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Is sustainable transport policy sustainable?

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Abstract

The paper challenges part of the sustainable transport literature. Sustainable transport plans often focus on reducing carbon emissions in a specific city, region or country, and this neglects two handicaps of strong unilateral action. The first is that climate is a global commons problem, so a strong binding international climate agreement is unlikely. The second is that a unilateral reduction of oil consumption may be partially, or even completely, offset by market responses – in some circumstances, cumulative emissions may even come earlier (the "green paradox"). When a coalition of the willing reduces oil use in the transport sector, this may delay rather than reduce total emissions. This requires rethinking climate policies for the transport sector: What policies remain cost effective in reducing greenhouse gas emissions?

Keywords:

Climate policy, sustainable transport, oil consumption, international negotiation

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1 Introduction

There is consensus that policies must be sustainable in the sense that they respect the living conditions of both present and future generations. Sustainable transport policy encompasses many related but distinct aspects, such as climate, air quality, security, traffic safety, and health. In this paper, we focus on perhaps the most difficult and contentious aspect of sustainable transport policy, namely curbing the climate effects of the transportation sector. It is well established that man-made greenhouse gas (GHG) emissions contribute to global warming with potentially disastrous consequences (IPCC, 2013). The contentious issue, then, is not whether GHG emissions need to be reduced, but what measures are effective. With thirteen percent of total GHG emissions, the transport sector is not the most important polluting sector globally, but its share is growing quickly: the GHG emissions from the transport sector are expected to double by 2050 if no action is undertaken (ITF/OECD, 2012). In many countries, it already makes up a substantial share of total GHG emissions.

In this paper, we challenge the apparent focus on unilateral action in public debate, applied policy and much of the research literature, and question the effectiveness of several common policy recommendations. We discuss what the reasons might be for the widespread advocacy or adoption of policies that may be largely ineffective. Finally, we discuss what policy measures could be effective in mitigating climate effects from transportation.

Our main observations can be summarized as follows. All GHG emissions enter the atmosphere and will affect the world's climate for the next 100 to 300 years. Emission reduction efforts in any single country, even if it is large, will hardly affect the climate. Despite this, there is a large literature on potentials, methods, and costs for emission reductions from single countries, regions, or even cities. Such policy analyses are meaningful if they are interpreted as preparations for an (as yet hypothetical) global climate agreement where individual actors will agree on their respective targets for emission reduction. We review the sustainable transport literature and discuss how it can be put in a meaningful context in section 2.

Since any single actor is small, unilateral emission reductions will not make an appreciable reduction in global GHG emissions. But in fact, it is even more problematic : due to how oil markets work, a reduction in oil consumption—even by a coalition of countries—could be partly or even completely offset by a corresponding increase in oil consumption either by countries outside the coalition (spatial leakage) or by future generations (intertemporal leakage). Intertemporal leakage is likely to occur even if the willing coalition encompasses all countries in the world. The intuitive reason is that actors with cheap oil reserves will eventually sell all of their oil as long as the oil price is higher than the extraction cost. Unilateral reductions in oil consumption by a coalition of willing countries may increase the period during which the oil is sold and hence delay rather than reduce emissions. This may result in a decrease in incentives to find and extract non-conventional oil sources (e.g. oil sands). But the depressing message is that unilateral cuts in oil consumption are not only too small to make a global difference; market reactions will water down initial reductions of oil consumption substantially, and may even erase them completely. This does not apply to all energy resources to the same extent, though. When the consumption of coal drops, there will be a reduction of production and no shift of production into the future, because, with ample coal reserves in the world, the difference between the extraction cost of coal and the world price of coal is much smaller than in the case of oil. The mechanisms summarized here and the implications for transport policy are discussed in section 3.

Since global warming is a global problem, international agreements are necessary. Unfortunately, both experience and theoretical analyses suggest that such agreements are unlikely to be reached, unlikely to be obeyed if reached, and difficult to enforce if not obeyed. There are several reasons for this: enforcement difficulties, heterogeneous views of costs and benefits among countries, and limited accountability of signatories, to name but a few. A possible motivation for a country to undertake unilateral emission reductions could be that the country believes that this might increase the possibility of reaching multilateral agreements, perhaps by signaling other countries to the seriousness of the problem, or that the cost of emission reductions are in fact not prohibitively high. But if marginal abatement costs are increasing and negotiations have a quid-pro-quo logic (parties will only agree to cut emissions if other parties do so too), unilateral emission cuts or binding promises of future cuts may, in fact, reduce the possibility to reach an agreement since prior cuts decrease the ability of a country to promise additional cuts in the negotiation process. International agreements are discussed in section 4.

None of these arguments or problems is new and they should be familiar to politicians, researchers, and NGOs. This raises the question of what might motivate the widespread advocacy for and promises of substantial unilateral emission reductions. We discuss some possible such motivations in section 5.

Finally, in light of these rather depressing observations, we discuss implications for the effectiveness of sustainable transport policy measures in section 6.

2 Transport GHG reductions – research and policy

Some countries and regions are forerunners in terms of sustainable transport and climate objectives. The EC is very explicit in its Transport Roadmap 2050 (EC, 2011): "Looking 40 years ahead, it is clear that transport cannot develop along the same path. If we stick to the business as usual approach, the oil dependence of transport might still be a little below 90%, with renewable energy sources only marginally exceeding the 10% target set for 2020. CO_2 emissions from transport would remain one third higher than their 1990 level by 2050." This challenge has been translated into precise objectives for the medium to long term. The ambitious GHG objectives require policies like phasing out conventionally fuelled cars in cities by 2050. Overall, the target is to reduce carbon emissions by 60% in 2050 compared to 2010. Several countries and cities are making similar plans. Of course one can treat these as vague plans, as possible ideas for a policy or preparations for future negotiations. But the words are also followed by action at least to some extent, both at the EU level and in many individual countries. For example, all EU countries have already implemented strong fuel economy targets for cars since more than 10 years, and there is a massive support for the development of electric vehicles. These actions and plans are costly and their effects need to be assessed.

One can classify the research literature on sustainable transport policy into two approaches. The first one is more local and planning-oriented; the other approach is the more traditional economic approach to transport and environment.

Banister (2008) is the classic paper on sustainable mobility policy and planning. He advocates a different spatial development leading to denser cities, reducing the need for car use and long distance trips. The paper is very much in the urban planning tradition and also pays attention to public acceptability constraints. The sustainable mobility strategy is expected to reduce long term energy use and carbon emissions as a consequence, but it is not necessarily the main objective.

Later we see more papers focusing specifically on the reduction of carbon emissions as one of the important objectives of transport policy. Some papers focus on reducing emissions in a city and some are on a country or on the EU level.

Hickman, Ashiru, & Banister (2010) study how GHG emissions can be strongly reduced in London using different transport policy approaches. With a reduction of emission of 80% by 2050, the British GHG emission reduction targets are very ambitious. The authors find that it will be difficult to contain GHG emissions using narrowly defined transport policies like speed restriction, modal choice, emission taxes, etc. Their conclusion is that a deeper change of mobility patterns is needed to reduce carbon emissions drastically.

Crozet & Lopez-Ruiz (2013) present a scenario exercise for France and conclude that a reduction of 80% of GHG emissions can be achieved, with more than half coming from technological change and the rest from behavioral adaptation. This behavioral change is a structural break, away from air transport, and with substantial changes in urban mobility patterns.

Musso & Rothengatter (2013) present a methodological framework to achieve ambitious transport policy objectives. They use a multi-objective programming formulation that allows them to derive shadow prices as well as a set of other policies to achieve the targets. The targets determine shadow prices of emissions and the authors contrast this with the more traditional external cost approach. The paper uses the approach to discuss the EC transport and climate policies (EC, 2011). Overall, they find that the multi-dimensional approach combining fuel efficiency standards, infrastructure policies, and modal choice strategies are the way to go to achieve the targets.

Nakamura & Hayashi (2013) classify the different strategies that have been used over the world to reduce carbon emissions in the transport sector. They use a double classification (avoid/shift/improve and technology/regulation/information economy) and compare what policies have been pursued by different cities and continents. This international comparison shows that there is no single solution for all cities to reduce carbon emissions. Developing countries may benefit more from land use planning, while developed countries had better count on advanced public transport systems and on low emission vehicles.

Most sustainable transport policy papers in the planning tradition use an (ambitious) emission reduction objective for the transport sector and focus on the transport sector of a city or country. We return to the question how this should be put into context.

The traditional economic approach to environmental issues in the transport sector is surveyed in Proost & Van Dender (2012). The economic approach starts from a marginal damage estimate ($/ton) for carbon emissions. The marginal damage value is derived from integrated assessment models that model benefits and costs of climate action for the world (Nordhaus & Yang (1996) and Stern (2008) are the best known examples). This marginal damage value is then used at an individual country level to assess climate policy for all sectors of the economy. These common values vary a lot due to the inherent uncertainties in the economic and climate modeling. Tol (2012) surveys the marginal damage estimates for the world and cites values of $5 (discount rate of 3%) to $76 (discount rate of 0%). Because a common value is used for the whole world, there is no absolute reduction target for the transport sector. The marginal damage is used to judge the choice of instruments and the overall level of efforts in the transport sector. This has generated an extensive literature on the merits of fuel efficiency standards and gasoline taxes and, to a lesser extent, on land use policies (Proost & Van Dender, 2012). There is no consensus on the need for efficiency standards unless if there is a strong belief that consumers are very myopic, but the evidence for this is weak (Busse, Knittel & Zettelmeyer, 2013) or mixed (Greene, 2010). When having to choose between taxes and efficiency standards, gasoline taxes are often preferred as instrument because they also address other externalities such as congestion. Other transport policy instruments (road pricing, parking, public transport subsidies, etc.) can be useful but do not target carbon emissions and are therefore not usually considered as climate policy instruments in the transport economics literature.

A characteristic of the transport economics papers is that they use a marginal climate damage estimate to determine the extent of efforts in the transport sector and that they, just like the planning-oriented literature, focus on the best choice of instruments for their country. If the marginal damage cost is replaced by an (exogenous) shadow price for carbon emissions for the whole economy, then the analyses and insights remain largely unchanged because the shadow cost plays the same role as the marginal damage cost in guiding investment and other choices.

Most of this literature attempts to answer the question of what targets can be reached, how, and at what cost, for a given city/region/country. That is useful to know given an international climate agreement with binding targets for individual countries or when preparing negotiations for such an international agreement, since countries can get better information about what obligations it can shoulder and what it will cost. But this literature should not be interpreted as directly addressing the question of how GHG emissions can be substantially reduced. This is because each individual country is too small to make a difference – not to speak of cities or regions – but even more because any unilateral emission reduction, even by coalitions of countries, runs the risk of being, at least partly, offset or even erased by market responses. Such mechanisms are discussed in the next section.

Countries strongly dependent on oil imports, like the EU, can motivate the reduction of oil use in the transport sector as a risk reduction strategy[2]. This requires a correct assessment of the world oil market events[3] and a comparison with other risk reduction strategies. Besides a reduction of oil consumption, this should also include larger stockpiles, more natural gas vehicles, more indigenous oil production, etc.

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[2] "Oil will become scarcer in future decades, sourced increasingly from uncertain supplies. As the IEA has recently pointed out, the less successful the world is in decarbonising, the greater will be the oil price increase. In 2010, the oil import bill was around € 210 billion for the EU. If we do not address this oil dependence, people's ability to travel – and our economic security – could be severely impacted with dire consequences on inflation, trade balance and the overall competitiveness of the EU economy." (EC, 2011)

[3] Kilian (2008) shows how many oil "supply" shocks were either demand shocks or were mitigated by other dominant suppliers. Knittel & Pindyck (2013) show how for the period 1999-2012, speculation had little, if any, effect on prices and volatility.

3 Could oil consumption reductions be futile? The "green paradox"

GHG reductions by any single country will only make a small dent in global GHG emissions, since even the large polluters are small compared to total global emissions. But if many emitting countries enter a "coalition of the willing", would they not together be able to substantially reduce global emissions? The problem is that a reduction of fossil fuel consumptions is partially, and in some circumstances even completely, offset by various processes known as carbon leakages.

"Carbon leakage" refers to the phenomenon that if a country (or coalition of countries) reduces its consumption of fossil fuels by some amount, accumulated global emissions are only reduced by some fraction of that amount. Such offsets of the initial emission reductions are of two kinds, called spatial leakage and intertemporal leakage. Leakages are especially important when fuel reserves are limited, because this scarcity will cause market price to be above marginal extraction cost, a so called scarcity rent. Scarcity rents mean that there is room for a price reaction over space and time if consumption is reduced, and this price reaction offsets at least some of the initial consumption reduction by increasing consumption in other places or points in time. The market price for oil is equal to the extraction cost for the reserves that are most costly to extract (with profit). Since there are other reserves which are much less costly to extract, the price for these cheap reserves will include a substantial scarcity rent. This means that the leakage effects are usually so substantial that any analysis of climate policies needs to take them into account. Otherwise, emission reduction benefits are virtually guaranteed to be overestimated. In extreme cases, leakages may even erase the initial demand reduction completely. Other fossil fuels are also limited in supply, such as natural gas, so their price also includes a scarcity rent. Coal, on the hand, is in abundant supply, so the scarcity rent is negligible: its price is close to its marginal extraction cost (plus costs for transportation and similar things).

Spatial leakage can occur when some region in the world (e.g. a coalition of countries) regulates its GHG emissions and some other region does not. First, regulation may cause production generating GHG emissions to move from the regulating region to the non-regulating one. From the point of view of the regulating region, emissions have decreased, but global emissions have obviously changed less, and may even have increased. Moving production is not a big problem for the transport sector, which might be one reason that GHG emissions are taxed so much higher than emissions from other sectors. But there is a second, more important mechanism, namely that a reduction in fossil fuel consumption in the regulated region may cause the world market price for that fuel to fall; if the fuel price includes a scarcity rent, the price fall is virtually guaranteed. The price decrease will cause consumption to increase in the non-regulating region, so the initial emission reduction in the regulating region is offset to some extent by increased emissions in the non-regulating region. Spatial leakage has been estimated to offset the initial emission reduction by 10-30% (Babiker & Rutherford, 2005).

Intertemporal leakage can occur even if all regions regulate their emissions. The intuition starts from the simple observation that as long as the market price for oil (or any other fossil fuel) is higher than its extraction cost, those who own oil reserves will eventually sell them all; the only question is how fast and at what price. This mechanism can be formalized in a simple Hotelling model. Take a fixed stock S of a fossil fuel resource with a substantial rent (such as conventional oil) and production cost *c* and assume that these reserves are spread over a few suppliers so there is perfect competition[4]. The world demand function for the fossil fuel is given. This world demand function has a maximum willingness to pay for the fossil fuel *P**, which is the cost of a backstop technology that can substitute for the fossil fuel, e.g. renewable electricity. Every producer of fossil fuel will compare the profits they can make by selling today rather than tomorrow or in 10 years etc. Given an interest rate *r*, the inter-temporal arbitrage condition for profit maximizing suppliers results in an equilibrium profile of prices such that the rent (price – extraction cost) increases at the rate of interest. In Figure 2, the solid curve 1 is an equilibrium price profile. A second characteristic is that the stock *S* is consumed completely in the last period when the choke price *P** is reached. So the choice of the choke price *P** and the inter-temporal arbitrage condition lead to the price profile. These conditions hold at any moment in time, so that whenever new information comes available the price profile is adapted.

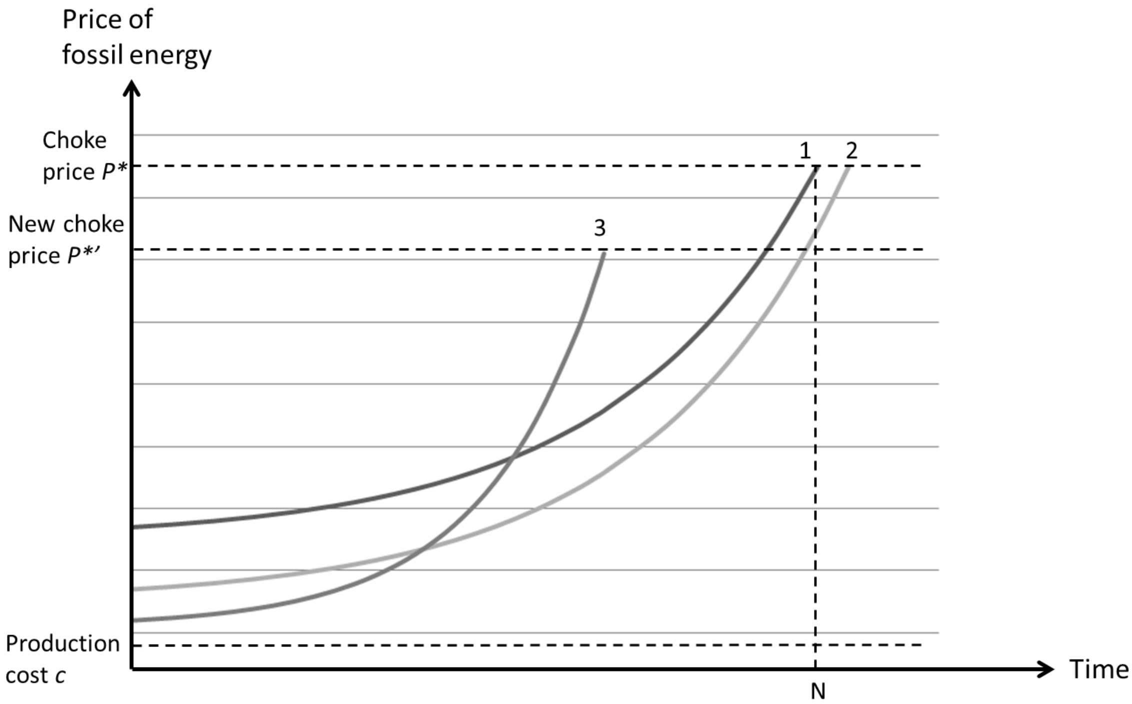

Figure 2 Effect on world fossil fuel equilibrium prices of a climate effort of one country (2) and of an improvement of the backstop technology (3) compared to the reference (1)

Consider first a significant, deliberate, and long lasting emission reduction in the transport sector in a few countries. This means a decrease of oil consumption by these countries. A decrease in the world demand implies that one needs a new price profile over time. The current price of oil will decrease and with the new equilibrium price profile (2), the world will use oil for a longer period. However, the total quantity of carbon emissions will not decrease: emissions will only be delayed.

Consider next an improvement of the backstop technology of oil, brought about by strong R&D efforts – say the electric vehicle, hydrogen vehicle, or biofuel vehicle fuelled by nuclear or renewables. This will imply new inter-temporal price profiles. The maximum price at which oil can be sold will decrease. Taking into account that sellers want to sell all their reserves, this implies a drop in the current oil price and that emissions will come *earlier*, while total emissions over the whole time

[4] Anyway, if we repeat the reasoning for an imperfectly competitive oil market, one obtains similar results.

period still remain unchanged. Only when the backstop technology offers an alternative to oil that is cheaper than the extraction cost *c* would the whole world switch to the clean alternative. The counterintuitive effect that an effort to improve alternatives to oil may cause emissions to happen earlier is called the *green paradox* (Sinn, 2008).

Given these assumptions, the bottom line is simple: ultimately all oil will be used, so a reduction in consumption can only, at best, delay emissions. Fortunately, these discouraging conclusions do not necessary hold in more elaborate models (see van der Werf and di Maria (2012) for a review). It may be possible to reduce accumulated emissions if the cost of the backstop technology decreases over time, since delaying emissions can then mean that the backstop technology will outcompete oil earlier, decreasing the stock of reserves that can be exploited with a profit. It can also be possible to reduce accumulated emissions if marginal extraction costs are increasing, i.e. if oil gets more and more expensive to extract. In that case, either demand reductions or improved backstop technology may reduce accumulated emissions in some circumstances. On the other hand, as we have seen, if R&D efforts are increased so the future backstop cost decreases, or if future demand is expected to be lower than today, producers may choose to sell their reserves earlier than otherwise, and total emissions remain unchanged.

Fisher and Salant (2013) analyse a model where the world is divided into one region which regulates emissions through an emission tax, and one region which does not regulate emissions. The price of fossil fuel includes a scarcity rent, and the backstop technology gets cheaper over time. This means that both spatial and intertemporal leakages may occur. They show that accumulated emissions tend to decrease the larger share of emissions the regulating region stands for, the higher the emission tax is, and the faster the backstop technology improves. These are all intuitive and somewhat comforting results: in many circumstances, it may in fact be possible to reduce total emissions by trying to extend the coalition of regulating countries, introduce emission policies and improve alternative technologies.

However, several of the discouraging conclusions from the simplest “green paradox” model remain. , The crucial determinant accumulated emissions time is how the cost for the backstop technology compares to the marginal extraction cost of oil – not the market price of oil. Since the market price includes a scarcity rent, producers will continue to sell their reserves until the backstop cost falls below the extraction cost. It is a common mistake to compare costs for backstop technologies to the price of oil on the world market, thinking that it will be enough to beat the market price for oil to make oil-based technologies uncompetitive and obsolete. But clearly, this is naïve: the relevant comparison when analyzing alternative technologies is the extraction cost of conventional oil reserves, and these are unfortunately often far below the market price for oil. Demand reductions may decrease the market price for oil and hence reduce accumulated emissions if oil reserves have different extraction costs; but still, all oil reserves with extraction costs below the market price will be extracted. Efforts to decrease the backstop cost may still cause a “green paradox” effect where emissions come earlier. The green paradox may also apply to cases where there are policy announcement effects: if implementation of policies and international agreements takes a lot of time, resource owners may temporarily increase production.

Note that this applies to oil and other fuels with substantial scarcity rents. The situation is different for coal. Since there is an almost unlimited supply of coal, the market price is roughly equal to marginal production costs[5]. Hence, a demand reduction is *not* offset through price reactions over space and time to the same extent. Hence, it is often more effective to reduce emissions from coal than from oil.

Unfortunately, there are large reserves of oil with extraction costs well below the cost for alternative transportation technologies in the foreseeable future. The only way to prevent these reserves from being used is to convince oil-producing countries to keep them in the ground, through conviction, compensation or coercion. One drastic policy option, suggested by Harstad (2012), is that climate-conscious countries buy the deposits of fossil fuels in other countries in order not to use them. In his analyses, the most efficient policy would be to buy the reserves that are the most carbon intensive (coal, non-conventional oil) and the most costly to extract, as they are cheaper for the country that does not want to use them. The practical difficulties with such supply-side policies are of course considerable. It can be very costly for the buying countries, enforcing that the reserves are indeed never used is not trivial, it increases the incentives to find more fossil fuel reserves, and if total fuel reserves are large, the effect might be small compared to the cost for buying country.

So what are the implications for climate-mitigating policies in the transport sector? First, any assessment of effects, benefits and costs of proposed policies needs to take into account that emissions reductions will be at least partly offset by spatial and intertemporal leakages. Second, all oil reserves will eventually be used up to the point where marginal extraction costs equal the cost for alternative technologies. The good news is that demand reductions can make it unprofitable to extract the reserves that are most costly to extract. The bad news is that there are large reserves of oil that will be profitable to extract even given significant demand reductions, since extraction costs are so low. Demand reductions can also reduce accumulated emissions by delaying oil consumption until other technological alternatives have improved so much that oil-based technologies become obsolete. But when judging the potential of new technologies to reduce oil consumption, the cost of the new technology must be compared to marginal extraction costs of oil reserves, not the market price for oil. This gives a more discouraging perspective on the viability of alternative technologies. Fourth, it is more effective to reduce emissions from coal than from oil, since the lack of scarcity rent in the coal price means that spatial and intertemporal leakage will be moderate or minimal. This has implications for what benefits would be generated by an electrification of the transport system, in the form of electric vehicles or high-speed trains. Replacing oil-driven cars with electric ones may be a dubious policy if electricity is coal-generated at the margin. The net effect may be that accumulated oil consumption remains virtually unchanged while global coal consumption increases.

4 Are international climate agreements likely?

All greenhouse gas emissions enter the atmosphere and will affect the world's climate for the next 100 to 300 years. Emission reduction efforts in one country, even if it is large country, will hardly affect its own climate. Hence, international cooperation is needed. International cooperation is also necessary to reduce spatial leakage, as explained in the previous section.

International climate negotiations started in Rio de Janeiro (1992) and led to a first agreement in Kyoto (1997). These negotiations are an ongoing process and at present, one is still looking for a

[5] Haftendorn & Holz, (2010) show how the international market for coal is rather competitive so that market prices are approaching the marginal production costs.

successor to the Kyoto agreement that has been extended from 2013 to 2020. Up to now, the success of the climate negotiations has been rather limited: there is only limited participation (the US, China, and India did not join) and many of the signatories have not complied with their promises.

The signing of an environmental agreement is a complex process. Preparation by technical experts, the political process of each country that determines its negotiation position, the treaty negotiation process itself, and finally ratification all contribute to this complexity. Theoretical analyses of negotiations have shown why agreements are difficult to reach, why they are unstable, and why they are unlikely to be followed or enforced. The mechanisms at work can be illustrated using a simplified representation, where the negotiation is a simple game between countries. We will summarize some of the main insights from these theoretical analyses.

According to cooperative game theory, if the benefits and costs of climate policy are known by all countries, it is always possible to make an agreement that reaches an optimal level of abatement and which is beneficial for all countries. . All one needs is a correct computation of costs and benefits by country and transfers among countries so that all parties gain. This is the idea of the grand coalition (Eyckmans & Tulkens, 2003). Unfortunately, while it may be possible to reach a wide agreement, enforcing it will be very difficult. International agreements, such as Kyoto, have been signed by coalitions of the willing, but the agreements were not observed by all signatories. Contrary to environmental problems at the country scale, there is no global authority that can enforce international environmental agreements. One country might introduce trade sanctions against non-complying countries, but such enforcement actions are also costly for the country taking the sanctions and will not be easily undertaken, as they are costly for one country but benefiting all other signatories.

Barrett (1994) reaches firm conclusions using a simple model with identical countries and constant marginal benefits of abatement. He defines self-enforcing international environmental agreements as agreements that are such that every country that joins the agreement is better off within the agreement than outside the agreement and vice versa for those outside the agreement. He finds that the equilibrium number of signatories in an international environmental game that is played only once equals 3, whatever the number of countries in the world. So there is hope for a small improvement compared to the Nash equilibrium, but the overall result is close to the typical outcome of a tragedy of the commons problem: each country only considers its own costs and benefits rather than the benefits for the whole world.

These results apply to a “one shot game”, i.e. a game that is played over and over again without players taking past or future behavior of the other players into account. One could also think about the behavior of countries as more consistent with more continuity over time. The game could be seen as a repeated game, in which each country can start by cooperating and punish those that stop making effort by also stopping its own efforts and doing this forever. When the future is sufficiently important, the sanction of stopping cooperation forever is important and Barrett proves that more effective international agreements become possible, but the result remains far from the grand coalition. But, one could also argue that a one shot game is the right concept given that the political majorities in countries can change and that a new government is not responsible for what the previous government did (think about blaming Obama for Bush’s poor climate negotiations behavior).

The simple Barrett model uses smooth damage functions, but climate change damage is highly uncertain and may not be smooth at all. Indeed, it may even be catastrophic. The risk of very high, catastrophic damage is the main motivation for the calls for stringent climate policies by Stern (2008) and many others. Modeling a catastrophe is difficult. In negotiations, therefore, it is important to know what the threshold is that triggers the catastrophe. Barrett (2013) models a catastrophe with a damage function that jumps when the threshold is exceeded. Assume first that there is no uncertainty on the exact threshold (say 3°C warming should not be exceeded) and the damage of the catastrophe is extremely high compared to the abatement cost per country, then an agreement in which all countries coordinate to avoid the catastrophe can be self-enforcing. Because if one country defects, it knows it may be responsible for a catastrophe and this means that there are far higher chances for a successful international agreement.

Uncertainty about the extent of the catastrophe is not crucial as long as the damage is high enough. Unfortunately, Barrett (2013) shows that uncertainty about the threshold itself is more problematic for international negotiations. Assume that one starts with a division of effort among all countries such that the catastrophe is certainly avoided. A country defecting and reducing its abatement efforts is now only responsible for an increase in the probability of a catastrophe and the expected sanction is therefore less important. This acts as an incentive not to comply with the agreement and to free-ride on the others.

This does not imply that international negotiations are not important. Glazer and Proost (2012) look at international negotiations as a way to allow a minister in one country to learn about the beliefs held by a minister in another country, thus pooling information. Partial international agreements can also be a step forward if they take into account the possible adverse reactions on the energy markets. In conclusion, reaching a global climate agreement is very unlikely according to economic theoretical analyses, and, up to now, reality has not proved theory wrong.

5 Why are unilateral GHG targets so widespread?

An important part of the transport research community and many governments seem to believe that unilateral carbon reduction policies in the transport sector are justified and effective. In the light of the above, this seems to present two puzzles. The first is why there is such a large support for ambitious unilateral goals and policies. The second is the apparent focus on reduction in the transport sector. We will discuss these in turn.

Unilateral actions – “going first”, “leading the way” - has been the first step for the development of a successful policy for many environmental issues. Acid rain, tropospheric and stratospheric ozone are three international problems for which significant progress has been made over the last 20-30 years. The initiative was often in the hands of a few initiating countries. For example, Glazer and Proost (2012) see the reduction of CFC emissions (responsible for stratospheric ozone) as an example of unilateral actions that triggered other nations to take effective action. They rely on the study by Murdoch and Sandler (1997) of the national CFC reduction policies in the years before the Montreal protocol entered into force. The long negotiation and information exchange before the Montreal protocol and the emission abatement of some countries changed the information on which countries decided how to act. This information, which suggested that control of CFCs could yield large benefits at low cost, induced both signatories, and non-signatories, to reduce emissions of CFCs. The support for the treaty by the United States, not considered a strong supporter of environmental action, suggested to other countries that action was worthwhile, inducing other countries to reduce emissions. What makes these previous environmental problems different from climate change? Why can the initiators of a strong climate policy not expect the same success?

There are four key differences between climate change and acid rain, tropospheric, and stratospheric ozone. First, the three latter environmental problems have a shorter horizon (a few days (tropospheric ozone) to ten years or more (acid rain etc) instead of 50 to 300 years for climate), so the current generation of politicians may see some of the benefits. Second, the three problems mentioned have a more regional dimension than climate change and this helps to build a coalition of the willing because neighboring countries need each other also for other transboundary issues. Third, the costs of strong reductions are much higher in the case of carbon: strong reductions of carbon emissions may cost a few percent of GDP because there are no easy end-of-pipe solutions. It is possible to reduce the sulfur content of fuel oil in the refinery at a low cost and reduce acid rain or replace CFC's by a less stratospheric ozone eating substance but there is no such alternative for reducing carbon emissions. Fourth, emission reductions are offset by spatial and intertemporal leakages.

It is curious that despite all these handicaps, there is still a significant coalition of politicians in favor of strong unilateral carbon emission reductions. There are several possible answers to this. First, advocates of unilateral reductions may honestly believe that they are effective. Above, we have argued that emission reductions will be offset through spatial and intertemporal leakages, making many conventional climate policies ineffective, or at least less effective than they appear at face value. But these mechanisms are not obvious and sometimes appear counterintuitive, so it is perfectly possible that at least some decision-makers and activists overestimate the effectiveness of many policies.

Second, they may hope that by setting an example, other countries can be convinced that the climate problem should be taken seriously, or that emission reductions are less costly than the other countries had thought, or both. This could make a global climate agreement more likely, or at least induce more countries to enter a coalition of the willing.

Third, they may hope that strong climate policies will accelerate the pace of technological development of alternative energy sources. This would be a kind of incubator strategy: demand for alternative technologies can be increased through subsidies, or taxing conventional technologies, and then once development has taken place, taxes and subsidies can be phased out. Policy experiments may also be useful for finding the most efficient emission-reduction strategies, in the hope that lessons can then be applied by other countries which want to reduce carbon emissions.

Fourth, there are also several political economy explanations. Politicians may view current promises and plans as unimportant as they will remain largely just plans and will never be realized; however, they attract the votes of the green part of the population that want to do something. There is a large body of literature (surveyed in Besley (2006)) that study how inefficient policies can result from the desire of politicians to stay in office. If the pivotal voter happens to like climate policy or if the climate policy can act as a commitment device because only certain politicians will continue a particular type of policy, this could explain particular policies (Robinson & Torvik, 2005).Moreover, there are mechanisms that explain "extreme" policies. For instance, Majumdar and Mukand (2004) show how reputational concerns distort an incumbent's policy choices. They demonstrate that an official with low ability who wants to signal high ability may inefficiently experiment by undertaking a new policy initiative that he knows is likely to fail. Some of the "extreme" policy choices may also be driven by the international context. Indeed, when the elected official must later bargain with other parties, extreme views may increase his bargaining power and generate larger benefits to his supporters. According to Helm (2010), climate policy, and in particular the EU emission trading system is an example of rent capture by carbon intensive industry that saw its profits increase by the grandfathered rights.

The second major puzzle is the attention of politicians in some countries to push us into the direction of strong emission reduction goals specifically in the transport sector, despite the fact that emission reductions in the transport sector are more costly than in many other sectors. In many countries, in particular in Europe, emission reductions in the transport sector are currently more costly than in other sectors, since carbon emissions from cars are taxed more heavily than carbon emissions in other sectors[6], and since reduction of oil use is at least partially offset by market responses. Reduction of coal use is much more effective. When a society as a whole wants to reduce carbon emissions, it makes sense to do this at the lowest cost: this would maximize the emission-reducing effect for any given budget or effort. This implies more efforts and more ambitious targets in those sectors where it is cheaper to reduce emissions. This means that reduction of energy use in buildings and more efforts to cut coal use will be more cost effective ways to reduce emissions.

One possible explanation to this is that policy is also affected by interest groups, and one can easily understand that carbon intensive industries want to shift some of the required efforts to the transport sector. Another explanation is that the public acceptability of strong policies for oil savings in the transport sector is increased by the fact that European car users perceive oil as three times more expensive than the real opportunity cost and this is the market price before taxes, so all savings of oil are very welcome to them. However, the net value to society of reducing expenditure on oil is only the cost saving net of taxes – the tax is just a transfer. In other words, each car driver, opting for a more fuel efficient car, does not realize that he will ultimately have to pay the saved excise taxes on gasoline via higher taxes somewhere else.

6 Policy implications

For a policy to be successful and survive in the long run, it needs to be effective, credible, and publicly acceptable. The former are usually requisites for the latter. Credibility is necessary to have the consumers and producers investing in line with the government policy, and an ineffective policy will not be credible in the long run[7]. Even an onerous policy can get public acceptance if it is perceived to be effective and credible; but if it is not, the public acceptance tends to wither, and then the policy will not survive. Getting acceptability for the next policy measure is then likely to be more difficult – why trust that politicians know what they are doing this time? - and in the longer run, it may also erode the credibility and public acceptance of strong effective climate policies. It is therefore important to aim for truly effective policies. Policy analyses on how to achieve unilateral emission reductions are certainly not pointless, but they need to be seen in a particular context: such

[6] We tend to forget that the gasoline tax acts as a carbon tax .

[7] We rely here on the mainstream political economy theory as synthesized by Besley (2006) .

analyses answer the question what targets are reachable, how and at what cost. They do not, however, address the question of how global climate problems can be effectively mitigated.

Policies aiming at optimal adaptation to future climate change—such as guarding against floods, switching to other crops, etc.—are of course much more credible when there is no strong belief that a grand sustained coalition against climate change is likely. The main advantage of adaptation is that every country and region benefits itself from such investments.

So—are there no effective unilateral climate policies in the transport sector? The good news is that there are some. The bad news is that they are not so effective and are different from the ones most of us have in mind. Space constraints force us to focus more on guidelines rather than on concrete policies.

Technological developments

Conventional air pollution emissions (NOx, SO2, etc.) have been successfully reduced in many countries by better engine technology (catalytic technology, low sulfur diesel). The reductions of emissions per mile were of the order of 80 to 95%. This is usually considered as a success based on fast diffusion of technologies developed in one country (USA). There is no similar technology breakthrough available or in sight for carbon emissions in the transport sector. The cheapest options are still gradual improvements of fuel efficiency (cf. IEA 2009).

Technological developments in the transport sector can be roughly separated in improvements of alternatives to fossil fuels (e.g. electric vehicles) and increases in fuel efficiency of conventional vehicles. The cost of backstop technologies is one of the determinants of cumulative oil consumption, as explained in section 3. Improved fuel efficiency may reduce oil consumption, which may reduce cumulative emissions provided either that the backstop cost is decreasing over time or that the marginal extraction cost is increasing.

In principle, a country interested in carbon emission reduction in the world can achieve a larger total emission reduction by shifting the emphasizing from activity reduction (high car taxes, car use restrictions) to technology improvements. The reason is that the technology improvements can spill over to the rest of the world while the activity reduction is per definition local (Barla & Proost, 2012). Technology spillovers can occur once a technology improves efficiency in some way, e.g. fuel efficiency or efficient public transport. In other words, the technology must be (or have potential to be) sufficiently cheap to implement so that it can survive without subsidies. This means that some technologies potentially offering deep but expensive cuts in vehicle emissions (electric, hydrogen etc.) have smaller chances to be adopted by the rest of the international community than simple technologies (small gain in fuel efficiency, electric bicycles) as they are not ready to pay for the same deep emission reductions per car.

There may also exist innovative policy inventions with a potential global impact through spillover effects, analogue to technological improvements. Congestion pricing may be an example, and perhaps certain policies to encourage fuel efficiency of vehicles.

Electric vehicles deserve a special word of caution, as was mentioned earlier. If some region reduce their coal consumption, this means that global emissions are reduced by virtually the same amount, while reductions in oil consumption will be at least partially offset by an increase in other countries' consumption. Ceteris paribus, reducing coal consumption is hence a more effective strategy than reducing oil consumption. It follows that replacing oil-powered vehicles with electric vehicles is unlikely to be a good strategy when the marginal electricity production comes from coal. The global reduction in oil consumption may stay almost unchanged (especially over a longer period), while coal consumption increases, causing aggregate carbon emissions to increase. To beat the "green paradox", the electric vehicle must come at a cost lower than the cost of a conventional gasoline vehicle, where gasoline is priced at the extraction cost (which is a small fraction of the current consumer price of gasoline).

When comparing electric vehicles with conventional engine technologies, there are two mistakes to be avoided. First the electric vehicle needs to be compared with the future conventional technology. According to Proost & Van Dender (2012) if average carbon emissions in OECD per vehicle mile are put at index 100, plug in hybrids and electric vehicles could achieve an index of 14 to 45. But conventional technology could achieve an index 45 to 80. So even conventional technologies could be effective in delaying carbon emissions. Second, we tend to forget that in many countries, electric vehicles are heavily subsidized and pay no excise taxes and this biases the comparisons, especially since conventional fuels and vehicles are heavily taxed. The relevant comparison for policy assessment would be between the cost of the electric vehicle, net of subsidies but including costs and possible externalities of marginal electricity generation, and the cost of the conventional vehicle, net of taxes but including costs for externalities such as local air pollution and climate emissions, and comparing

Putting transport efficiency first won't harm

The main non-climate challenges for an efficient and sustainable transport system are well known: congestion, accidents, and air pollution in urban centers. Effective strategies build on four synergistic cornerstones: attractive public transport, walkability, compact land use planning, and restraints on car use. These can be complemented with e.g. smart vehicle technologies which can increase traffic safety and reduce travel costs. Such policy strategies will increase the efficiency and sustainability of the transport system, but the largest benefits from such policies are other than reducing GHG emissions. Still, such strategies will likely reduce oil consumption as well, overall carbon emissions will likely decrease. The problem with offsetting effects through leakage still remain, though, so net cumulative carbon emission reductions will be less than they appear at face value.

The trend[8] of moving away from automobile fuel taxation as the main control and financing instrument is often considered as a bad signal for carbon emissions because these become cheaper for the car user. However, the present fuel efficiency standards combined with another pricing of the volume of transport (road pricing, parking etc.) will probably continue to contain the overall carbon emissions in the transport sector (Proost, Delhaye, Nijs, & Regemorter, 2009). The main reason is that addressing the other externalities will require a limitation of the volumes of traffic, certainly in urban areas, such that when using the same types of fuel efficient cars, the growth of carbon emissions will be limited.

[8] This is a policy trend in the EU where the European Commission as well as several countries favor the introduction of other ways of pricing road transport. This has been implemented for trucks already in many countries and for cars it started at city level (London, Stockholm) and for motorways (using tolls, vignettes etc.) (cfr. Commission of the European Communities, 2007).

Reducing emissions abroad may be efficient

Many sustainability policies go for a strong limitation in the home country transport sector or even within a city. As counting emissions at home is easy, this has the advantage of easy accountability for the agency and politicians in charge. In addition, it gives a warm glow for the environmental consciousness of the locals. It also demonstrates to the rest of the world it can be done ("leading by example"), and if necessary, our industry can supply the technologies to do it.

Deep cuts in one sector in one country are usually more costly than smaller reductions in other sectors or countries. Therefore, cost efficiency tells us that spreading efforts is better as long as they can be controlled. Within national borders, or whenever several countries join the same emission trading zone, this can easily be organized and controlled. Buying additional efforts in another country that is not interested in limiting carbon emissions may however be more difficult as the monitoring of the extra effort is difficult because the other government and the local polluter have different objectives than the government, who wants to reduce the emissions. Put in simple terms, the other government and its local polluter can gain by overstating the carbon reduction they sell by using a more polluting reference point. There are certification mechanisms to overcome this; if they are implemented, there is an important potential for more cost-effective emission reduction. The present emission trading systems do not discriminate between carbon emissions saved by reducing coal use and emissions saved by reducing oil use. When we take into account the green paradox, we know that reducing coal use may be a more effective emission reduction because there is no (or less) postponement of emissions as we would have for oil.

7 Conclusions

This paper has analyzed two problems in the formulation of sustainable transport policies. The first is the difficulty to reach and enforce international climate treaties, and the second are the spatial and intertemporal leakages. The difficulty in reaching an effective international climate agreement implies that most countries are not willing to pay for a strong reduction of carbon emissions. Intertemporal leakages imply that whenever only some countries reduce their conventional oil use, this may at best delay the extraction of the stock of oil, but not necessarily reduce the overall emissions, and at worst may even advance emissions in time (the green paradox). Both handicaps are very difficult to overcome and imply that the present efforts to reduce strongly carbon emissions in the transport sector, which are mainly oil based, may be ineffective and may need to be reconsidered.

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