I   The Environmental Kuznets Curve Hypothesis

How do emissions vary as countries develop? The world contains a number of fast developing countries which are also big polluters, such as China. Will these countries pollute more or less as their economies grow?

Definition 25 *The ENVIRONMENTAL KUZNETS CURVE HYPOTHESIS (EKC) states that pollution initially rises and then falls as a country develops.*

If the EKC holds, we might be tempted to make an even stronger statement: growth-promoting policies in less developed countries (LDCs) cause incomes to rise and are thus environmentally friendly. We do not need to bother negotiating with developing countries to reduce emissions. Let LDCs develop, and they will eventually solve their own environmental problems, even if in the short run pollution rises. This idea has been embraced by the World Bank and IMF. Under this idea, trade agreements are also environmentally friendly even if the LDC has lax pollution regulations.

However, the EKC is controversial. It is not clear either in theory or the data that pollution eventually decreases with income, or what the TURNING POINT (the level of income after which pollution falls) is.

A   Three effects

We will trace out three effects of income on the environment:

1. Technique effect.

2. Scale effect.

3. Composition effect.

1   Technique effect

As income grows, a country may use more pollution efficient production processes.

Definition 26 *TECHNIQUE EFFECT. As incomes rise, firms use more pollution efficient production processes, reducing pollution.*

EMISSIONS INTENSITY or pollution per unit of output falls as income rises.

The technique effect is what the EKC proponents are describing. If environmental quality is a normal good, then people should desire more environmental quality as their incomes rise, all other things equal. These preferences must somehow be translated into a government policy for more stringent regulation. Assuming in a democracy that the preferences of the people are (imperfectly) translated into government policy, we should see regulation become more stringent as incomes rises. Then environmental compliance spending should rise, and emissions intensity should fall.

The process is thus:

1. Incomes rise, increasing preferences for environmental quality, assuming environmental quality is a normal good.

2. Preferences result in more stringent environmental policy.

3. Firms respond to the regulation by undertaking costly reductions in emissions per unit of output.

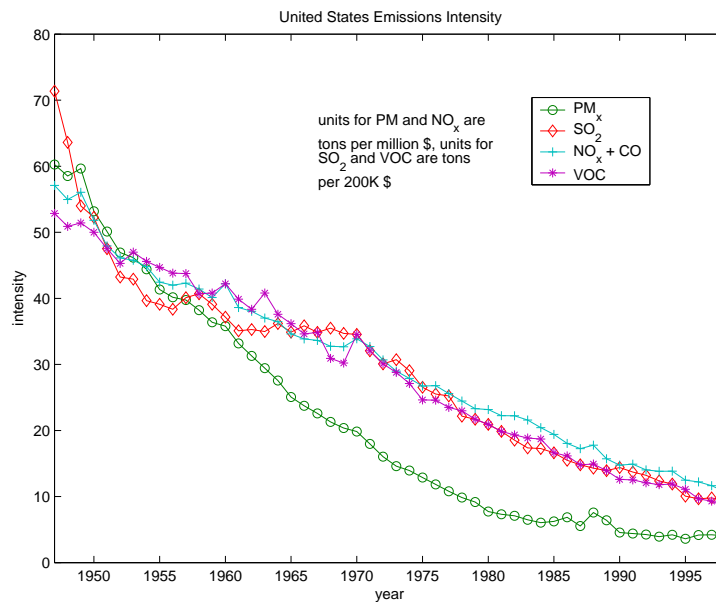4. Emissions per unit of output falls, and compliance spending rises.

Figure 51: Air pollution emissions intensity (emissions per unit of GNP).
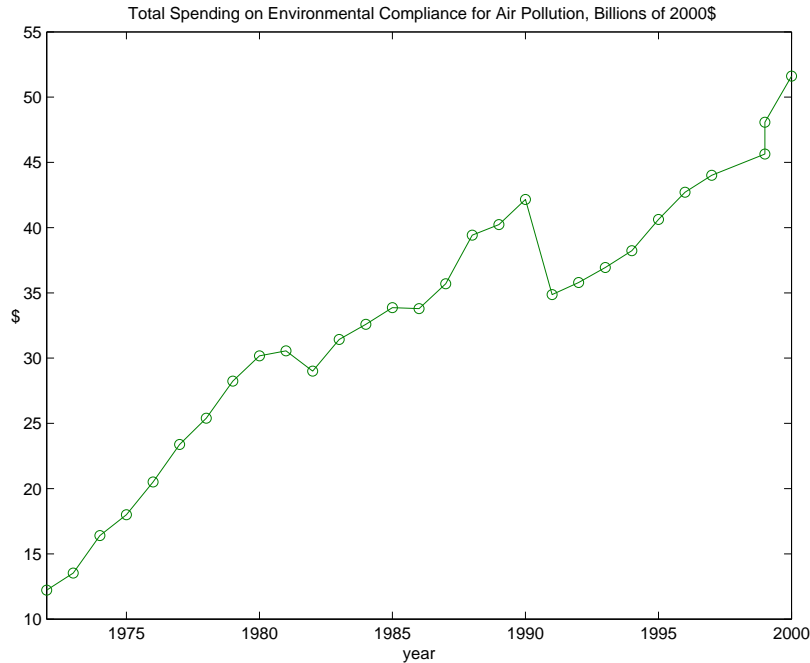
79

Figure 52: Air pollution compliance costs, calculated using EPA data.

In the data, the technique effect is clear.

2 Scale effect

We don't care exactly about pollution per unit of output, we care about total pollution. As incomes rise, so does the size of the industrial base. A bigger industry produces more pollution, all other things equal.

Definition 27 *SCALE EFFECT. As incomes rise, the industrial base rises, which increases pollution.*

The scale effect is what environmentalists worry about with increasing incomes in developing countries, as well as increases in income. Consider China, who has experienced rapid increases in their industrial base:
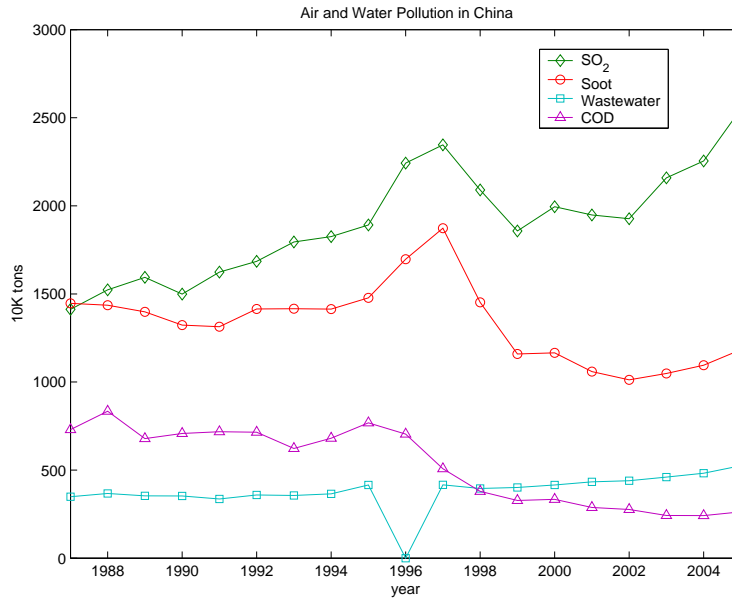
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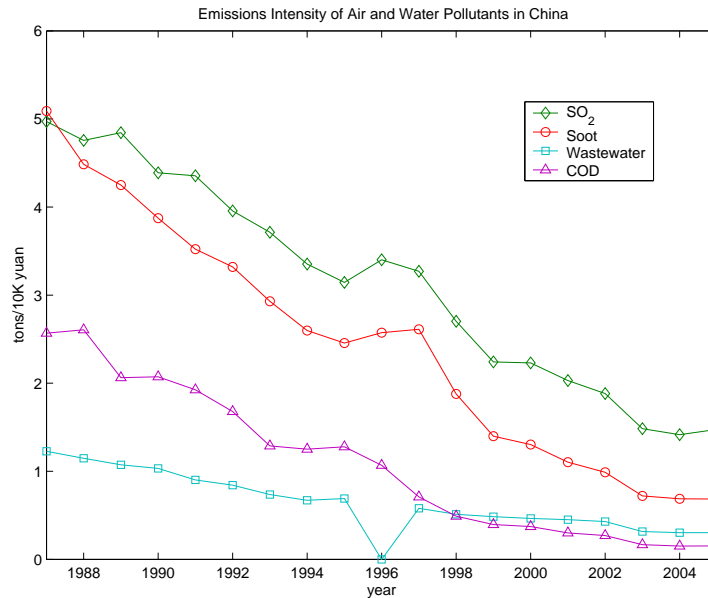Figure 53: Air and water pollution in China.

Figure 54: Air water pollution emissions intensity (tons per 10K yuan of output) in China.

The technique effect is causing pollution per unit of output to fall, but the large scale effect is causing total pollution to increase.

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3   Composition Effect

As incomes rise, we consume a different set of goods. Production of these goods may be more or less pollution intensive.

Definition 28 *COMPOSITION EFFECT. As incomes rise, we may consume goods which are more or less emissions intensive to produce.*

As incomes rise, we might switch from buses to cars, for example. A bus with 10 passengers likely has less emissions than 10 cars each with one passenger, for example. Conversely, at still higher incomes, we might switch from cars to planes. Ten people riding a plane from Miami to Santa Barbara might result in less emissions than 10 cars driving across the country.

Overall, the relationship between pollution and income likely varies by pollutant depending on the strength of the various three effects. Growth only helps the environment if the technique effect eventually is stronger than the scale effect.

Next let's see how various things affect the size of each effect.

B   Luxury goods

An EKC occurs when the technique effect is initially weak, but eventually stronger than the scale effect. Suppose I flip the axes so that emissions are on the y-axis and marginal costs and damages are on the x-axis. Marginal costs are inversely related to emissions, so the marginal costs are still downward sloping. Similarly, the marginal damages are still upward sloping.
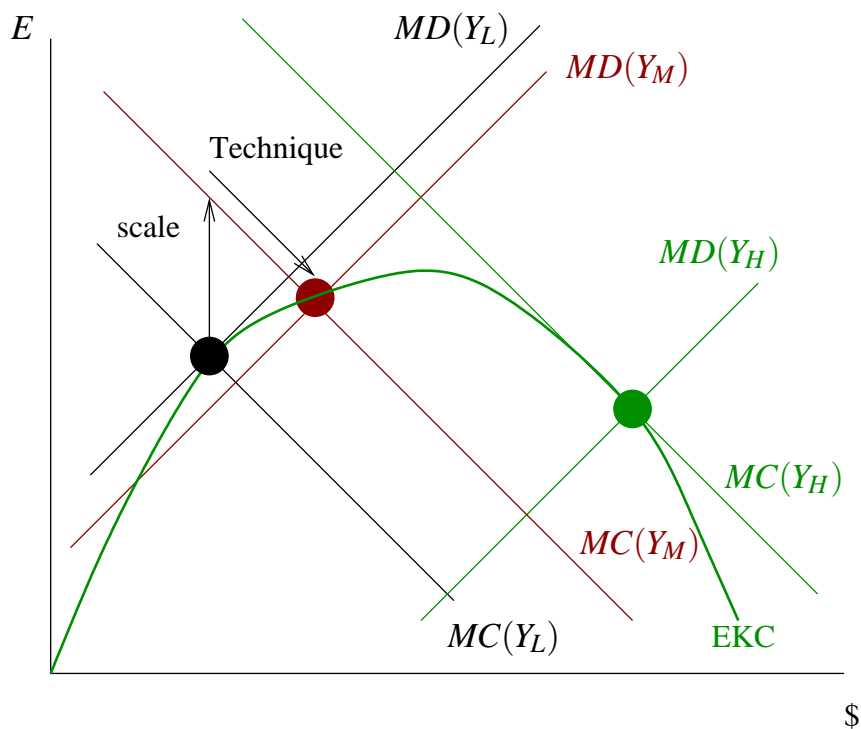
Figure 55: EKC results when environmental quality is a luxury good.

As the size of the industrial base grows, the cost of reducing emissions to a given level rises. In Figure 55, the marginal cost curve shift right as the size of the economy grows. To reduce emissions to 10 when 100 factories exist (high income) is more expensive than reducing emissions to 10 when one factory exists (low income). An increase in the demand for environmental quality means that pollution damages, or decreases, utility more. In Figure 55, marginal damages initially increases by a small amount, but later by a larger amount. This is the case if environmental quality is a luxury good, so that as incomes rise, a bigger and bigger percentage of income is spent on environmental quality.

The scale effect is represented by the shift in marginal costs. Holding spending on the environment constant (the x-axis), we see that emissions rise. The technique effect is the movement along the marginal cost curve, where we move to a more expensive, but more pollution efficient production process, holding the size of industry fixed.

Conversely, if environmental quality was a necessity, we spend a smaller and smaller fraction of income on environmental quality as incomes rise. Then pollution increases with income:
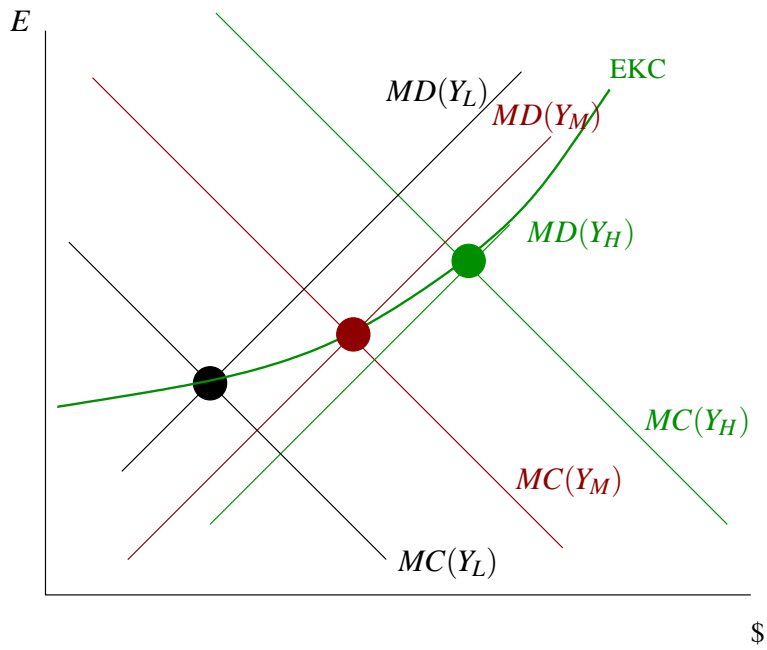
Figure 56: Pollution increases with income if the demand for environmental quality rises slowly.

Is the share of income spent on environmental compliance increasing?
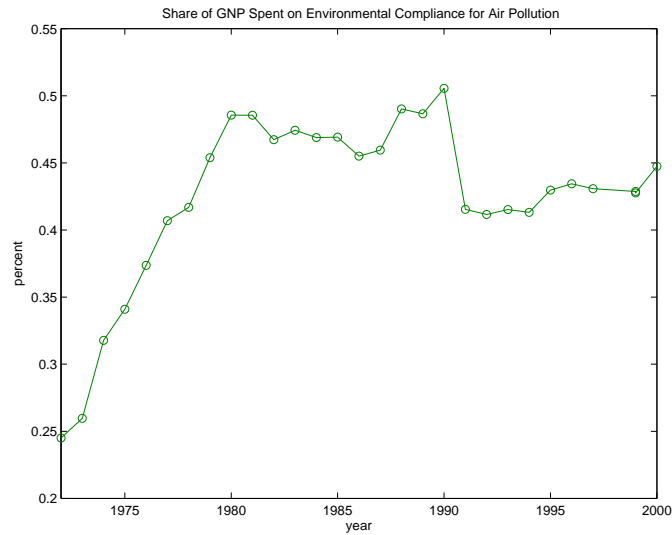

Figure 57: Air pollution compliance costs, calculated using EPA data.

Compliance costs rose in the 1970's as a share of GDP, when pollution peaked in the U.S. However, pollution has continued to fall, despite the share of compliance costs being

constant since the 1970's.

C   Corner Solution

Suppose marginal damages and marginal costs grow at the same rate, but we are initially at a corner solution.
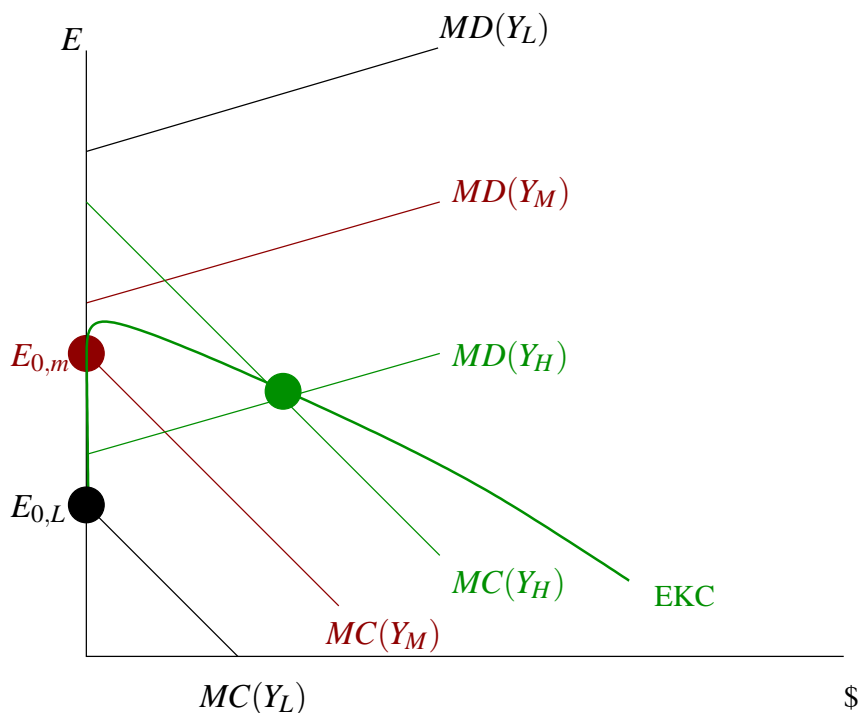

Figure 58: Corner solution EKC.

For both low and middle incomes, marginal costs are everywhere greater than marginal damages, so we have a corner solution in which it is efficient not to reduce emissions. Emissions still increase, however, because of the scale effect. Eventually, increases in the marginal damages cause the efficient solution to have emissions reduction, and so emissions start to decrease.

Many U.S. pollutants peaked in the early 1970s (airborn lead, SO_2, VOCs, NO_x, and carbon monoxide). Spending at this time was only about 0.25% of GDP. Bartz and Kelly (2008) show that if in fact it was so cheap to reduce emissions, then under the corner solution theory, we should have reduced emissions much earlier in development.

D   Institutions

Another possible explanation is that perhaps countries are poor and dirty because they have weak institutions. A country like Zimbabwe has poor growth because it has poor institutions. Any property or wealth in the country is subject to confiscation by the government or various factions. No functioning police or justice system exists. Without these institutions, why go through the effort of trying to create wealth? Similarly, we would be surprised to find a well-functioning EPA enforcing environmental laws in such a country.

In this case we have:
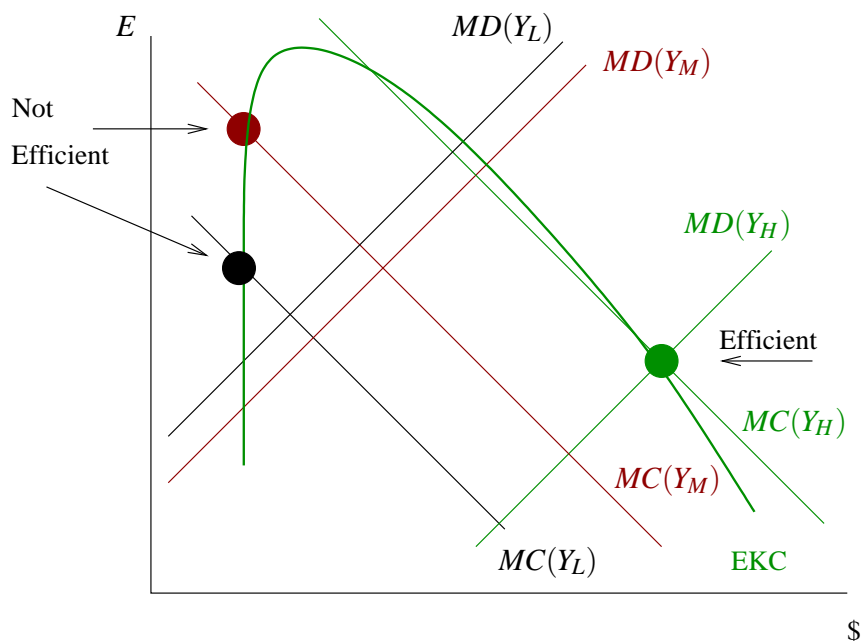
Figure 59: Non-functioning institutions in less developed countries.

No corner solution exists. Instead low and middle income countries do not emit where marginal costs equal marginal benefits. Welfare loss results, and the technique effect is absent for low and middle income countries. People prefer more environmental quality, but these preferences are not translated into a functioning policy.

E   Fixed costs

Suppose we must now pay a fixed cost, say to install a scrubber, in addition to marginal costs such as changing the filter and catalysts and other maintenance. Suppose the fixed

cost is \$5 and the marginal benefits and marginal costs are:

$$MD = y - 4 + e \tag{69}$$

$$MC = 6 - e + y \tag{70}$$

$$\text{Income } = y = 0, 1, 2 \tag{71}$$

So we have 3 levels of income corresponding to less developed, developing, and developed countries.

Consider now the LDC. When $y = 0$, setting $MD = MC$ gives:

$$0 - 4 + e = 6 - e + 0 \quad \rightarrow \quad e = 5 \tag{72}$$

However, the total welfare gain from reducing emissions from $e_0 = 6$ to five is:

$$\frac{1}{2}\left(MD\left(e_0\right) - MC\left(e_0\right)\right)\left(e_0 - e\right) = \frac{1}{2}\left(2 - 0\right)\left(6 - 5\right) = 1 \tag{73}$$

This is less than the fixed cost, so it is efficient not to reduce emissions and remain at $e_0 = 6$.

Similarly, for the developing country, we have:

$$1 - 4 + e = 6 - e + 1 \quad \rightarrow \quad e = 5 \tag{74}$$

Marginal costs and benefits have shifted by the same amount, so the e which equates MC and MD is the same. However, there is a larger welfare gain, as now $e_0 = 7$:

$$\frac{1}{2}\left(MD\left(e_0\right) - MC\left(e_0\right)\right)\left(e_0 - e\right) = \frac{1}{2}\left(4 - 0\right)\left(7 - 5\right) = 4 \tag{75}$$

The welfare gain is still not enough to overcome the fixed cost. Efficient emissions is at $e_0 = 7$.

For the developed country:

$$2 - 4 + e = 6 - e + 2 \quad \rightarrow \quad e = 5 \tag{76}$$

Marginal costs and benefits have shifted by the same amount, so the e which equates MC

and MD is the same. The welfare gain with now $e_0 = 8$ is:

$$\frac{1}{2}\left(MD\left(e_0\right) - MC\left(e_0\right)\right)\left(e_0 - e\right) = \frac{1}{2}\left(6 - 0\right)\left(8 - 5\right) = 9. \tag{77}$$

Now it is efficient to pay the fixed costs, with the final welfare gain for the developed country equal to four. Efficient emissions are five. So we have an EKC.

Figure 60 shows the problem graphically. First, solving the equations for e gives:

$$e = 4 - y + MB \tag{78}$$

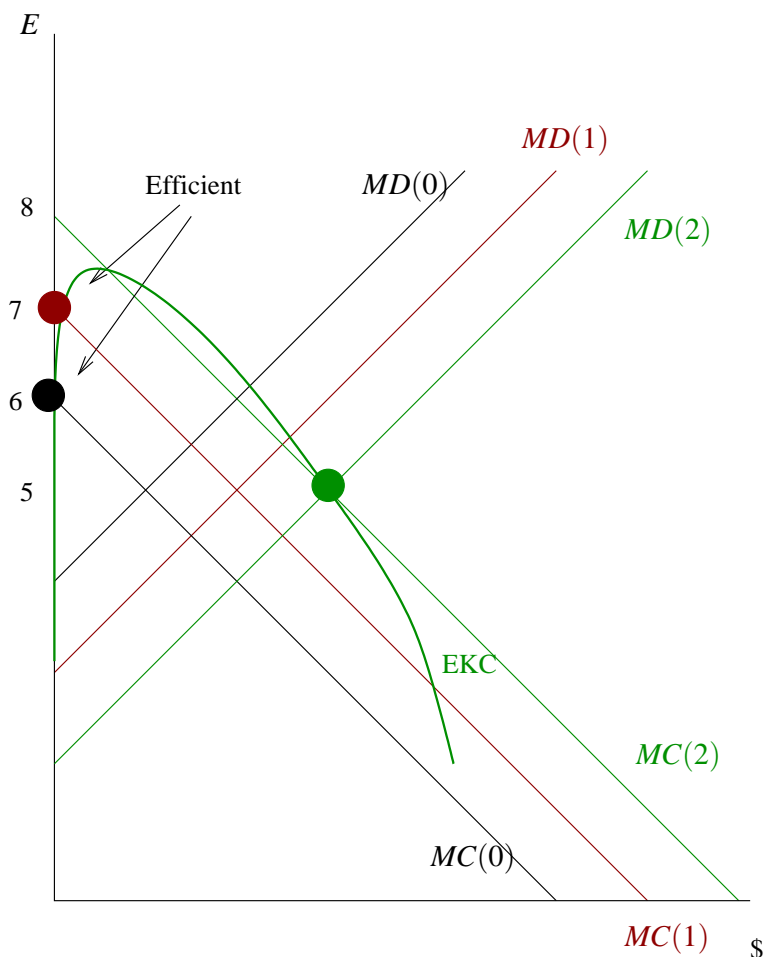$$e = 6 + y - MC \tag{79}$$

Then:

Figure 60: Increasing returns.

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However, the U.S. compliance spending does not seem to have the jump from zero implied by the fixed cost argument. In fact, emissions reduction was very inexpensive.

F   International pollutants

Note that for pollutants which cross borders, especially global pollutants like carbon dioxide, it is difficult to agree to reduce emissions. This is because if one country agrees to reduce, then all other countries benefit, even if they do nothing. Therefore, it becomes optimal to free ride. The graph is identical to the poor institutions case, except that an inefficient level of pollution occurs even for wealthy countries.

G   Conclusion

For what pollutants and EKC exists and why remains unclear. What is odd is that the timing of emissions reduction for most developed countries was around 1970. This could indicate that some sort of shift in preferences occurred. around this time. Once we became aware that we wanted a cleaner environment, we found it to be cheap enough to take action.

II   Pollution Havens

Here we examine the idea that countries or regions or states with lax environmental regulations attract polluting industries. This is a major concern of environmentalists, especially with regard to free trade agreements. In the absence of free trade, a country with lax environmental regulations is not necessarily a big problem. An industry which locates in the pollution haven would be prohibited from exporting back to the US, if the US did not allow free trade. Therefore, the US could implement strict regulations without fear of production (and pollution) "leaking" outside the US. Concern about pollution havens was a major issue with NAFTA and China's WTO agreement, for example.

Definition 29 *Pollution Haven Hypothesis (PHH): Polluting industries tend to locate in countries or states with lax environmental regulation.*

Definition 30 *Leakage Effect: Some emissions reduction associated with stricter environmental regulation is lost when polluting industries relocate to a country with lax environmental regulation.*

The PHH and leakage are a major concern with environmental agreements as well. For example, since developing countries are exempt from Kyoto and other climate agreements,

the fear is that strict emissions reductions in the US will lead to polluting industries relocating to China, India, and other exempt countries. In this case, CO_2 emissions might not fall much at all, which is the leakage effect. For this reason, the Waxman climate bill includes import tariffs from China to discourage relocation. These may violate WTO rules however.

A   Empirical Evidence

Theoretically, the PHH does not seem controversial: raise costs in one country and industries will relocate. However, the magnitude may be large or small. Many factors need to be considered when deciding where to locate: labor costs, tax rates, corruption, the skills of the labor force, exchange rate risk, etc. Given that even in the US we spend less than 1.5% of GDP on pollution reduction, it may be that pollution regulation is not a big factor in location decisions.

A statistical test would be to see if net exports are negatively correlated with pollution regulation stringency. The results here are minimal: no statistically significant relationship exists.

A second test would be to see if capital (new factories) flow to countries with lax regulation. That is, check the correlation between foreign direct investment (FDI) and regulation stringency. Here we do have a statistically significant negative correlation. However, the effect is small in magnitude.

B   Reasons for a Small Pollution Haven Effect

Many potential reasons exist:

1. As noted above, pollution reduction costs are small, even for developed countries.

2. We could be seeing an EKC: FDI to developing countries results in higher income and therefore more strict environmental regulations.

3. FDI may result in industries bringing the latest pollution control technologies to developing countries.

4. Most trade is between developed countries with similar pollution regulations.

5. It is not easy to relocate manufacturing facilities to other countries.

6. The Factor Endowment Hypothesis (FEH).

Surprisingly, support exists for most of these except (1). Although pollution control costs are small, they may be large for a small set of polluting industries. On the other hand, many polluting industries, such as electricity generation or agriculture, are difficult to move, which supports (5). Further, evidence exists for a large technique effect following FDI, since industries grow but pollution does not. This could be the result of either (2) or (3). The factor endowment hypothesis is addressed in section III.

C   Example

Suppose we have marginal costs and marginal damages as:

$$MC = 12 - E, \tag{80}$$

$$MD = E. \tag{81}$$

The efficient emissions is:

$$MC = 12 - E = MD = E, \quad \rightarrow \quad E = 6. \tag{82}$$

We will assume the regulation is an emissions standard. If instead we had an emissions tax, tax costs would also need to be considered below.

Suppose the North uses the efficient Pigouvian tax and the South has no pollution regulations. Both countries have the same marginal damages, though. We are assuming the South does not have the institutions to properly regulate pollution. Start with no trade and the industry in the North. Therefore, initially we have $E_N = 6$ and $E_s = 0$ and the total $E_t = 0 + 6 = 6$.

What are the compliance costs? We have:

$$MC = 0 = 12 - E_0, \quad \rightarrow \quad E_0 = 10, \tag{83}$$

$$CC = \frac{1}{2} (E_0 - E) (MC(E) - MC(E_0)) = \frac{1}{2} (12 - 6) (6 - 0) = 18. \tag{84}$$

Suppose finally that the firm believes it can save \$12 in labor costs by moving south and that the fixed costs of the move are \$20. After the trade agreement, will the firm move? What will be the emissions in each country?

By moving south the firm saves \$18 in compliance costs, saves \$12 in labor costs, and

pays $20 in moving costs. The total savings from moving is thus:

$$\Delta\pi = \$18 + \$12 - \$20 = \$10 > 0. \tag{85}$$

So the firm relocates. Emissions are now: $E_N = 0$, $E_s = E_0 = 12$, and $E_t = 0 + 12 = 12$. Total emissions have risen, because the firm moves to a country with lax regulations. Emissions fell in the North, who is getting the best of both worlds: cheap goods and low pollution.

What is the leakage effect? When considering the regulation in the North only, emissions reduction is:

$$\Delta E_N = E_{0,N} - E_N = 12 - 6 = 6. \tag{86}$$

So the regulation was suppose to reduce emissions by 6. Actual emissions reduction is:

$$\Delta E_t = E_{0,N} - E_{\text{total}} = 12 - 12 = 0. \tag{87}$$

So actual total emissions reduction was 0. All 6 units of emissions reduction "leaked" to the south:

$$\text{Leakage} = \Delta E_t \,(\text{ No trade }) - \Delta E_t \,(trade) = 6 - 0 = 6. \tag{88}$$

What is highest pollution tax and lowest emissions that keeps the firm in the North? We need compliance costs to be at most $20 - $12 = $8. We have:

$$CC = 8 = \frac{1}{2}\,(E_0 - E)\,(MC\,(E) - MC\,(E_0))\,, \tag{89}$$

$$8 = \frac{1}{2}\,(12 - E)\,(12 - E - 0)\,, \tag{90}$$

$$16 = (12 - E)^2\,, \tag{91}$$

$$4 = 12 - E, \;\; \rightarrow \;\; E = 8. \tag{92}$$

We can only reduce emissions to $E = 8$ and keep the industry. The standard required

would be:

$$t = MC = 12 - E = 12 - 8 = 4. \tag{93}$$

Note that it is not desirable for the North to do this. Given the south is offering to produce cheaply, and assuming the pollution does not cross the border, the north should specialize in less pollution intensive industries.

III Factor Endowment Hypothesis (FEH)

The FEH states that:

Definition 31 *FEH: Following trade liberalization, capital intensive industries relocate to the country which is more abundant in capital.*

Suppose we consider North-South trade, like the US and Mexico. The north (US) is more capital intensive, but also has stricter pollution regulations. These two effects offset.

1. The capital intensity effect dominates. The capital intensive industry moves to the US as it is better to take advantage of the abundant capital despite the high pollution control costs. Since capital intensive industries tend to be polluting, pollution moves to the North. Since the US has stricter pollution control, total emissions in both countries falls. Suppose initially the firm has emissions E_0 and is located in Mexico. We have:

$$E_{\text{total}} = E_{\text{US}} + E_{\text{Mexico}} = 0 + E_0 = E_0. \tag{94}$$

After the move we have:

$$E_{\text{total}} = E_{\text{US}} + E_{\text{Mexico}} = E^* + 0 = E^* < E_0. \tag{95}$$

Pollution falls in Mexico since the industry leaves. Pollution rises in the US due to a scale effect. Pollution overall falls as the US has more strict pollution control laws.

2. The Pollution regulation effect dominates. Here the US has more abundant capital, but the industry moves to Mexico to take advantage of weaker regulations. We have for an industry starting in the US:

$$E_{\text{total}} = E_{\text{US}} + E_{\text{Mexico}} = E^* + 0 = E^*. \tag{96}$$

After the move we have:

$$E_{\text{total}} = E_{\text{US}} + E_{\text{Mexico}} = 0 + E_0 = E_0 > E^*. \tag{97}$$

Overall pollution rises.

Overall, since pollution control costs are small, we would expect the FEH to hold and case 1 to be observed. However, the result can vary greatly by industry. Consider for example, the logging and mining industries. These are very capital and pollution intensive. Suppose mining was previously done in the US, with strict pollution regulation. After the trade agreement, the industry moves south since the pollution regulations are weak. Of course, it must move all the capital south as well, at significant cost. But this is probably offset by another factor, which is that the mine in the south is relatively untouched, and therefore cheap to mine. So the industry moves south and pollution rises, as described in case 2 above.

IV   The case of the Buffalo

The case of the near extinction of the buffalo provides a common example of the impacts of free trade on the environment given weak property rights. In 1871 a new process for tanning buffalo hides was developed in Britian. The worldwide leather market at the time was huge, and cow hide was used almost exclusively.

Given the size of the world wide leather market, one could convert the entire buffalo population into leather and see little change in the world price.
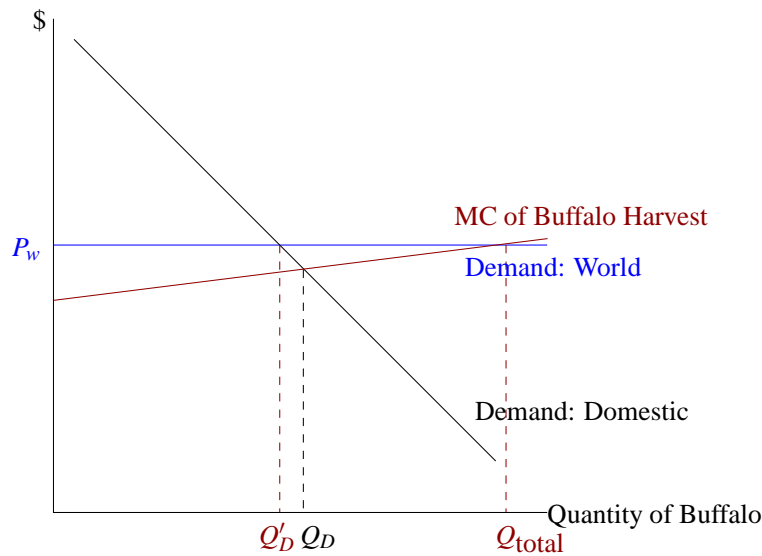
Figure 61: Buffalo Harvest, before and after opening to trade. Here Q_D is domestic harvest, Q'_D is part of the harvest used domestically after opening to trade, Q_{total} is the total harvest, and $Q_{\text{total}} - Q'_D$ is the part of the harvest which is exported.

In figure 61, world demand is flat. No matter how much buffalo is turned to leather, the price of leather will not be much affected in world markets. Conversely, the domestic demand is more steep, the market is smaller and so less people are willing to pay the world price to get leather. Thus, if the buffalo market were initially closed to trade and then opened, domestic consumption falls from Q_D to Q'_D.

Now some information about the supply of Buffalo. We are assuming the property rights of the buffalo are not defined. On a buffalo farm, the farmer may invest in breeding buffalo, and will not convert the entire stock to leather at once. How much leather is converted depends on how fast buffalo breed, the interest rate, etc.

But with no secure property rights, there is no interest in maintaining a herd. All that matters is the cost of converting buffalo into leather. If you leave a valuable buffalo roaming, someone else will take it, so you might as well get there first.

Further, I have drawn the marginal cost of harvesting buffalo flat. With many endangered species, the cost of harvesting rises as the species becomes more rare. The typical example is fish. Suppose there is a wahoo craze in Japan. Harvesting begins, and the fish eventually becomes scarce and difficult to find. The wahoo does not go extinct, because it is just too expensive to find all of the fish. Marginal costs are upward sloping.

Unlike the wahoo, which is solitary and lives in the water, buffalo travel in herds and live in the plains. Slaughter part of one herd and it will band together to form larger herds. So

the marginal cost remains flat even with large harvests.

The conclusion from the near extinction of the buffalo is that free trade can magnify the negative effects of poorly designed regulation or poor property rights. Of course, the most efficient solution is to fix the regulation, not eliminate free trade.