aggregate measures of environmental quality may deteriorate because this pollutant is replaced by other pollutants. This may be a problem in particular since stock pollutants replace short-lived pollutants, which amounts to a shift of the environmental burden to future generations. Similarly, Kuznets curves of different countries overlap. While rich countries reduce emissions of a certain pollutant, poor countries may at the same time increase emissions in their growth process. Thus, pollution is shifted from rich to poor places. As a result, the existence of an EKC for a certain pollutant does not guarantee that worldwide environmental quality improves over time. This phenomenon is particularly important because the poor countries, which tend to increase emissions with production, account for a much larger share in the world economy than the rich one and some of them are growing at above-average rates (notably China).

IV. INTERNATIONAL TRADE AND THE ENVIRONMENT

A. The pollution haven hypothesis

The evidence on the EKC points out that national environmental policies differ between high-income and low-income countries and that as a result of income growth pollution in the North may be reduced over time at the cost of increasing pollution in the South. There have been concerns that this process is reinforced by international trade of goods and by foreign direct investment between North and South. More stringent environmental policies in the North force pollution-intensive industries located in the North to raise their prices relative to the prices charged by firms in the South. Consumers in the North may then profitably import more goods from the South and firms in the North may profitable relocate their plants to the South. This claim on the effects of differences in stringency of environmental regulation is labeled the "pollution haven hypothesis".

Empirical evidence for the pollution haven hypothesis is not very strong. The hypothesis has been tested in various (mainly indirect) ways. Typically, in a first step polluting industries are identified, based on their emissions per unit (dollar) of output, or pollution control costs as a fraction of value added. At the top of these rankings we find industries like iron and steel, nonferrous metals, mining, pulp and paper, industrial chemicals, petroleum refineries, rubber and leather products. In a second step, the performance of these sectors in different countries is related to the country's environmental stringency, controlling as much as possible for other country differences. Stringency is either measured as an index based on law and regulation, or a measure of pollution control expenditures.

Within the US, polluting industries tend to export smaller volumes, start fewer new plants, and attract less investment in states with more stringent environmental regulation than in states with more lenient environmental regulation. Among different countries, the effects of differences in environmental regulations are harder to trace. Overall, industrial countries have reduced their share in world trade of goods from polluting industries relative to developing countries over the last decades. However, there is no evidence that this trend is mainly due to differences in environmental regulation or due to international trade. The pattern of growth in these countries may be caused by a shift to pollution-intensive industries (as a movement along the upward sloping part of the EKC). Moreover, the industrial countries remain the largest exporters in the most polluting industries. Hence, we must reject the claim that internationally most pollution is created in countries with lax environmental standards. The main explanation behind this finding is that other factors than environmental regulation are much more decisive in determining production cost or location advantages. The share of compliance costs for environmental regulation in total cost is small relative to the cost savings that can be gained from the availability of skilled workers able operate advanced technologies, access to large consumer markets, and political stability. Polluting industries sometimes have high transport costs so that proximity to consumer markets is important. Polluting industries are also typically capital-intensive and operated by skilled workers. These factors make developed countries a more attractive location for polluting industries. Hence, differences between North and South in availability (that is, endowments) of capital and skilled workers offset the differences in environmental regulation.

B. Is trade beneficial?

For given differences in endowments of capital and labor, relatively lax environmental regulation in some countries, in particular the poorer ones, is likely to shift some of the dirty industries to the South. The question is whether this is always undesirable. According a standard economic argument, there may be mutual benefits from relocation of pollution intensive industries between different countries. For example, countries with low income but enough space to keep away pollution from its population may be willing to accept pollution if this can greatly boost income. High-income countries with high population density care less about increases in income if it comes at the cost of pollution problems. In this case, both types of countries benefit if pollution is relocated from high-income to low-income countries.

While lax environmental policies in the South seem to burden citizens in the South with pollution havens, workers in the North may be concerned about the stringent environmental policies in their countries. The North loses jobs in pollution-intensive industries and export performance in these sectors falls when these industries move to the South. However, at the same time, trade with the South allows the North to improve performance in clean industries, so that again trade creates mutual benefits for North and South (although these benefits may come only after some time-consuming – and therefore costly – adjustments in the economy). Indeed, if the North would not be engaged in trade with the South, environmental regulation would also result in job losses in polluting industries and shifts to clean industries, but it would forego the benefits from importing and consuming goods that can be produced at lower costs in other countries and it would forego the opportunity to earn a living by exporting goods that can be produced at a comparative advantage in the North.

In general, differences in environmental regulation may reflect differences in social costs to deal with pollution and form a true basis for mutually beneficial trade. However, if national environmental regulation ignores the average citizen's preference for pollution and fails to reflect the social costs of pollution, trade is no longer always mutually beneficial. This is why large multinational corporations have been criticized when they negotiate concessions with elite governments and exploit their monopoly power. However, hard evidence on unbalanced benefits and costs from the activities of such firms is not available.

Other situations where trade not necessarily leads to mutual gains occur when pollution is *transboundary*, that is when pollution from one country harms citizens of other countries. Since national governments are not likely to take into account these pollution spillover effects, they tend to set pollution regulation too lax. For all countries to gain from trade, environmental regulation in each country should reflect the cost of pollution not just to own citizens, but to the world community as a whole. Thus, when SO_2 emissions in UK hardly affect British citizens but cause forests in Scandinavia to die, the UK may be tempted to impose lax regulation of SO_2 emissions, thus creating a comparative advantage in SO_2-intensive goods and boosting export of these goods. This trade would harm Scandinavia.

A final situation of harmful international trade may arise when countries have strategic reasons to set overly-lax or overly-stringent environmental policies. Some environmentalists have feared that governments set environmental policies overly lax. Governments may have an incentive to accept environmental standards that are lower than is socially desirable, in order to attract foreign direct investment or give domestic industry a cost advantage over foreign firms, and thus make higher profits. (This has been labeled "ecological dumping"). However, if many governments try to protect their polluting industries in this way, they may all fail in a "race to the bottom": the lax standard in one country is offset by the response in the other country to also lower environmental regulation. Only if firms' location choices and cost levels are sufficiently responsive to differences in environmental standards, national governments can use environmental policies as a strategic instrument against other countries. In the past, the lack of strong evidence for pollution havens has been interpreted as evidence against significant firm responses to environmental stringency and the fear for strategic use of environmental policy seemed ungrounded. Recently, however, evidence of firm responses become stronger so that strategic environmental may still be reasons for concern.

C. Is trade good for the environment?

Although we have no hard evidence on the magnitude of the net benefits (or costs) of trade in polluting goods, and there is no strong evidence on large effects of environmental regulation on trade and foreign direct investment, we have some detailed analyses of the effects an increase in world trade has on pollution in different countries. Trade has significant effects on pollution, but often more trade implies a cleaner environment.

World trade has intensified enormously the last decades. Between 1973 and 1998, world merchandise exports and global foreign direct investment have grown at annual rates of 9 and 14 per cent respectively. This expansion of trade cannot be held responsible for increases in world pollution. The share of dirty products in world trade has declined. Comparing open economies (countries with high shares of exports and imports in GDP) to closed economies (countries with little foreign trade), statistical analysis shows that open economies have less pollution per unit of GDP (other things equal). Open economies tend to adopt clean technologies more rapidly.

Trade often has a beneficial impact on the environment because of the interaction between comparative advantages and adjustment of environmental regulation. High-income countries tend to have higher environmental standards. High income countries can also, however, produce pollution-intensive (which are often skilled-labor or capital-intensive) products at a relatively low cost thanks to access to advanced technology, and large endowments of skilled labor and capital. It implies that high-income countries have a *comparative advantage* in producing pollution-intensive goods. When they liberalize trade, they tend to export more of these goods. Thus, world trade becomes greener since trade shifts production of polluting goods to countries where environmental standards are higher. Moreover, international trade increases income, which leads to a policy response since richer countries tend to impose more stringent environmental regulation. Thus, also countries with lower incomes tighten their environmental regulation. Multinational firms adopt environmental practices overseas that are (partly) determined by environmental regulations in their home countries, under pressure of consumer actions and for fear of loss of reputation.

Although evidence on an aggregate level suggests that international trade is benign to the environment, in certain areas trade has serious adverse impact on the environment. Certain types of pollution or natural resource use remain unregulated and it is in these areas that trade give rise to concerns. A first example is *transport*. The growth in world trade has been accompanied with increases in transport movements, which are heavily energy-intensive. The pollution costs (externalities) associated with transport are not fully reflected in regulation so that welfare losses and excessive pollution may stem from the increase in transport. Since the costs of transport cross borders, appropriate policies require international coordination, which is often hard to establish. Secondly, transport involves the problem of *invasive species*: the accidental or intentional introduction of harmful non-indigenous species of plants and animals can damage environmental resources. The cost of screening and quarantines is often prohibitive. Thirdly, the concentration of *agriculture* in certain locations without appropriate regulation puts stress on biological diversity with potential loss of soil quality in larger regions in the longer run. It destroys habitat of species and may lead to extinction of theses species and loss of biodiversity.

V. ENVIRONMENTAL REGULATION AND PRODUCTIVITY

A. The cost of environmental regulation

Environmental regulation aims at improving environmental quality but may come at the cost of jobs, productivity, or other undesirable economic effects. To justify environmental regulation on economic grounds, it should be shown in a cost-benefit analysis whether the benefits are large enough to incur the costs. In some cases, the costs are found to be small or even negative, that is, there are benefits to be reaped not only in terms of environmental improvement but also in other fields. Estimates of the total costs of environmental regulation vary enormously between different studies.

The traditional argument is that environmental regulation imposes costs on firms as well as governments and consumers. Governments incur costs of administration of the regulation. Firms are burdened with costs because, first, they have to install and operate pollution control equipment, intensify monitoring, and face higher administrative burdens. Second, under certain types of regulation, they may face pollution charges, expenditures on buying pollution permits or quotas, or fines in so far they emit more than the quotas that are allocated to them. Third, depending on the degree that they pass through costs to prices, they see demand for their output fall and suffer from lower profits.

The total burden on polluting firms depends much on firm characteristics and the employed technology. Estimates of direct costs of complying with environmental regulation vary from less than one percent of GDP in 1972 to more than 2.5 percent at the end of the 1990s in the US and slightly lower figures in Western Europe. Across industries, petroleum and coal industries faced pollution control capital expenditures up to one quarter of total capital expenditures, while for industries in rubber and plastics production the number was only 2 per cent.

More crucial from an economic perspective is that the burden of regulation depends on the design of the regulation; in particular on the flexibility firms have to choose their own way to comply with the regulation. At the one extreme, the regulator prescribes the technology the firm has to use or the pollution control actions it has to take, leaving little flexibility to the firms. At the other extreme, the regulator allows firms to emit up to a specified emissions allowance and leaves it to the firm's discretion by what means to reduce emissions as well as whether to trade pollution allowances with other firms (system of marketable pollution permits). Compared to the former type of regulation (the command-and-control approach), the latter type of regulation (the market-based approach) minimizes the costs of regulation. First, it allows firms to choose the cheapest way to reduce emissions. Profit-maximizing firms will have an incentive to do so. Second, it gives incentives to firms that can reduce emissions at lowest cost to do most of the reduction and sell their pollution allowances to other firms. Thus, total pollution control costs are minimized. Alternative market-based instruments are charges (taxes) proportional to emissions.

Up to now, market-based instruments have been applied less frequently than command and control instruments, but their importance grows. Successes with marketable permits have been established with respect to reductions of lead content in petrol, air pollutants and sulphur dioxide emissions in particular. Estimates of the cost savings potential of moving from command-and-control to market-based instruments range from 50 to 90 percent.

Sometimes regulated firms find zero cost options to comply with more stringent environmental regulation, or even make profits out of it. Case studies have documented situations in which the reductions of materials or toxic chemical use for environmental reasons saved enough on the firm's expenditures on inputs to easily pay back the investment cost of adjusting the production process. Even without environmental regulation, the investment would have been justified, since it allowed for a real efficiency improvement.

It is unlikely that these situations systematically arise, since managers of firms are supposed to look for opportunities to improve efficiency and exploit them even without intervention by environmental regulators. Thus, when firms maximize profits and regulation constrains their choice of technologies, the smaller choice menu must lead to fewer opportunities to operate at certain profit levels and regulation is costly. This conclusion is unlikely to change if we acknowledge the limits to profit maximization because of informational and managerial problems. No doubt, inefficiencies in firms' production processes and organization remain pervasive, since managers’ span of control is insufficient to assess and eliminate all of them. Because of the small share of environment-related costs, managers may systematically ignore environment-related inefficiencies. Then, environmental regulation may make managers more focused on cost savings potentials related to pollutants and materials use. However, it may come at a cost by turning away their attention from other inefficiencies so that on balance it is unlikely that environmental regulation can systematically – that is, economy-wide –improve overall efficiency.

Opportunities for cost savings have been explored by engineering, or “bottom-up”, studies. These studies start from an emissions reduction target for the economy as a whole and then identify all the technological measures by which this target can be achieved. For each of them, the researcher estimates the cost incurred by firms and adds these up to an economy-wide total. Often the numbers are surprisingly low, suggesting that technological opportunities abound to improve the environment at low cost. The problem with these studies is that many hidden costs are ignored. Adoption of new technologies will not only change firms’ emissions, but also product characteristics and quality, employment structure, and input demand. It requires adjustments beyond the simple installation of pollution control equipment. The entire production and marketing process may be affected.

The alternative method to assess pollution control costs, sometimes labeled the “top-down” approach, starts from a statistical (and econometric) analysis of the relationship between production costs and environmental regulation, and between emissions and regulation across industries. The statistical results are used to make a projection how costs are affected by a hypothetical change in emissions, which corresponds to the policy target. This requires building a stylized model of the entire economy, which involves the incorporation of many assumptions and additional statistical results on how markets work and react to policy changes. These “top-down” studies suggest much higher costs of environmental policy than bottom-up studies. Hence, adjustment costs are substantial. A drawback of this method is that it necessarily relies on historical data on firms’ reactions to regulation and that it cannot incorporate the details of available new technologies to meet the environmental target. The results are also quite sensitive to the modeling structure and assumptions made.

Econometric techniques have also been used to estimate the effects of environmental regulation on employment. One would expect to find a negative correlation between stringency of environmental regulation and employment changes in pollution-intensive industries. Most studies find small effects when relating environmental regulation across US states to employment. Often the correlation between employment in dirty industries and environmental regulation is even positive. The main explanation is that we should not expect a causal relation from environmental stringency to employment, but rather view both employment and regulation as being determined simultaneously by economic and political factors. States with a strong economy, high productivity of their industries and high income can afford –and may actually prefer – more stringent regulations than poorer states; at the same time the former states may experience strong employment growth as a result of the favorable economic conditions.

B. General equilibrium effects

To assess the over-all costs of environmental regulation, we have to measure not only how it directly imposes costs on a regulator and regulated firms, but also how it affects other items on the government’s budget and how it affects customers and suppliers of regulated firms. Almost all activities in the economy are linked to each other: a consumer buys goods from firms and gets her income from (another) firms, pays taxes to governments, which subsidize firms and provide infrastructural goods for firms. Hence, regulating certain firms may affect the entire economy through these linkages. Such indirect effects are labeled general equilibrium effects, as they reflect the effects after all markets in the economy have reacted and adjusted such that a new equilibrium in the economy as a whole results.

The linkages between economic activities may sometimes mitigate the cost of environmental regulation, and sometimes reinforce them. When regulated firms have cut back their polluting activities, they buy less from their suppliers and these experience loss in sales, too. However, other firms may gain. Regulated firms may need to buy specialized equipment to control pollution, so firms selling this equipment gain. When regulated firms pass on their higher costs into higher prices, their customers switch to other producers. Hence, firms likely to gain from regulation are those that supply goods that customers view as a suitable substitute for the regulated firms' goods.

The overall cost of environmental regulation is the sum of all gains and losses. The indirect gains are not likely to fully offset the direct costs for one obvious reason. Regulation aims at reducing pollution, and this requires reductions in polluting inputs. If the economy as a whole has to cut back on inputs, total output is likely to fall, too. This effect may be reinforced over time, through effects on investment. Investment in new capital goods fuels growth in the economy. The return to investment is likely to be smaller if new capital goods have to be run with less energy or polluting inputs, so that the incentive to invest is crowded out through more stringent environmental regulation. Thus growth may be impaired by environmental regulation.

The economy-wide impact of environmental regulations can only be estimated – rather than directly measured – since we cannot observe how the economy would have evolved in the absence of the regulation. Estimates therefore heavily depend on the model that is used for the estimation. Based on standard macroeconomic or growth-theoretic models, estimates of the total cost are in the same order of magnitude as the direct pollution control costs, about two percent of GDP. Some researchers have noticed that the surge in regulatory costs coincides with the growth slowdown in the 1970s. Yet, all calculations show that only a very small portion of the slowdown can be attributed to environmental regulation.

C. In search of "Double Dividends"

Despite the fact that environmental regulation amounts to restricting inputs in the economy and is therefore likely to reduce output, counterarguments have been advanced that environmental regulation may bring about large gains. The key argument is that environmental policy shifts economic activity away from polluting sectors to other sectors in which the contribution of economic activity to welfare is larger. Hence, while regulation forces the economy to cut polluting inputs, it may raise total output by improving the average efficiency at which inputs are employed.

1. Removal of inefficient subsidy and tax programs

Efficiency gains can arise from environmental regulation if efficiency differs between sectors, in particular if efficiency in polluting sectors is lower than in clean sectors. Normally, differences in efficiency are competed away by market forces, but (non-environmental) regulation may distort these market forces and create sectors where resources are inefficiently used. Important examples are agriculture and energy. In the

OECD agricultural output is heavily subsidized so that high-cost/low-productivity agricultural activities in these countries remain viable. This support creates inefficiencies and the tax revenue could be better spent from an efficiency point of view. The widespread use of energy subsidies to firms also creates support for low productivity energy-intensive production. If these subsidies are abolished and replaced by environmental regulation that reflects, for example, the adverse impacts of pesticide on soil and water quality or those of energy use on world climate, efficiency gains can be large by shifting economic activity away from inefficient farming and energy-intensive industries.

2. Environmental tax reform

Gains from environmental regulations have also been claimed to be feasible when they can be combined with reductions in certain taxes. On the one hand, governments have relied on taxes on labor and capital to fund their budgets. These taxes may reduce the incentive to participate in the labor market or to invest in capital, so that the taxes distort markets and create inefficiently low levels of employment and investment. On the other hand, environmental taxes (charges on emissions, auctioning off of pollution permits) not only give incentive to address environmental problems but also raise revenue.

Indeed, the first important insight from the theory of public finance theory is that it is better to “recycle” the revenues from environmental taxes through reductions in distortionary taxes than to use them to fund the general government budget. However, the second insight is that replacing distortionary taxes on labor and capital by revenue-raising environmental taxes will reduce the efficiency of the tax system and increase the burden of taxation. That is, the improvement in the environment (a first dividend) is not likely to be offset by a cheaper way for the government to raise taxes (which would give a second – non-environmental – dividend). The reason is that a switch from taxing labor and capital to taxing pollution narrows the base on which the taxes can be levied. Capital and labor income each constitutes a much larger fraction of total income than the share of pollution in total cost. As noted above, environmental taxation reduces inputs in production and forces firms to spend more on pollution control. This reduces output and income in the economy, the tax base becomes smaller and the government raises less tax revenue from non-environmental taxes. The revenues from environmental taxes are insufficient to make up for the loss of revenues from non-environmental taxes.

In practice, the replacement of non-environmental taxes by revenue-raising environmental taxes may yield a double dividend if the existing tax system is highly inefficient along other, non-environmental dimensions (for example if capital is excessively taxed relative to labor). In this case, the tax system can be improved even without the introduction of environmental taxes, but vested interests or distributional concerns may prevent these tax reforms. Results from economic simulation models suggest that gains from the combination of environmental taxation and tax reform may yield substantial benefits in practice, but not for all groups in society. The major challenge is to find out ways to compensate losers from tax reform, without providing the wrong incentives. For example, workers and capital owners in polluting industry are likely to be hurt by environmental tax reform; but compensating them for losses should not reduce their incentive to invest funds and to find alternative employment outside the polluting industry.

3. Environmental quality as a source of productivity

Environmental regulation has short-run costs but long-run gains. These gains arise primarily in terms of a cleaner environment; they take time to materialize since the recovery of environmental quality is time consuming. However, as a feedback effect, a cleaner environment may improve productivity in the economy, which may offset the economic costs. The most obvious example is the effect on productivity in sectors that heavily rely on environmental resources. Policies to improve water and air quality of certain regions may boost the attractiveness of these regions for tourism or residential development. Hence, profits and productivity of tourism and construction may rise. Policies aimed at marine resources may also boost fish populations, thus improving productivity of the fishery. Forest management may give rise to both environmental benefits and improved yields for forestry.

In general, productivity of sectors or the economy as a whole is measured by multi factor productivity, which is a measure of the amount of outputs per unit of inputs. The factor productivity of conventional inputs like labor and capital may increase if environmental quality improves. Capital equipment and residential buildings may depreciate less fast if air pollution is less. The productivity of labor may benefit from health improvements that are induced by better environmental quality. Less working days are lost if health improves, which increases output per unit of input. Health care costs fall, which alleviates private and government budgets. Substantial costs can be avoided if climate change is mitigated, like risks of sea level rise (which directly affect agriculture, urban areas in coastal regions, and dike maintenance costs), and the loss of harvest in agriculture due to draughts or changes in precipitation.

D. Confronting costs and benefits

Summarizing the results above, we may state that most empirical research suggests that improvements in environmental quality require costly regulation, despite the various general equilibrium effects on efficiency and productivity that may mitigate the direct costs of regulation. The focus on costs of environmental regulation may distract attention from its benefits: these costs are incurred to achieve environmental benefits. The costs are worthwhile being incurred if the benefits outweigh the costs in a social cost-benefit analysis.

The social benefits from environmental improvements are often found to be large, but they are less visible than the costs of environmental regulation. Measuring the benefits requires putting a value on improvements in environmental quality, in health, and environmental amenities. When asked in surveys, individuals indicate that they are willing to give up large amounts of money and income to pay for these improvements. We can also infer individuals' valuation of environmental amenities from the amount of money individuals spend on traveling to locations with environmental amenities, or the premium people are willing to pay on houses located near them. The numbers from these studies can be used to construct an aggregate indicator of the value of environmental improvements, which can then be confronted to the cost estimates to undertake a social cost-benefit analysis.

The problem that the value of environmental amenities is unobservable (that there are no market prices) can thus be solved. However, perceptions may still be biased. Since neither market transactions nor market prices are associated with environmental goods, the current system of national accounts does not include the value of environmental goods as it only measures the value of marketed goods. As a result, the environmental benefits that environmental policies create are not part of national income, and environmental improvements do not count as economic progress. Attempts have been launched to adjust national income figures so as to include imputed values of environmental improvements and degradation (see Bartelmus' entry in this Encyclopedia). These "green GDP" figures would more appropriately measure well-being and progress than current GDP figures do. As long as these adjustments are not standard, there seems to be a trade-off between environment and growth, while once we take into account the value of environment for well-being, there is a close positive connection between environment and economic progress.

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