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Climate and Industrial Policy in an Asymmetric World

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Abstract

Climate change is a phenomenon leading to randomly distributed disasters around the globe. Due to massive economic and technical asymmetry between the advanced North and the developing South efficient climate and industrial policy is particular difficult. Globally efficient policy would need to equip the South with pollution reducing technologies. However, there is a tradeoff between capital accumulation for consumption growth and low-carbon development. The pollution stock affecting today's climate was historically accumulated by the North, therefore, the 'ability-to-pay principal' and the 'polluter pays principle' suggest to allocate the main burden of climate change policy to the advanced economies.

Keywords: climate change policy, North-South asymmetries, stock pollution, distribution of burdens

JEL classification: Q54, Q25, Q14

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Tables and figures appear at the end of the paper.

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1 Introduction

In today's globalized world there is a complex relationship between economic activity and the environment. In addition, there is a feedback mechanism from the environment to economic activity and welfare. Besides the fact that economic development is a driving force for climate change, policies that aim to mitigate global warming may also impact negatively on the speed of global development processes. We aim to demonstrate that there can be no solution for the problem of global warming on a global scale that does not account for the effects that climate policy has on economic development, especially for less developed countries. Even more, the causal interdependencies are highly asymmetric. Looking at the variety of countries in the world, we observe major asymmetries and heterogeneities. There are asymmetries in welfare, technology, industry structure, pollution, and the accumulation of a pollution stock, and in the way countries are affected by climate change. The effects of these asymmetries in the world economy are neither adequately understood nor taken into account. This paper seeks to highlight the main effects of the global asymmetries on the efficiency of a global climate and industrial policy (IP), and to illustrate the distribution problems that arise from such a policy. Since economic theory is well developed with respect to environmental economics we can use the associated findings as a starting point for analysing the asymmetry issue.

2 Global asymmetries

An important step towards understanding the relationship between economic development and global climate policy is to understand the enormous asymmetries and heterogeneities in the global economy. We consider the six most important of these.

2.1 Income: poor versus rich

It is only possible to comprehend what happens in international talks on climate policy and understand the positions of the different countries if one understands the major income asymmetries and wealth disparities in the participating countries. Milanovic and Yitzhaki (2002) provide a good overview of existing disparities and income inequalities in the global economy. Table 1 shows these disparities using mean income, Gini-coefficients and the overlapping index. A simple comparison of the mean incomes in this table reveals that at the beginning of this century, three-quarters of the world's population earned less than 10 per cent of the richest 16 per cent of the world's population.

Only 16 per cent of the world's population live in the rich countries.[1] They produce and enjoy 58 per cent of world income. By contrast, 76 per cent of the world's population live in poor countries and generate only 29 per cent of world income. During the last 150 years of growth the richest 16 per cent of the world's population were able to accumulate an estimated share of over 80 per cent of the world's wealth. In other words, these 16 per cent own the main share of real world capital and in turn most of the

1 According to Milanovic and Yitzhaki (2002) this group consists of the G7 or G7-equivalent states, the latter having at least the per capita income of the G7.

world's firms and corporations. This affluent population group also participates in 60 per cent of international trade and an even greater proportion of international financial transactions. So on the one hand, the richest 16 per cent of today's population have been able to generate the technological and economic growth that has led to progress in human development, but also to the major disparities we observe today. On the other hand, even if the disparities in per capita income remain drastic, absolute economic activity, which can be an indicator for political power, indeed shows that the developing world has not only started to grow more rapidly, but has already undergone a considerable catching-up process. These developments described in Figures 1 to 3 have clear effects on the functioning and mechanisms of global governance. Because most of the economically successful countries are in the northern hemisphere we refer to these countries as the rich North[2], in contrast to the poor South[3]. To simplify the discussion we do not take all countries into account but rather focus on the G20 states. The G20 represent by far the largest share of global economic activity, and using them we can demonstrate the asymmetries in the world most vividly. Hence, we split the G20 group into Northern and Southern countries.

Looking at Figures 1 to 3 it becomes apparent that the North is no longer the by far dominant part of the world economy. The world economy faces a 'global shift'[4] in relative weights with important effects on both, the North and the South. The reasons for these differences in development are complex and go far beyond the scope of this paper. Nevertheless, identifying these enormous heterogeneities and asymmetries is a prerequisite for understanding the global climate debate and the various positions taken by the countries in developing an appropriate policy.

2.2 Industry structure: physical production versus value added in services

Income disparity is not the only factor to contribute to the range of positions and conclusions when negotiating a global environmental, industrial, and climate policy. Equally important are asymmetries in industry structure. Per capita income in the South accelerated thanks to rapid modernization and structural change. There is no sustainable development process that is not directly connected with a structural shift away from agriculture towards the modern industrial or service sector. Indeed, there is an ongoing debate about the role of industrialization in the process of development. Some evidence for Latin America and Africa seem to indicate even a process of deindustrialization since the 1980s. A direct shift from an agriculture-dominated towards a service-driven economy seems possible. However, the most impressive development processes, particularly in Asia, are fuelled by massive industrialization and hence an expanding industrial sector. Comparative advantages in labour-intensive, standardized production processes clearly point less at the importance of the service sector, but at a rapid expanding manufacturing industry within an internationally-oriented outward-looking development strategy. Due to the emergence of industrial sectors in the South and a shift in comparative advantages between the South and the North a large part of today's

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2 The rich countries of the G20, or the North, are the USA, Germany, Japan, the UK, France, Italy, Canada, and Australia.

3 The poor countries of the G20, or the South, are China, Brazil, Russia, India, South Korea, Mexico, Turkey, Indonesia, Saudi Arabia, South Africa, and Argentina.

4 For a more detailed discussion of this shift in the global economy, see Gries (2007).

global industrial production takes place in the South. However, industrialization in the South is beneficial not only for the successful emerging markets, the North also benefits via international trade. Many of the goods produced in the South are eventually consumed in the North. Northern consumers benefit in particular from low prices which increase real purchasing power in the North. In other words, the development process undergone by the South also affects the North very positively.

However, international integration has led to acceleration in the economic division of production processes all over the world. The late take-off of developing economies, and the process of industrialization that goes along with development, means that developing countries are currently passing through the stages of industrialization that advanced economies went through long ago. Typically this process begins with a massive expansion of industrial production. Value added is created in the shape of physical production using standardized technologies and labour-intensive production processes. As products become more complex and sophisticated technologies become commonplace, the value adding processes change. The proportion of standardized physical production declines in favour of high value adding high quality services. This represents yet another structural change, which brings with it another substantial change in resource-intensity. Whereas physical production during the first phase of industrialization is characterized by high resource- and energy-intensity, we observe declining resource- and energy-intensity in advanced countries as technology and human capital intensity increases.

Generally speaking, the stage of development at any one time partly determines (a) the production structure and in turn (b) resource and energy intensity. This has two implications for the current negotiations on a global climate policy. First, high-income countries are fortunate enough to no longer have a dominant physical industrial production sector. In these countries the less energy intensive service sector is responsible for about 70 per cent of value added, so they have a production structure with high energy and resource efficiency. Second, since emerging economies are in the relatively early stages of development their production structures are undergoing increasing physical industrialization. The success of these countries is driven by the fact that they are responsible for a rising share of the world’s physical production. Their development is an industrialization process driven by the alignment of their production structures with their comparative advantages. Thus the North-South structural asymmetry is the result of international integration and a successful, export-driven development strategy.[5] Whereas in the North successful development goes hand in hand with ongoing deindustrialization and a growing technology and service sector, the South is growing through industrial modernization.

2.3 Technologies: high tech versus backward technology

The third considerable asymmetry relates to the technological differences between the North and the South and partly to the developmental asymmetries mentioned above. There are enormous technological differences between the North and the South in all dimensions and areas of economic activity. In addition to the structural advantages of the industry of the North (with a less energy-intensive structure), energy efficiency in

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5 On developmental and catching-up processes, international integration, and structural changes see also, Gries (1995) and Gries and Jungblut (1997a; 1997b).

the North (with the exception of the USA) is far better than in the South. In this section we focus on the differences in the use of fossil energy resources.

Figure 4 illustrates this difference. Germany and Japan are two examples of Northern countries with high efficiency in avoiding pollution. China is an example of a Southern emerging economy with low energy-efficiency, while the USA stands for a rich and developed country with the efficiency in avoiding pollution of a developing economy. CO_2 emissions per unit of output in the North are far lower than in the South for two reasons. First, higher per capita income in the North seems to influence the preferences towards a cleaner environment. Second, this shift in preferences encourages the development of technologies that reduce pollution from production processes. Energy-efficient technologies are in demand. In particular, more efficient electrical power plants are leading to a significant reduction in pollutant emissions. While technologies with low CO_2 emissions are available, most of them are implemented only in the North and hence asymmetrically. Even if many of these technologies were developed with high public subsidies, property rights are often privatized. Today, most of these technologies are owned by private firms in the North. These asymmetries in availability and ownership have to be taken into account as well when negotiating a global climate policy.

2.4 Current pollution emissions

The fourth global asymmetry is based on the differences in economic development and emissions efficiency. As shown in Figure 5a most of today's global pollution is generated by the two country groups under review. On the one hand, there are the rich countries of the North; on the other, there are the emerging economies of the South. Interestingly, in Figure 5a we can observe that since 2005 the emerging markets have contributed more pollution than the Northern countries.

However, for both country groups it is clear that pollution is linked to the level of economic activity. A high absolute level of economic activity leads to a high absolute level of pollution. Because the advanced countries still account for the largest absolute share in world production they still have high pollution, despite their structural advantages. This becomes especially apparent when we convert absolute pollution to per capita pollution. Thus most of today's global pollution is due to income and welfare generating activities in the rich countries, even though some successful emerging countries like China, India, and Indonesia do contribute a considerable amount of pollution.

2.5 Historical pollution (pollution stock)

These asymmetries in pollution become even more dramatic if we not only consider today's pollution flows but also the pollution that has accumulated over time. Figure 5b displays current accumulated pollution levels that are responsible for global warming. Although the emerging markets are catching up fast and generate a noteworthy amount of pollution themselves, most of today's pollution can be traced back to more than two-thirds of the Northern countries. Hence some of today's prosperity and wealth in the advanced countries has been virtually paid for with global pollution and global warming. Assuming inter-generational responsibility is an accepted principle, the Northern countries ought to—and owing to their prosperity, are able to—contain the damage they have caused in an adequate way. This basic consideration becomes even more drastic when absolute values are converted to per capita values. As is shown in Figure 7, not only is the North by far the biggest polluter in absolute terms, but these countries are also the greatest beneficiaries in terms of the use of fossil resources for the sake of wealth development, expressed in accumulated per capita pollution.

2.6 Natural disasters and resulting damage

The final asymmetry affects the vulnerability of the North and South to future climate change-induced effects. Of all the asymmetries discussed above this is the most theoretical one, in particular because to this day we have no reliable forecasts concerning the impact of global warming on different regions in the North and South. There are some clear indications of growing desertification, a rising number of extreme weather events and an increase in weather-related disasters. There are also indications that sea levels are rising and that ocean currents may shift, yet all of these statements involve so much uncertainty and coincidence that it is impossible to make stylized predictions. Statements about potential exposure vary depending on the likelihood of that exposure, ranging from the predominant exposure of the Southern countries (in particular because of their proximity to the equator and the resulting desertification issues and extreme weather conditions) to a rising vulnerability of Northern countries (for example due to changes in the great marine conveyor belt causing extreme weather and wind phenomena). In this regard, there are asymmetries in both regions. Which of these asymmetries will occur or whether there will be any asymmetries at all is completely unclear, as it stands today. Maybe this uncertainty about the future symmetric or asymmetric exposure offers the greatest chance of reaching an agreement. As for the cost of global climate change-induced damage, Stern (2006) assumes that it equates to between 5 and 11 per cent of global GDP each year.

3 Climate change and the global efficiency problem

Since using the environment as an absorbent for pollution affects welfare and quality of life, pollution-producing activities have to be closely monitored. To consider the environment as a resource implies an economization of the environment. The economic objective is to find a reasonable, ideally even an optimal, way to manage this resource in order to improve global welfare. How can we manage the ‘environment resource’ in the best possible way? So far the global climate policy debate has not appropriately tackled the issue of global efficiency and global fairness, in particular with regard to the strong North-South asymmetry. While references to the asymmetries between these are made once in a while, they do not form part of a comprehensive proposal for global policy implementation.[6]

To solve the problem of finding a global environmental policy for an asymmetric world, special consideration must be given to two characteristics that arise from the use of the environment as a resource. The first one is the global ‘public good characteristic’ of CO_2 pollution. Emissions, no matter where they are produced, cause global warming which can potentially affect everyone. Hence, pollution causes damage for potentially everyone and correspondingly also reduces universal wealth. Second, pollution

6 For a comparison of different proposals, see, for example, Agrawala (2005) and OECD (2009a; 2009b).

accumulates to become a more and more serious problem. The enormous pollution stock accumulated slowly over time has created today's global warming problems.

These two characteristics have to be taken into consideration when finding ways to treat the current emissions problems effectively. In the following we will describe some stylized thoughts that may lead to a more efficient solution of the pollution stock problem that is causing climate change. We will do so in two steps. In the first step we assume a homogeneous world: our approach towards the problem of developing an efficient environmental policy involves 'assuming away' all the asymmetries in the global economy as described in Section 2, an experiment that will shed light on the fundamental and economically useful aspects of a global environmental policy. In a second step we consider the existing asymmetries in the global economy. We identify the special challenges of an asymmetric world, again within a stylized discussion, with the aim of illustrating a global environmental policy under asymmetric conditions.

All lines of argumentation are based on the model described in the next section and the version of this model of a asymmetric world is given in the Appendix.

3.1 A simple global pollution stock model in a homogeneous world

This contribution cannot claim to present a fully developed model for an optimal global policy with asymmetric world regions. However, what it can do is to outline an optimal environmental policy in a homogeneous world and in the Appendix, present a first extension of this model for the asymmetric world.

In this first reference model[7] we assume that these asymmetries do not exist. There are no differences between agents, technologies, or countries. Hence we assume a representative agent consuming *C* from world production. Pollution causes damage all over the world. This damage *E* enters the agent's utility function causing disutilities *U (C,E)*. Hence w*elfare W* of the society, including future generations, is defined as

$$W = \int_0^\infty U(C,E)e^{-\rho\tau}d\tau \qquad U_C > 0 \qquad U_E < 0$$

Environmental damage *E* is generated by two components: the consumption of fossil energy resources *R* and the existing state (stock) of pollution *A*.

$$E = E(R, A) \quad E_R > 0, \quad E_A > 0$$

World product *Q* is produced using the flow of extracted exhaustible energy resources *R* and accumulated capital *K*. Since environmental damage *E* is a negative public good it also affects the production process as a negative externality.

$$Q = Q(R, K, E), \quad Q_R > 0, \quad Q_K > 0, \quad Q_E < 0$$

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7 As a starting point this simple model is closely based on the standard descriptions of this problem given in e.g. Perman et al. (2003: chapter 16). Further theoretic models are presented by Farzin (1996) and Lieb (2004).

while pollution causes damage, there is also a clean-up technology *F*. While the production technology determines how efficiently resources are used, the clean-up technology reduces existing damage. With *V* being the cost of applying the clean-up technology, we improve the effectiveness of this technology by spending more

$$F = F(V) \quad F_V > 0$$

The effects of economic activity on resource stocks *S* and accumulated pollution *R* are

$$\dot{S} = -R$$

and for exhaustible resources

$$\dot{A}(t) = M\left(R\right) - \alpha A - F(V)$$
$$A(t) = \int_0^t \left(M\left(R\right) - \alpha A - F(V)\right) d\tau$$

As for stock pollution dynamics we assume that stock pollution changes as a function of the current use of resources $M\left(R\right)$ less the natural regeneration rate indicated by rate α and less the effects of the clean-up technology F .

The model is closed by considering the budget constraint for the representative agent

$$\dot{K} = Q - C - V$$

To solve this problem we use optimal control theory as described in Appendix 1. From the first order condition concerning resource use we obtain the efficient price path as

$$P^{net} = \omega Q_R = P - U_E E_R - \omega Q_E E_R - \lambda M_R, \tag{1}$$

where P^{net} is the net price that corrects for negative externalities of resource use to obtain an efficient allocation of resources. We discuss the message of this efficiency condition in the following section.

In Figure 6 we see the price path for a fossil resource causing flow and stock pollution effects. The fact that the resource is exhaustible and not easy to completely substitute leads to a generally rising price. However, the damage caused by the pollution requires a price adjustment to reduce the use of the resource and cut down the damage. There are two flow externalities, one damage affects consumers and another producers. For both effects a price correction could reduce the damage towards and efficient use of the resource. A third effect is the one generated by the accumulated stock of pollution. Since the accumulated stock of pollution together with today's additional pollution causes further future negative effects this stock pollution effect also requires a price correction.

3.2 A global environmental policy in a homogeneous world

Based on the theoretical concept discussed in the previous section we now discuss a world with no differences between North and South. In this world, wealth is positively affected by consumption and negatively affected by pollution both pollution flows and pollution stocks already accumulated. In this model the pollution comes from burning fossil fuels to generate electricity. Hence they are major factors of production. If burning fossil resources is necessary for production, on the one hand, but generates welfare-reducing pollution on the other, one can find an optimal level of use. From equation (1) in the above model we learn that under free market conditions the resource is used too intensively and the pollution caused by burning fossil resources is too high. Figure 6 shows the theoretical price path of the resource that arises without an environmental policy, as well as the efficient price path that should be taken via policy instruments to guarantee efficient resource use.

The condition reflects well-established insights from the economics of externalities and public goods. First, Figure 6 shows that the gross price ought to increase by the marginal values of all three kinds of damage, namely the direct marginal effect on utility [$U_E E_R$], the marginal negative effect on production [$\omega Q_E E_R$], and the marginal stock pollution effect of accumulating CO_2 that negatively affects the next generation [λM_R]. Second, the resulting net price should determine resource use in production and—with an increasing net price—adjust total extraction and the burning of fossil resources downwards. Third, there are various instruments that can be used to implement this price adjustment. The best-known policies are the Pigou tax (an eco tax)[8] and tradable permits.[9] Both instruments lift the price so that resource inputs and damage are reduced.[10]

In a world with no differences and asymmetries where policy instruments are enforceable by a governmental authority, a global environmental policy would not be much of a problem. In fact, there are many examples of countries where such environmental problems have been solved.[11] However, not much theoretical modelling has been done so far concerning highly asymmetric countries.[12]

3.3 A global environmental policy in an asymmetric world

In the asymmetric world described above the policy conditions are fundamentally different. The theoretical approach underlying the following discussion extends the above model (see Appendix 2). As it primarily serves to understand the different perspectives and the associated factors that strongly influence the optimization problem, we have not yet tried to suggest a global optimal policy strategy. Our objective is to

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8 The idea of internalizing external effects of public goods goes back to Pigou (1920). His approach was later extended in the context of environmental economics by Baumol and Oates (1971, 1988).

9 See, for example, Dales (1968), Cansier (1996), and Dorn (1996).

10 For a comparison see e.g. Giraudet and Quirion (2008) or Oikonomou et al. (2008). For accumulated pollution see also the discussion in Hoela and Karp (2002).

11 See, for example, Christiansen et al. (2005) or Convery (2009).

12 See, for example, Rose et al. (1998).

suggest a starting point to address the issue rather than to provide a comprehensive solution.

To include the impact of global asymmetries on decision-making from different perspectives we assume that there are two separate world regions, the North and the South. Each of these regions constitutes its own world in which it produces, consumes, and develops independently. The central link between these two world regions is the effect of pollution. Pollution, both accumulated (stock) and current pollution (flow), impacts negatively on welfare in the whole world, in the South as much as in the North. To focus on the problem of pollution and to identify an efficient global solution, the only asymmetry between the North and the South, is the technological capability of avoiding pollution when using fossil resources. The existing pollution-reducing technologies in the North mean that this region generates significantly less pollution with the same resource input. Even if the North produces heavy pollutant emissions due to a high level of production and income, the marginal efficiency of pollution per resource and per output unit is significantly higher in the North. From this simple asymmetry[13] we can already draw some early conclusions concerning an efficient control of polluting resources and an efficient environmental policy. From the very simple model in Appendix 2 we can derive environmental uncoordinated policies of the *North* and the South, respectively, or if acting coordinated and simultaneously. The first and most important principle of an efficient policy is: pollution reduction has to start where it can be achieved most easily (with the lowest possible marginal opportunity costs). As more and more pollution is reduced, pollution-reducing technologies will become more and more expensive (decreasing marginal efficiency), so we have to begin with the technologies that are the most effective. Since the technologies used in the South have low energy efficiency we have to begin in the South because here maximum reductions are possible with very little investment, whereas the North would incur very high expenditures to improve what are already efficient technologies. From a global point of view the most efficient measure is to implement efficiency-improving technologies until the South has reached the level of marginal resource efficiency of the North. Looking at this efficiency condition says nothing about the issue of bearing the burden of implementation costs. We discuss the question of burdens and their fair distribution in Section 4. To make our point as clearly as possible we separate the two issues, efficiency and fair distribution at this stage, initially focusing solely on efficiency before coming back to the problem of fair distribution later.

How can a global government execute this kind of efficient environmental policy? From our theoretical model in Appendix 2 it is apparent that the inefficient use of resources in the South has to become more expensive, relative to the North, until marginal environmental damage reaches the same level. Rising prices would be an incentive for preventing damage until an equal efficiency level in the North and South is reached. This relative price increase can be implemented theoretically via a Pigou tax or an optimal number of tradable permits. In any case these instruments would be a necessary incentive for implementing resource-saving technologies. Further, thinking about implementing resource-efficient technologies in the South requires a more detailed

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[13] In reality asymmetries are even more complex. Further interdependencies like trade (e.g. Bommer and Schulze (1999) and Neary (2006) would not simplify the problem.

insight into the characteristics of pollution-reducing technologies that partly already exist in the North. We can distinguish three cases.

1. The technology of the North is a blueprint technology, i.e. it is an improvement in efficiency due to a pure increase in expertise. The implementation of this expertise allows for high reduction of emissions in the production process at no cost. A first straightforward example for this kind of efficiency improvements is a simple increasing awareness of environmental inefficiency. Preventing waste of resources is an easy step towards a de facto more efficient technology. Another example of such a blueprint technology could be a simple filtering technology where the chemical composition and engineering of the filter, and not the expensive components of filter production, generate the filter effect. The physical components of the filter demand no serious resource input. Hence, the value of this technology is solely generated through the knowledge of filter engineering expertise. It could be freely available or protected by a patent that generates license fees.
2. A second kind of technology would be similar to the first, except its implementation would incur major costs. These could consist of potential license fees, but also of set-up and installation costs. These costs need to be considered when evaluating efficient policy instruments.
3. The third case involves a technology embodied in real capital. In this case the production process requires a substitution of the presently implemented real capital by another more energy efficient capital stock with an integrated energy-saving technology. Under these conditions, not only would a power plant need filters in its smokestacks, it would also have to make major changes to the power generation process and hence replace a substantial share of the existing capital. Pollution could only be reduced as intended with massive investments in physical capital.

Depending on the empirical relevance of these three cases the design of environmental and industrial policies need to take account of various aspects. Further, as the three scenarios imply very different financial requirements, the issues of global efficiency and the fair distribution of burdens are affected in different ways.

1. Environmental and industrial policy based on a blueprint technology: this scenario would be the simplest and affect the cost and distribution issue the least. As this kind of technology would imply no rivalry in usage the only problem is the appropriate treatment of property rights of the technology owner. A blueprint technology that is used in one power plant can be simultaneously used in any number of other power plants without resource rivalry. As this kind of technology is characterized as a ‘public good’ it can be used simultaneously by several users with almost no direct costs. The optimal policy strategy in this case is for the ‘global government’ to pay appropriate compensation to the technology owner and supply the technology to the world for free. Like a public good, this technology would be available to all potential polluters at no cost. This would have a maximum impact on potential sources of pollution. The details of financing the appropriate compensation would have to be negotiated between the North, the likely owner of this technology, and the South. The result of these negotiations is not part of the efficiency problem, but a part of the distribution problem discussed below. The efficiency problem would be solved through deprivatization in the North and the transformation of a privately-owned technology to a global public good.

2. Blueprint technologies with considerable implementation costs: the second case links the extremely positive characteristic of a 'public good technology' with the problem that in reality this technology is not available for free. Even if emissions filters were available at virtually no cost, installation and adjustments in the power plants would require a more or less considerable amount of resources. Hence a considerable investment would be required to implement a low-carbon economy. The implementation costs alone would lead to investment activity and capital accumulation that is not directed towards the output of private goods. In this respect industrial policies may face a partial trade-off between implementing low-carbon technologies and a resource allocation promoting a higher speed of capital accumulation. Hence these investments would conflict with other development goals like growth in private goods. Depending on who provides the resources, the North or the South, one party would have to carry a burden.

First, collecting these resources in the South would slow down private output growth due to a slowdown in capital accumulation. Resources allocated to pollution-reducing technologies simultaneously reduce the funds available for investment in classic production processes. Hence the speed of capital accumulation for private production and in turn, the speed of development, decelerates. Because Southern countries are poor and have a huge backlog in development this would conflict with the United Nations' Millennium Development Goals.

Second and alternatively, resources could be collected in the North leading to a real North to South transfer. Even if the necessary investment goods or implementation services were purchased in the North, which would positively affect production and employment in the North, funds still have to be raised. For a real North to South transfer taxes have to be levied in the North leading to a reduction in disposable income and consumption. Put simply, the North needs to raise taxes to buy resource-efficient investment goods from its own economy and send these goods to Southern countries.

Obviously, implementation costs lead to a reduction in private consumption in the South or the North. So aside from the ideal case of a technology that is one hundred per cent a public good, climate protection clearly generates costs. However, these burdens are the opportunity cost of the gains we obtain by curbing global warming. These opportunity costs are the reasonable (and efficient) investment that is necessary to prevent damage through global warming. Both the South and the North have to develop an awareness that these costs exist and that it is necessary to distribute the burdens in an efficiently organized global economy.

3. The technology is a substantial part of the capital good: this third scenario is the most difficult one. Here, the technology cannot be installed within the existing capital stock. The technology is directly embodied in capital goods, and hence the current capital stock cannot be upgraded. Countries need to build a completely new or a supplementary capital stock with the adequate pollution-efficient technologies. Theoretically this is comparable to scenario 2. The difference is that implementation costs are not just small once and for all flows of payment, but require a substitution of existing capital by a long-term accumulation of a new and presumably even higher valued capital stock. Industrial and environmental policies face an even more serious trade-off between fast consumption growth and low-carbon production. Again, who is capable of bearing this even greater burden? If the South mobilizes these resources, traditional production and development processes would be affected and the South would sustain a slowdown in consumption. Similar effects would occur in the North if there were a real transfer from North to South. For a real resource transfer the Northern governments, similar to scenario 2 above, would have to raise taxes in order to fund the efficient investment goods even if they were produced in the North. Raising taxes would reduce private income in the North and hence negatively influence the consumption path in the North. Nevertheless, this would increase welfare because the installation of pollution-efficient capital stocks in the South would overcompensate for the costs of global warming despite impacting on the current consumption path.

While this discussion makes clear that an efficient solution to the global climate problem is possible, it also emerges that a reallocation of resources is necessary and that there is extreme uncertainty with respect to estimating total costs and benefits and the distribution of these benefits and burdens. For example assuming that the introduction of a global carbon market could keep the temperature increase below 3°C, this policy would, according to OECD estimates, cost about 0.1 per cent of average global GDP growth between 2012 and 2050.[14] According to the UNFCCC (2007) investments of more than US$200 billion are necessary each year in order to maintain global greenhouse gas emissions at current levels until 2030. Even if the total value seems huge, this amount is less than US$1 per day for each citizen of the North. The Intergovernmental Panel on Climate Change estimates these costs to be around 3 per cent of world GDP (IPCC 2007).[15]

Closely connected to the required resources is a finance problem[16] which incorporates a large-scale conflict concerning the distribution of burdens. Therefore, we have tried to make clear that in addition to the issue of an efficient solution any policy strategy that aims to solve the global efficiency problem necessarily has to ensure a fair distribution of burdens. This holds as long as a reduction in global warming is linked by technological characteristics to a reduction of the classic consumption path, and no ideal and freely accessible public good blueprint technology is available. IP must be aware of the fact that low-carbon growth is not for free. Hence it is important to realize that, even though our model treats them separately, both problems—efficiency and a fair distribution of burdens—are closely linked

4 A fair distribution of burdens

Solving the efficiency problem will most likely incur substantial implementation and even accumulating investment costs. Therefore, we also have to answer the question of how to distribute these burdens fairly.[17] Finding a response to this is particularly difficult because there are two components to consider. First, there is no global government that is able to decide on any kind of reasonable policy strategy on a global scale, let alone implement such a strategy effectively. So far most discussions about

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14 See, OECD (2009b).

15 See, Ott et al. (2009: 11).

16 For a discussion on finance see, for example, Ott et al. (2009) and Harmeling et al. (2009).

17 Suggestions are discussed e.g. in Harmeling et al. (2009).

implementation have focused on policies within countries.[18] Second, the considerable asymmetries and heterogeneities in the world, as described in Section 2, make it even harder to decide what constitutes a ‘fair’ distribution of burdens. Both of these points are hardly discussed in the present debate, even if they are crucial to finding an effective solution. Since our paper focuses on asymmetries we place the distribution problem, which is an intra- and an inter-generational problem, at the centre of the debate.

The *intra-generational distribution* problem: there are huge global disparities in the current level of development and consumption. The UN has stated clear goals concerning the elimination of poverty and the promotion of development in developing countries. Assuming these are common goals for the benefit of the global population, then it must be determined which principle of distribution can best achieve them.

1. According to the *ability-to-pay principle* a major share of burden would have to be carried by the North. If this principal is applied the much higher income per capita of the North would suggest to allocate a substantial share of burdens to the North. This would mean a tax increase in the North and a transfer in favour of Southern countries.

2. According to the *principle of equal distribution* a worldwide tax per head would have to be levied under the assumption that everyone is affected in the same way. However, in reality this would not be feasible because most of the population would not be capable of paying this tax due to their low income. Further, it would blatantly violate the ability-to-pay principle.

3. The third possibility is the *polluter pays principle*, under which the producer of the pollution is expected to pay. The North would be most affected by this because it still produces high emissions in absolute terms. However, the South would also be affected since it includes successful emerging markets like China, India, Indonesia, and Brazil (Figure 5a). When calculating a measure of per capita equality—which seems reasonable—the burden on the South would decrease significantly, because in per capita terms the North still emits far more pollution than the South (Figure 7a). The burden on the South would drop further if we account for decreasing marginal utility of consumable income, as is often done in economic models (see Appendix 2). In this context the marginal utility of consumption in the South would be substantially higher due to its lower per capita income. Hence the opportunity costs of tax burdens are much higher in the South than in the North. This, too, would lead to a clear and considerable additional burden on the North compared to that on the South.

So far we have only discussed fair distribution in the context of current emissions and the current world population, that is, we have looked at conditions within a generation. The phrase ‘fair distribution’ has another important dimension, namely inter-generational distribution. Looking at the emissions stocks in Figure 5b this dimension becomes very obvious. The model, which is described in the Appendix, has been deliberately chosen as an emissions stock accumulating model. The current level of global warming has evolved almost entirely through accumulated pollution generated in the past in the North. Only 20 per cent of today’s accumulated pollution can be traced back to China and other Southern countries. This becomes even more obvious when

[18] See, OECD (2009a), even if OECD (2009b) incorporates the possibilities of international cooperation and assistance and no global coordinated programmes are discussed.

looking at accumulated pollution per capita (Figure 7b). Hence today's need for action can be almost solely attributed to past activities in the North. Even if an efficient solution of the whole problem is not possible without incorporating the South, the issue of fair intergenerational distribution plays a major role when examining the fair distribution of burdens in the shape of investment in climate protection. While past generations in the North were able to pollute at no costs and in turn undergo development without any regard for emissions and the resulting burden on future generations, the South, while still underdeveloped, may now be held liable for additional damage prevention. Therefore, current global asymmetries, but also intergenerational asymmetry, will be important components in the debate surrounding a strategy for a global low-carbon economy.

5 Conclusions

The search for a global climate protection policy is a central economic problem. An efficient global strategy that incorporates a fair distribution of burdens is needed. In this respect an essential problem of searching for an efficient and fair climate and IP is the massive economic and technical asymmetry between the rich advanced North and the mostly less developed poor South.

The first and most important aspect of an efficient climate and IP is that pollution reduction has to start where it can be carried out most effectively (with a minimum of resources). If the highest pollution reduction can be achieved in a developing or emerging country with low resource input, then a global strategy should invest in these countries first. It is far more difficult and expensive to continue improving the already efficient technologies of the North. From a global point of view the most efficient measure would be to equip the South with efficiency-improving technologies until such time as similar marginal efficiency levels have been reached. Policy makers also have to be aware that there is a trade-off between the speed of general capital accumulation for the speed of consumption growth and low-carbon development. A global low-carbon growth path is most likely not for free.

Hence, a globally fair distribution of the burden generated by these investments is the most serious problem. Because most of the historically accumulated total pollution that affects today's climate has been caused by the North, the ability-to-pay principle and the polluter pays principle would allocate the main burden to the advanced Northern economies.

In a way this is an academic discussions, some weeks ago, my family watched the news and my children saw pictures of a great flood in Pakistan and asked if this flood has to do with climate change. 'We don't know exactly, but may be', was my answer. Then, they asked, 'what could be done to stop it?' I said 'spend US$200 billion per year on low-carbon emission technologies'. 'What does that mean?' they asked, and I answered, 'An ice cream a day for each of us'. They looked surprised and said 'That is easy …'.

Appendix 1

Optimal price path: homogeneous world

A global government or representative agent solves the optimal control problem:

Present value Hamilton

$$H = U(C,E) + P(-R) + \omega[Q(R,K,E) - C - V] + \lambda\left[M(R) - \alpha A - F(V)\right]$$

F.O.C.

Consumption and capital accumulation

$$\frac{\partial H}{\partial C} = U_C - \omega = 0$$

Resource utilization

$$\frac{\partial H}{\partial R} = U_E E_R + \omega Q_E E_R - P + \omega Q_R + \lambda M_R = 0$$

Clean-up efforts

$$\frac{\partial H}{\partial V} = -\omega - \lambda F_V = 0$$

Shadow prices

$$\dot{P} = -\frac{\partial H}{\partial S} + \rho P \Leftrightarrow \dot{P} = \rho P$$

$$\dot{\omega} = -\frac{\partial H}{\partial K} + \rho\omega \Leftrightarrow \dot{\omega} = \rho\omega - Q_K \omega$$

$$\dot{\lambda} = -\frac{\partial H}{\partial A} + \rho\lambda \Leftrightarrow \dot{\lambda} = \alpha\lambda + \rho\lambda - U_E E_A$$

Appendix 2

A simple model of global pollution and environmental policy (with asymmetric dynamics of pollution)

Only a small number of papers have considered heterogeneous regions with respect to stocks of accumulated pollution. For a discussion see, for example, Xabadia, Goetz, and Zilberman (2005, 2008) or Hoel and Karp (2009). For a better illustration we introduce a simple model.

Representative agents in two world regions

The world consists of two regions. On the one hand there is the technologically developed North with high income; on the other there is the technologically backward South with low levels of income. Both regions produce and consume separately. The only good that is used by both sides is the shared environment (atmosphere). Hence we have two representative agents, one that consumes the Southern product and another that consumes the Northern product. Environmental pollution is global and the resulting environmental damage E has to be borne by both sides.

$$U^N = U\left(C^N, E\right) \quad U_{C^N} > 0 \quad U_E < 0,$$
$$U^S = U\left(C^S, E\right) \quad U_{C^S} > 0 \quad U_E < 0.$$

Welfare in both regions (when considering future generations) is

$$W^N = \int_0^\infty U(C^N, E)e^{-\rho\tau}d\tau$$
$$W^S = \int_0^\infty U(C^S, E)e^{-\rho\tau}d\tau$$

Environmental damage

Local environmental damage arises from the local use of fossil resources and is linked to the existing level of environmental damage A. Because the North has better technologies it is assumed that the North pollutes less than the South. To simplify the model this differential can be interpreted such that the North emits no pollution at all while the South does. Even if this is clearly not the case in reality, this extreme scenario illustrates the asymmetries between the North and the South, which is the focus of this paper.

$$E^N = 0 \text{ meaning clean technologies in the north}$$
$$E = E^S = E^S(R^S) + E(A) \quad E^S_R > 0, \quad E_A > 0$$

Production

Aggregated good Q is produced with exhaustible resource R and accumulated capital K. Asymmetric conditions are reflected in the production process. While the filter technologies of the North will, in extreme cases, have no direct negative impact on their own local production, the locally produced environmental damage in the South will affect its own production process as a negative externality.

$$Q^N = Q^N(R^N, K^N)$$
$$Q^S = Q^S(R^S, K^S, E^S).$$

Damage removal technologies

Damage removal is not damage prevention. While damage prevention technologies directly prevent damage in the first place, local technologies for damage removal F^i are capable of reducing already existing damage. Because the North does not create damage in our model it does not need any damage removal technologies. Because V_N represents the costs of damage protection, damage reduction improves with more effort.

$$F^N = F^N(V^N) = 0 \text{ not required, no local demage}$$
$$F^S = F^S(V^S)$$
$$F = F^S$$

Resource stocks and pollution stocks

Resource stocks S decrease with extraction and usage as a factor of production *R*.

$$\dot{S} = -R$$

$$R = R^N + R^S$$

Pollution stocks (e.g. CO_2) change with pollution through current usage $M^S(R)$ less natural reduction through regeneration at the rate of regeneration α and less the reduced damage from damage removal technologies.

$$\dot{A} = M^S(R) - \alpha A - F^S(V)$$
$$A(t) = \int_0^t \left(M^S(R) - \alpha A - F^S(V)\right) d\tau$$

Restricted consumer budgets

As both regions are completely separate with the exception of a shared environment (shared pollution) they also make their own decisions with respect to accumulation and consumption.

$$\dot{K}^N = Q^N - C^N$$
$$\dot{K}^S = Q^S - C^S - V^S$$

The optimal control problem and solution

Present value Hamiltonian

North and South are completely separate with only one common problem (variable), namely shared pollution.

$$N)\quad H^N = U^N\left(C^N, E\right) + P(-R^N) + \omega^N[Q^N\left(R^N, K^N\right) - C^N]$$

$$S)\quad H^S = U^S\left(C^S, E\right) + P(-R^S) + \omega^S[Q^S\left(R^S, K^S\right) - C^S - V^S] + \lambda\left[M^S\left(R^S\right) - \alpha A - F^S(V^S)\right]$$

$$\begin{aligned} World)\quad H^W = &U^N\left(C^N, E(R^S, A)\right) + U^S\left(C^s, E(R^S, A)\right) + P(-R) \\ &+\omega^N[Q^N(R^N, K^N) - C^N] + \omega^S[Q^S(R^S, K^S) - C^s - V^S] \\ &+\lambda\left[M^S\left(R^S, A\right) - \alpha A - F^S(V^S)\right] \end{aligned}$$

First-order requirement

Requirement of consumption and accumulation

$$N, S, W) \qquad \frac{\partial H}{\partial C^i} = U_C^i - \omega^i = 0, \qquad i = N, S$$

$$\begin{aligned} N) &\qquad \frac{\partial H^N}{\partial R^N} = -P + \omega^N Q_{R^N}^N = 0 \\ S) &\qquad \frac{\partial H^S}{\partial R^S} = U_E^S E_{R^S} - P + \omega^S Q_{R^S}^S + \lambda M_{R^S}^S = 0 \\ W) &\qquad \frac{\partial H^W}{\partial R^N} = -P + \omega^N Q_{R^N}^N = 0 \\ W) &\qquad \frac{\partial H^W}{\partial R^S} = U_E^S E_{R^S} + U_E^N E_{R^S} - P + \omega^S Q_{R^S}^S + \lambda M_{R^S}^S = 0 \end{aligned}$$

Resource use

Pollution clean-up

$N)$ no demage removal because there is no locally produced pollution

$$S, W)\quad \frac{\partial H^S}{\partial V^S} = -\omega^S - \lambda F_V^S = 0$$

Shadow-price developments

$$\begin{aligned} \dot{P} &= -\frac{\partial H}{\partial S} + \rho P, \Leftrightarrow \dot{P} = \rho P \\ \dot{\omega}^N &= -\frac{\partial H}{\partial K^N} + \rho\omega^N, \Leftrightarrow \dot{\omega}^N = \rho\omega^N - Q_K\omega^N \\ \dot{\omega}^S &= -\frac{\partial H}{\partial K^S} + \rho\omega^S, \Leftrightarrow \dot{\omega}^S = \rho\omega^S - Q_K\omega^S \\ \dot{\lambda} &= -\frac{\partial H}{\partial A} + \rho\lambda, \Leftrightarrow \dot{\lambda} = \alpha\lambda + \rho\lambda - U_E E_A \end{aligned}$$

From these first-order conditions we can develop optimal policy strategies for each problem. This should especially be done for the price path of the resource. An optimal solution for the whole system is identified in three steps.

Price path in the North and in South without considering pollution

Bear in mind that we assume that the North emits no pollution at all (unrealistically) in order to point out the effects of the asymmetries.

$$N) \quad \frac{\partial H^N}{\partial R^N} = -P + \omega^N Q^N_{R^N} = 0$$

$$S) \quad \frac{\partial H^S}{\partial R^S} = U^S_E E_{R^S} - P + \omega^S Q^S_{R^S} + \lambda M^S_{R^S} = 0$$

$$N) \quad P = \omega^N Q^N_{R^N}$$

$$S) \quad P^{net,S} = \omega^S Q^s_{R^S} = P$$

Price path when only considering the South

$$N) \quad \frac{\partial H^N}{\partial R^N} = -P + \omega^N Q^N_{R^N} = 0$$

$$S) \quad \frac{\partial H^S}{\partial R^S} = U^S_E E_{R^S} - P + \omega^S Q^S_{R^S} + \lambda M^S_{R^S} = 0$$

$$N) \quad P = \omega^N Q^N_{R^N}$$

$$S) \quad P^{net,S} = \omega^S Q^s_{R^S} = P - U^S_E E_{R^S} - \lambda M^s_{R^S}$$

Price path from a global point of view, optimal pricing for the world

$$W) \quad \frac{\partial H^W}{\partial R^N} = -P + \omega^N Q^N_{R^N} = 0$$

$$W) \quad \frac{\partial H^W}{\partial R^S} = U^S_E E_{R^S} + U^N_E E_{R^S} - P + \omega^S Q^S_{R^S} + \lambda M^S_{R^S} = 0$$

$$N) \quad P = \omega^N Q^N_{R^N}$$

$$S) \quad P^{net,S} = \omega^S Q^s_{R^S} = P - U^S_E E_{R^S} - U^N_E E_{R^S} - \lambda M^s_{R^S}$$

One world policy could be a Pigou tax which would only be levied on the resources used by the polluting South. This tax covers the components $-U^S_E E_{R^S} - U^N_E E_{R^S} - \lambda M^S_{R^S}$ However, this price segmentation is a considerable incentive for illegal arbitrage (smuggling) which in turn can only be prevented at high cost. A smuggle-free alternative could be a tax levied at source on resource extraction. Under this system the North, too, would pay the efficient resource price of the South. The result would be that the price charged in the North would be too high, considering the damaging effects, and resource use in the North would be too small.

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Table 1: Income and population in the world economy

	Population share (p_i)	Mean income (μ_i)	Gini (G_i)	Overlapping index (O_i)
Third world (poorer than or equal to Brazil)	0.76	1,171	0.494	0.89
Middle class	0.08	4,609	0.462	0.54
First world (equal or richer than Italy)	0.16	10,919	0.344	0.25
World	1	3,031.8	0.659	
Between group Gini			0.449 (68%)	
Within group Gini $\sum_i s_i G_i O_i$			0.210 (32%)	

Source: based on Milanovic and Yitzhaki (2002: table 16).

Figure 1a: Income per capita, North and South

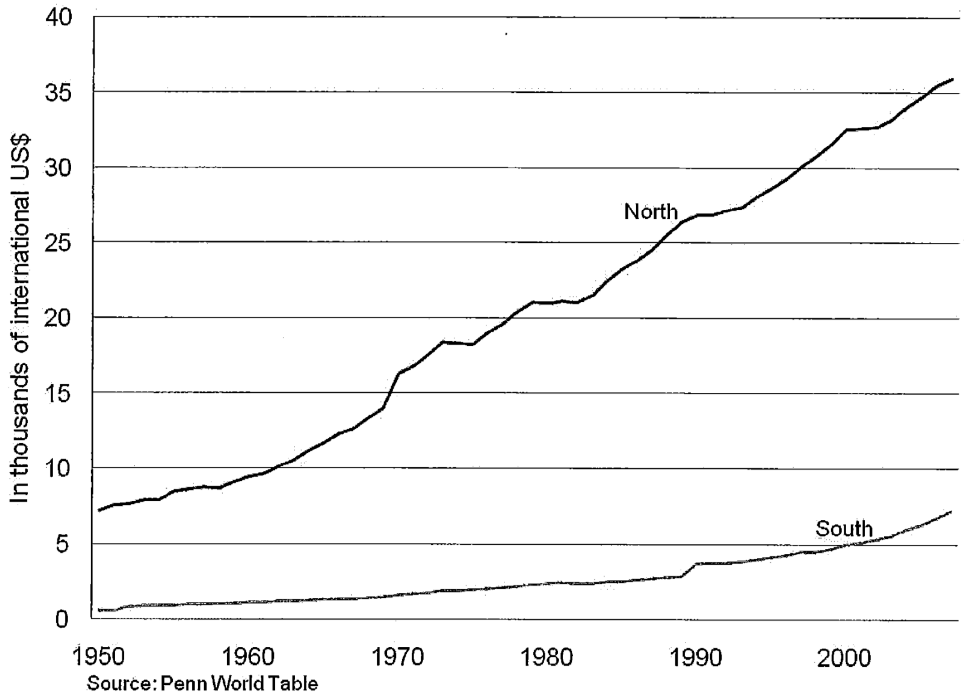

Figure 1b: Total income, North and South

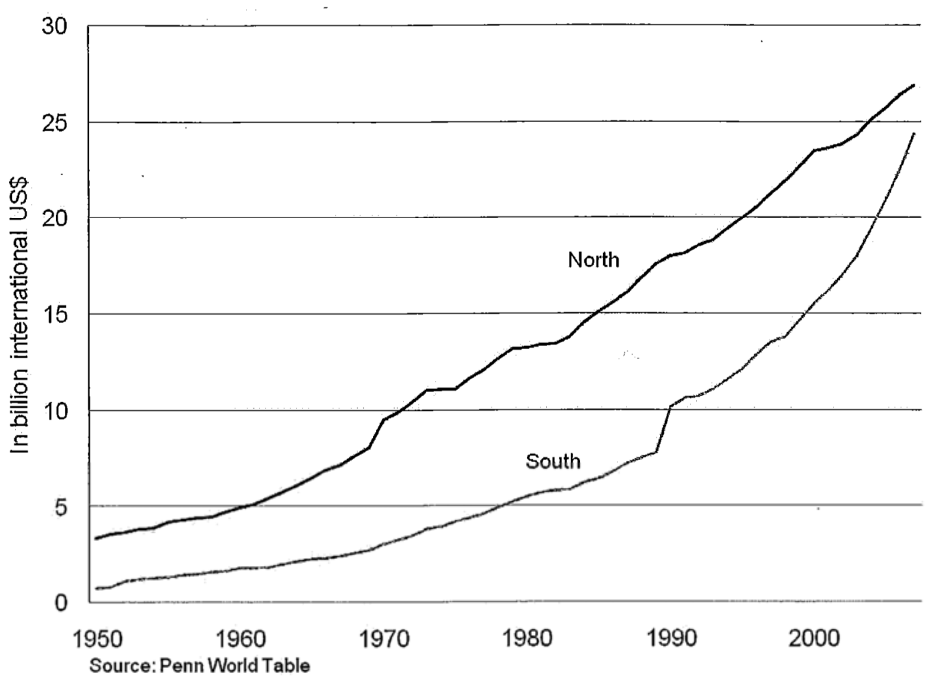

Figure 2a: Real capital stock per capita, North and South

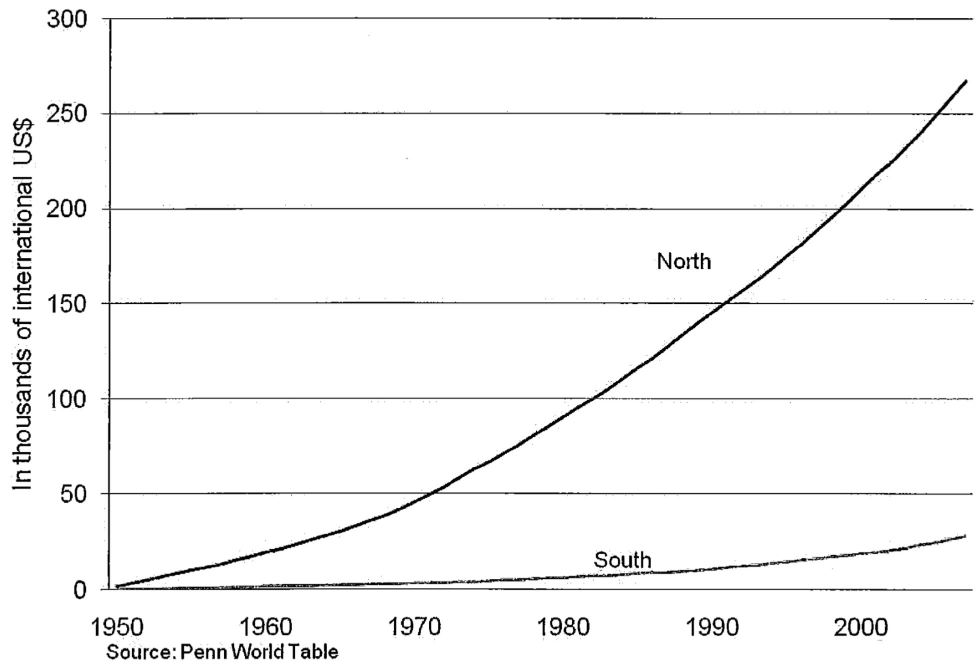

Figure 2b: Total real capital, North and South

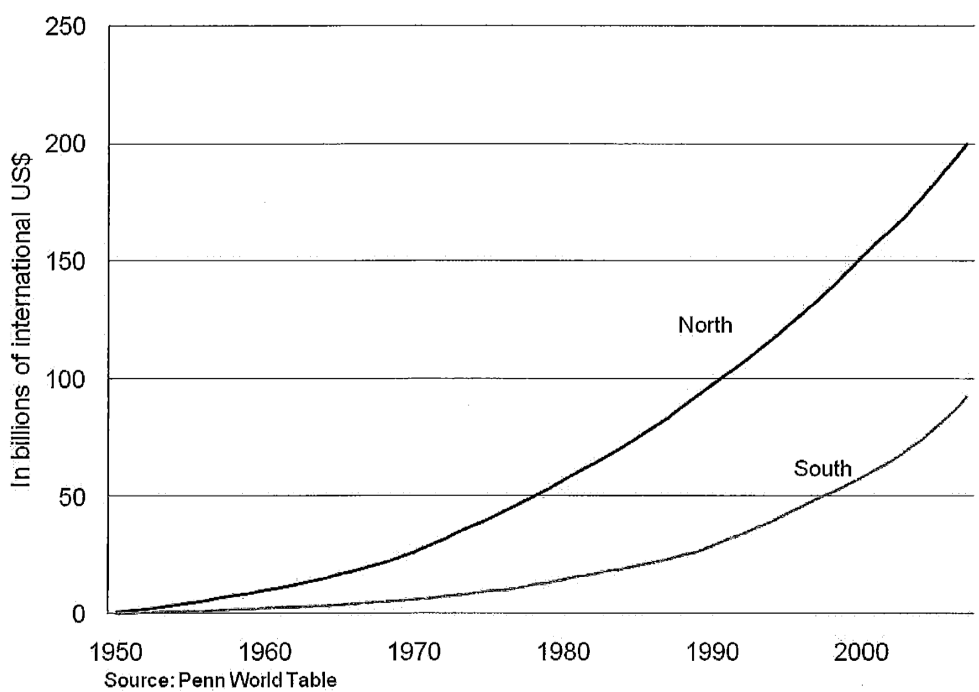

Figure 3a: Trade per capita, North and South

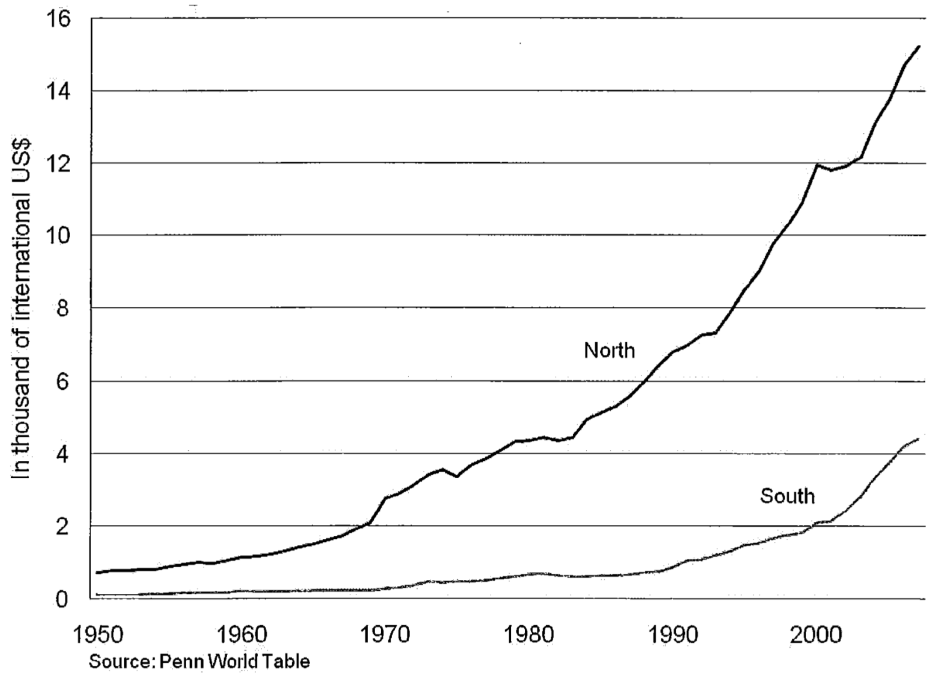

Figure 3b: Total trade, North and South

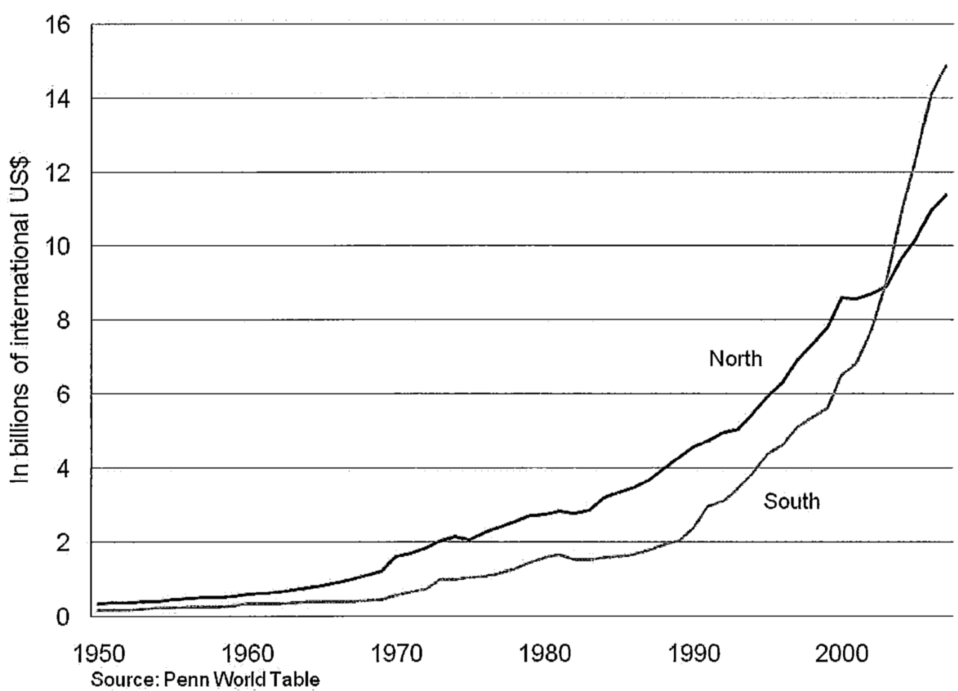

Figure 4: CO_2 efficiency in production

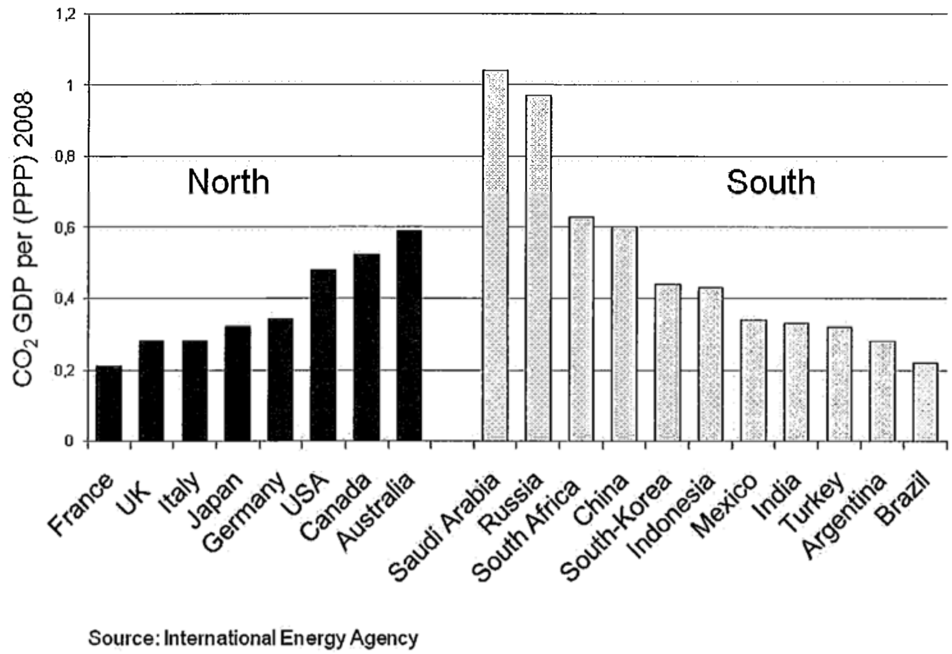

Figure 5a: CO_2 total emission, North and South

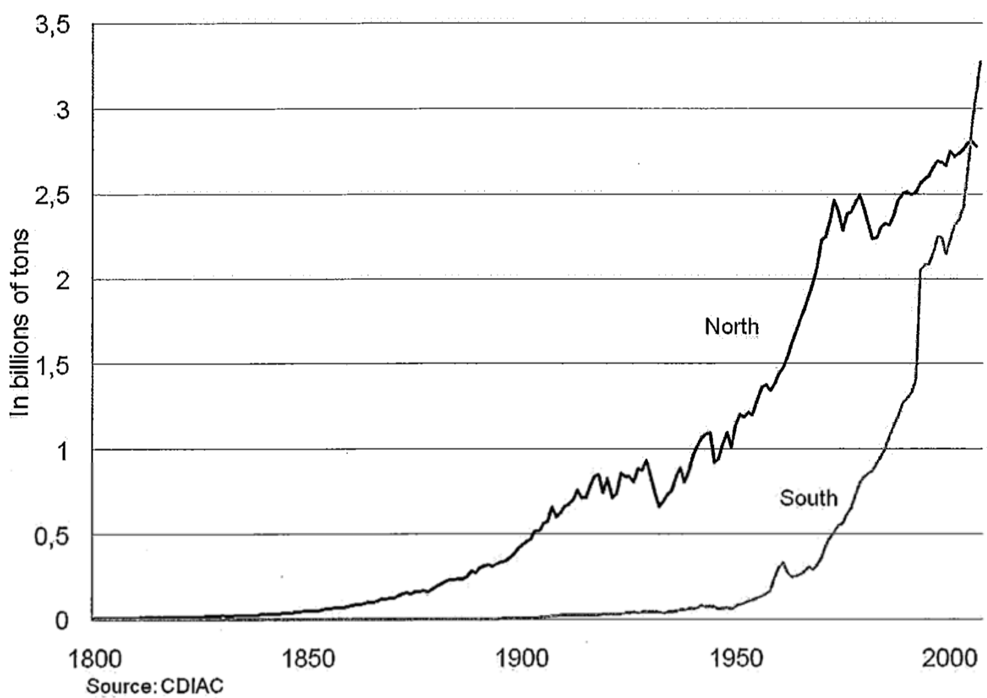

Figure 5b: Accumulated CO_2 emission, North and South

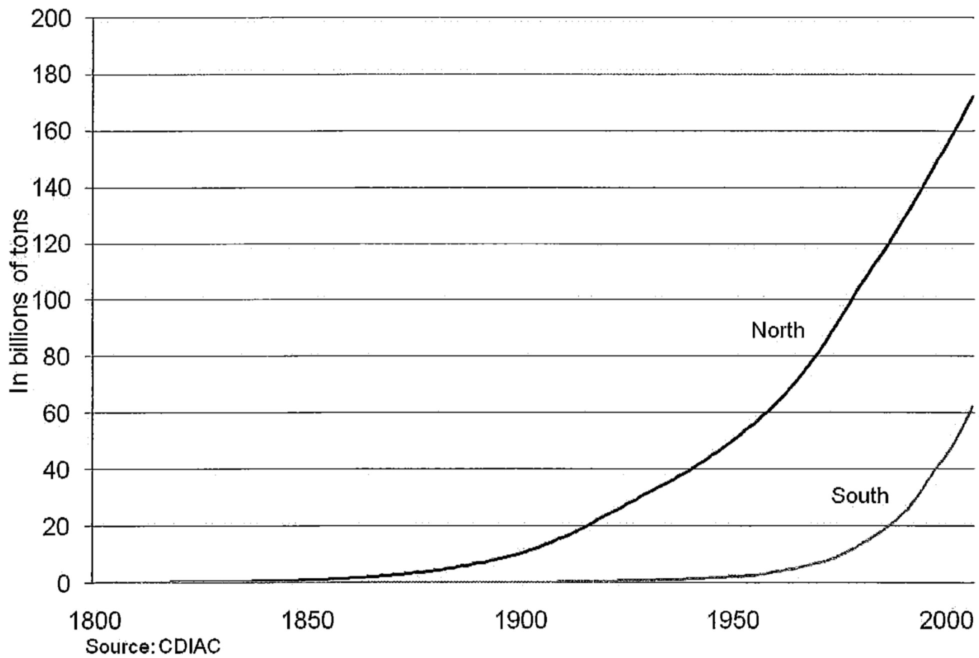

Figure 6: Price adjustment towards an efficient price pat

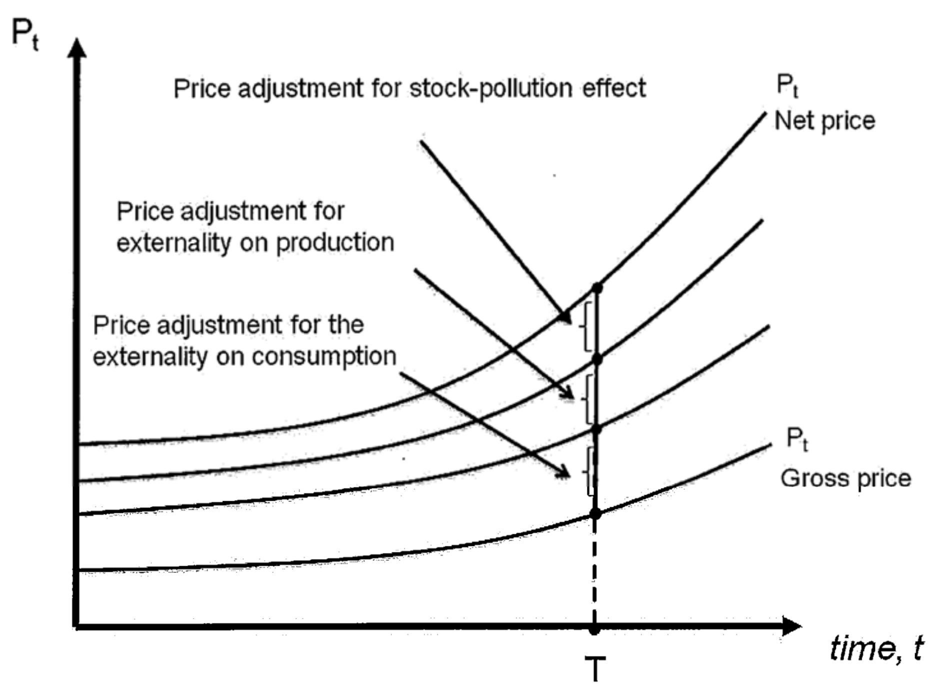

Figure 7a: CO_2 emission per capita, North and South

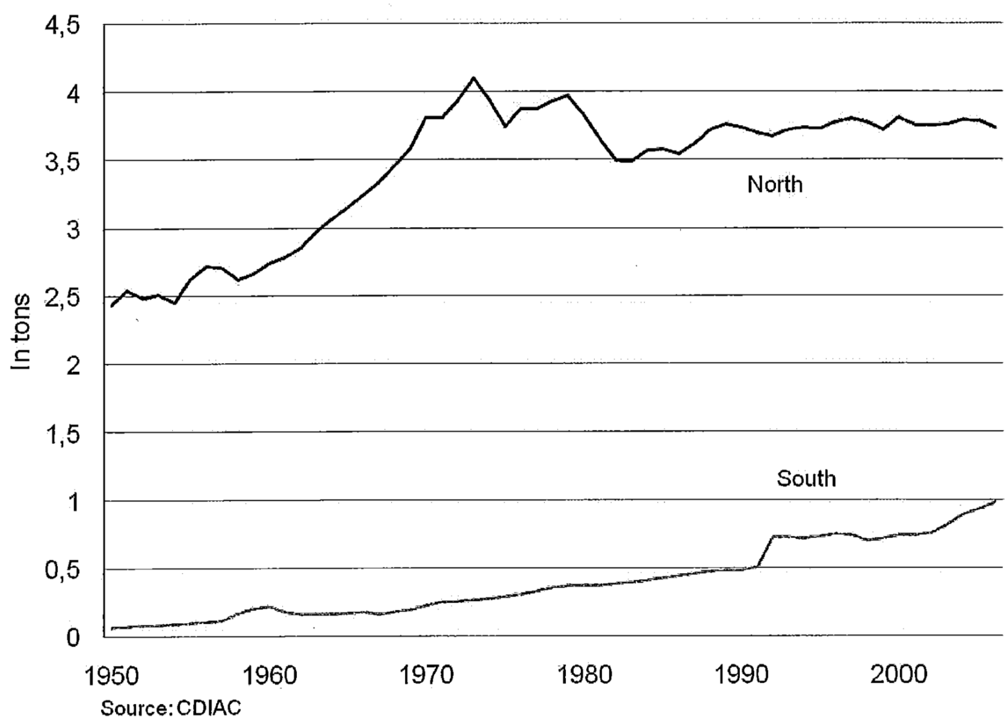

Figure 7b: CO_2 accumulated emission per capita, North and South