HANDLING RISK AND IRREVERSIBILITY OF TRANSPORT INTERVENTIONS

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ABSTRACT

Infrastructure decisions and transport policies are often based on the notion that all possible decisions are made at one single point in time, based on the best accessible evaluation of benefits and costs of alternatives. Transport sector is a complex and dynamic system. Inherent in the complexities are; uncertainty, risk, irreversibility, path dependency and lock-in effects. The dynamics of transport systems are determined by the interplay of the many different systems often with different time lags.

The early identification of unintended adverse effects *after* the introduction of measures or policy packages can help significantly to improve their effectiveness and increase the chance of meeting the goals they were designed to meet. While it is imperative to address the unintended adverse effects ex ante, there is no prescription and blue print for a correcting procedure. Hence, it is important to address the flexibility to change policy measures if intentions and outcome do not match.

Risk and uncertainty and irreversibility are often weakly understood by public officials. Hence it is an important task to improve risk assessment, risk valuation and risk management. And in general how to change planning framework to embrace risk and flexibility and from a static thinking associated with traditional methods to methods of dynamic planning where decisions are made continuously and based on steady flow of new information.

1. BACKGROUND

Transport sector is often associated with a socio-technical system or open and complex system. The term socio-technical system is a conceptual reminder that technologies affect and are an effect of their broader infrastructural, organisational, regulatory, and symbolic environments. By open and complex we mean that there are multiple interacting markets, with many types of increasing returns and many positive feedbacks mechanisms between these markets, with many non-linear relationships and the time delays and institutional settings as well as interactions with its surrounding markets and environment. Irreversibility, path-dependency and lock-in effect are some important characteristics of a complex system (See for example Richardson, 2005; Kaijser, 2005). These frequently differ from what an “informed and benign” social planner would find best. Policy interventions in such an environment are likely to encounter unintended effects.

Although it is possible to reduce the adverse effects of a policy intervention by adopting integrated policy combinations or ‘packages’, and through appropriate methodologies, tools and models, it is not possible to fully avoid unintended effects, foreseen or unforeseen. Real world decision making is done under uncertainty all the time.

Risks and uncertainties are particularly pertinent to the context of policy making at an EU level.

The focus of this paper is on the mitigation of unintended effects ex-ante, but also ex-post. Ex-ante mitigation of unintended effects favours reversible and flexible options acknowledging that decisions made under risk and uncertainty might lead to unintended effects. Thus the idea is keeping the cost of reversing the decisions as low as possible by incorporating risk management into the planning process. With availability of information, gained from monitoring, it is possible to reduce or eliminate risk and uncertainty and necessary adjustments in policy design can be made ex-post. The availability of information can also help in early detection of unintended effects, known or unknown, and ex-post intervention to mitigate the unintended effects. Hence collection of necessary data (spatial, temporal, sectoral, etc) is an important and necessary part of addressing possible unintended adverse effects after the implementation of a policy measure or a policy package.

Expecting unintended effects ex-ante or detecting unintended effects ex-post only leads to improvements if there is flexibility built in the policy processes. It demands rethinking traditional approaches that assume a deterministic model of the world in which the future is predictable.

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2. RISK AND IRREVERSIBILITY

Transport economics has extensively studied impacts of policy interventions such as changes in supply of or demand for transport services (see for example Small and Verhoef, 2007). Numerous economic assessments of transport policy interventions and their likely effects have been made, often with a focus on finding theoretically optimal solutions. However it is recognised that due to factors such as risk and uncertainty and irreversibility, it is not always possible to completely predict target groups responses with conventional economic models.

Most policies share three important characteristics in varying degrees; i) they are partially or completely *irreversible*, ii) there is *uncertainty* over the future benefits of the policy and iii) there is flexibility about the *timing* of project (Dixit and Pindyck, 1994). The traditional theory for the evaluation of policies does not recognise the important quantitative and qualitative interaction between irreversibility, uncertainty and timing. Policy evaluation boils down to deciding whether the benefits of a project or policy are larger than the costs. In the neoclassical approach the present values of benefits and costs, that usually occur in the future, are calculated using a discount rate, and the difference between the present values of benefits and costs, (the net present value or NPV) determines the desirability of the projects. When several alternative policies exist, and in a situation with budget constraints, the one with the highest ratio of NPV over costs should be selected. The problem is in reality more complicated, especially when costs and benefits of a policy occur over long time horizons and due to risk and uncertainty, and irreversibility. Most investments and environmental policies are in this category.

Regarding the environment, irreversibility is associated with its large-scale changes. The relevance of irreversibility is its association with the magnitude of the damage. In real options, however, irreversibility is defined in a technical manner. Irreversible investments are sunk costs, those costs that cannot be recovered totally. Transport investment projects are usually assumed as sunk cost since the expenditure cannot be recovered. Irreversibility can also arise due to government regulation or institutional arrangements (ibid).

Environmental problems generally involve three compounding levels of uncertainty—uncertainty over the underlying physical or ecological processes, uncertainty over the economic (and social) impacts of environmental changes and uncertainty over technological changes and behavioural changes that might restore those economic impacts and/or reduce the cost of limiting the environmental damage in the first place (Pindyck, 2007).

There are usually important irreversibilities associated with environmental policy. These irreversibilities can arise not only with respect to environmental damage itself, but also with respect to the costs of adopting policies to reduce the damage. Regulation that reduces one environmental risk might well increase other environmental risks; efforts to reduce the CO2 emission associated with fossil fuels, may lead to increased dependence on other sources of energy that have their economics as well as environmental costs. We are facing irreversibilities, not irreversibility. There is almost always uncertainty over the future costs and benefits of adopting a particular policy. These kinds of irreversibilities always work in opposite directions (see Sunstein 2005 and Pindyck 2009). In addition, political constraints may make an environmental policy itself difficult to reverse, so that these sunk costs are incurred over a long period of time, even if the original rationale for the policy disappears. If future costs and benefits of the policy are uncertain, these sunk costs create an opportunity cost of adopting the policy, rather than waiting for more information about environmental impacts and their economic consequences. This implies that traditional cost-benefit analysis will be biased toward policy adoption (ibid).

On the other hand, environmental damage can be partially or totally irreversible. For example, major greenhouse gases are well-mixed, and take many years to leave the atmosphere and, with additional emissions of GHG, results in high concentrations that are long lasting. And the damage to ecosystems from higher global temperatures can be permanent. This means that adopting a policy now rather than waiting has a sunk benefit, that is a negative opportunity cost. This implies that traditional cost-benefit analysis will be biased against policy adoption (ibid).

Irreversibility only matters if there is uncertainty. Uncertainty can affect policy even if there is no irreversibility, but in a more limited way than if irreversibility is present. Uncertainties over benefits and costs are related to the parameter uncertainty (e.g., uncertainty over the elasticity of emissions with respect to a tax rate on emissions), but also to the form of uncertainty over the shapes of the (nonlinear) benefit and cost functions (e.g., uncertainty over how that elasticity falls as the tax rate is increased). The problem becomes especially severe when there are ‘‘tipping points’’ (i.e., when at some level of environmental damage the consequences become near-catastrophic), but we do not know what that point is. And uncertainty has an important implication for the choice of discount rate that we should use in practice—it makes that rate *lower* than any expected future discount rate (Pindyck, 2007).

Governments can also create uncertainty by generating an expectation of policy change or by not taking a position on an emerging regulatory framework. Policy uncertainty can have significant effect on investment decisions. Hassett and Metcalf (1999) examine the impacts of policy uncertainty on investment decisions using a real option framework and show that these uncertainties reduce irreversible investments.

In summary, risk, uncertainty and irreversibility are associated with both environmental problems and the transport policy arena and in particular those with longer time horizons. Further complexities arise in a real world decision making, where there are possibilities of disagreements about the goals and/or means to achieve the goals and hence risk and uncertainty associated with the negotiated policy interventions.

3. INTEGRATING RISK AND UCERTAINTY IN POLICY DESIGN (EX-ANTE)

When policies face with an irreversible loss, and when there is uncertainty about the timing and likelihood of that loss, one should be willing to pay a sum—the option value—in order to maintain flexibility for the future. The option might not be exercised if it turns out that the loss is not a crucial one. But if the option is purchased, policy makers will be in a position to prevent the loss if it turns out to be large. Alternatively, they might obtain the right to scale back a project, to abandon it, to expand it, or to extend its life. Option theory has countless applications outside of the domain of investments.

Numerous researchers have applied option theory for environmental risk regulation and evaluations (see Sunstein, 2008). The simple concept is that when dealing with an irreversible loss, and when uncertain about the timing and likelihood of that loss, one should be willing to pay for an option in order to maintain flexibility for the future. Fisher (2000) has generalised this argument by suggesting "where a decision problem is characterised by (1) uncertainty about future costs and benefits of the alternatives, (2) prospects for resolving or reducing the uncertainty with the passage of time, and (3) irreversibility of one or more of the alternatives, an extra value, an option value, properly attaches to the reversible alternative(s)." This implies that irreversible decisions must pass a higher obstacle than in a cost benefit test.

There are numerous examples of the application of options theory in the literature in the context of "long-term effects". The area of technology adoption under uncertainty and irreversibility has received ample attention. So has the problem of infrastructure investment under demand and cost uncertainty and land allocation problem with economic and environmental uncertainty.

Three important policy areas in an EU as well as a national context are related to; environmental problems, alternative fuels and vehicles and infrastructure investment. These three policy areas will be briefly described to show the relevance of risk and uncertainty in their policy designs.

3.1 Environmental policies

Uncertainties over benefits and costs can affect policy design in at least three fundamental ways. First, they can affect the optimal choice of *policy instrument,* that is, whether pollution is best controlled through a price-based instrument (e.g., an emissions tax) or a quantity-based instrument (e.g., an emissions quota). Second, they can affect the optimal *policy intensity*, for example, the optimal size of the tax or the optimal level of abatement. Third, they can affect the optimal *timing of policy implementation* that is whether it is best to put an emissions tax in place now or wait several years and thereby reduce some of the uncertainty (Pindyck, 2007).

The consequence of uncertainty for the optimal choice of policy instrument has been studied extensively, beginning with the pioneering work by Weitzman (1974). He showed that in the presence of cost uncertainty, the relative slopes of the marginal benefit function and marginal cost function determine the choice of instrument; a price-based or a quantity-based. In a world of certainty, either instrument will be equally effective. With substantial uncertainty over the slopes, the choice of instrument can be crucial. Later studies suggest that, in the presence of uncertainty, policies that combine both instruments (hybrid) are generally more efficient than a single instrument (e.g., Roberts & Spence, 1976; Weitzman 1978, Pizer, 2002; Jacoby & Ellerman, 2004). The optimal design of a hybrid policy depends not only on the shapes of the benefit and cost functions, but also on the nature and extent of the uncertainties. Mandell (2010) argues that in an EU context the optimal design will depend on the relative cost structures within and outside the transport sector and that the optimal regime for the transport sector is a hybrid system, combining a cap-and-trade and an emission tax.

Uncertainties over benefits and costs can also affect the optimal policy intensity, i.e., the size of an emissions tax or the amount of abatement that is prescribed. Without irreversibilities, uncertainty usually leads to *lower* policy intensity. Uncertainty also affects the optimal timing of policy implementation—but only when there are sunk costs associated with implementing the policy, and/or irreversibility is associated with environmental damage. Depending on a particular situation, it may be optimal to postpone the implementation of a policy until there is more information on benefits and costs, or to accelerate the implementation to avoid irreversible damage.

3.2 Alternative fuels and vehicles technologies (AFV)

The creation of a self-sustaining market for AFV is very costly for society. It involves consumers, many industries, institutions and considerable investments including those related to the supporting infrastructures. “Irreversibility” is considerable in this process. The different stakeholders in these different interacting markets face decisions under uncertainty, including in their relation to governments’ policies. The examples of these policies are taxations, subsidies and regulatory measures related to fossil fuels and conventional vehicles and alternative fuel and vehicle technologies as well as the necessary measures related to the supporting infrastructures, and industries. The government needs to make the “right” choice among technologies and like other stakeholders face uncertainties and risks. What are the “correct” sets of policies and how should the policies be phased in and out? How should the government address the choice among technologies and what are the variables/factors that need to be taken into consideration for decision making? See for example, Ramjerdi, et al (2009) and Greaker and Heggedal (2010) on the role of governments in technology selection. While a government faces uncertainty in the adaptation of an “optimal” policy path, it can create uncertainty by generating an expectation of policy change or by not taking a position at the right time on an emerging regulatory framework. Policy uncertainty can have significant effect on the decisions of many other actors (OECD/IEA, 2007).

Environmental concerns are both local and global and the alternative fuel technologies need to respond to both demands. The adverse environmental impacts of production and use of alternative fuels, locally and globally, in a life cycle perspective could be even more than the conventional fossil fuel technologies. Take the example of alternative biofuels with wide range of local and global environmental impacts (Concawe 200; Holtsmark, 2010).

‘Getting prices right’ in the sense of choosing the desired (socially optimal) path, or scenario, and driving markets along a dynamic pattern of feasible technological change through externality taxation (or emissions permit quanta) may not be an easy programme. A single price on greenhouse gas emissions, or subsidy on greenhouse gas abatement, might not discriminate effectively between different technologies that take differing roles into account at different stages in the policy scenario. Arthur (1990) points out to the difficulties of such policy formulation.

3.3 Transport Infrastructure

There is a growing concern about the inadequacy of the traditional approach to the problem of transport infrastructure investment policies (see Flyvbjerg et al 2003; Broecker et al 2003). And there is an increasing recognition that the scope of project evaluation should be extended to account for risk, uncertainty, irreversibility and path dependency in particular in response to the challenges of environmentally sustainable development.

Urban areas and regions are complex systems and they display path dependency. Provisions of transport infrastructures in such a complex environment have many rebound effects that are long lasting and reinforce the "lock in effect". A move to another equilibrium that is potentially more efficient than the present might require substantial effort. As an example public transport and road are substitutes to a degree. Each mode is self reinforcing in that the more it is used the more funds become available for investment and improvements that attracts even further users. Then one mode may achieve dominance at the expense of the other. Changing the situation may require substantial subsidy and capital investments (see Arthur, 1990).

Another important setting that reinforces path dependency on "road system" is caused by the extent of the development of the road network compared with rail network, especially in an urban environment. This situation favours the extension of the road compared with rail. The extension of road in this setting most often seems marginal, with low uncertainty associated with cost, demand or discount rate and often the projects can be completed within relatively short time. Thus the extension of road network is almost always favoured compared with rail and even passes the hurdle to additional requirements set by real option framework. In order to overcome the path dependent development of the road system, extensive subsidies to the alternative mode might be desirable in the long run.

The uncertainties and risks associated with infrastructure investments are manifold with interactions, one upon another, and with consequence for the regions, environments and societies they are intended to serve. Flyvbjerg (2009) examines about 260 major infrastructure projects. Among some of their characteristics are: They are inherently risky owing to long planning horizons and complex interface; Decision-making, planning, and management are typically multi-actor processes with conflicting interests; Often there is 'lock in' or 'capture' of a certain project concept at an early stage, leaving analysis of alternatives weak or absent; Statistical; As a consequence, misinformation about costs, benefits, and risks is the norm throughout project development and decision-making, including in the business case. He draws on three main types of explanations to account for cost overruns and benefit shortfalls in major infrastructure projects: technical, psychological, and political-economic[1].

Strand and Miller (2010) address the options of scaling down energy consumption and carbon emissions in future and the costs of these policies.

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[1] Technical error may be reduced or eliminated by better forecasting models and better data; Psychological explanation is in terms of "optimism bias" (see Kahneman and Tversky, 1979; Lovallo and Kahneman, 2003); Strategic misrepresentation can be traced to agency problems and political and organizational pressures—for instance, competition for scarce funds.

Their focus is on bulky infrastructure investments, sunk at an initial time of decision, that “tie up” energy consumption for a long future period and make it more costly to reduce emissions later. With expected energy and environmental costs continually on the rise, inherent biases in the selection processes for infrastructure investments lead to excessive energy intensity in such investments[2]. The potential reasons for the bias include systematic under-valuation of future energy costs; failures to incorporate true (current and future) social carbon emissions costs; and excessive discounting. It is increasingly recognised that the presence of such an established infrastructure may form a major *ex post* obstacle to effective mitigation policy, for a long future period. This is the case regardless of whether the ex ante infrastructure investment is “optimal” or not. They warn that great care must be taken when choosing the energy intensity of the infrastructure at the time of investment. The overriding idea is that achieving a society with low GHG emissions (necessary for efficiency in the long run) requires a high concern for the design of current infrastructure investments.

3.4 Implications for policy design and implementation

Policy adoption is rarely a now or never proposition. With uncertainty and irreversibility associated with policy intervention, it might be desirable to delay action and wait for new information. With uncertainties and irreversibility, there is a leeway about the intensity of the policy and the timing of policy adoption with significant effect on the optimal policy adoption path. Option theory provides support for decisions under such circumstances.

How important are these irreversibilities and what are their implications for policy? The answers depend on the nature and extent of the uncertainties over costs and benefits, and how those uncertainties are likely to get resolved over time. The greater the current uncertainties and the greater the rate at which they will be resolved, the greater will be the opportunity costs and benefits associated with policy adoption (Dixit and Pindyck, 1994, Pindyck, 2007).

The compounding set of risk and uncertainties in the policy arena implies that policies and investment decisions are based on imperfect and incomplete knowledge. While ex-ante integration of risk and uncertainty in the designs of policy interventions is important, equally important is to collect the necessary information to intervene ex-post for the necessary policy adjustments.

If decision parameters cannot be observed and measured, there is a demand for rethinking traditional approaches that assumes a deterministic model of the world in which the future is predictable (Lewis, 2007, cited in World Bank, 2010). But the required structural changes can be difficult because of the inertia in the established management practices (see for example Brunner et al 2005; Folke et al 2002).

[2] See also by Brueckner (2000), Gusdorf & Hallegatte (2007a & b), and Glaeser & Kahn (2008) for the effects of infrastructure choice on energy consumption and CO2 emissions.

4. SUMMARY AND CONCLUSIONS

Policymakers in the transport sector are often required to make decisions in the face of risk and uncertainty. Most evidently, this stems from a lack of information concerning a particular transport problem, the inability of existing modelling tools to accurately encompass the range of variables and causal relationships involved and the messy, intractable nature of the policy process itself. Risks and uncertainties are particularly pertinent to the context of policy making at an EU level, where an extraordinarily diverse array of technologies, markets and political, institutional and socioeconomic contexts are present. As we have reiterated throughout this paper, contemporary European transport systems may thus be considered to represent complex socio-technical systems, prone to conditions of path-dependency and lock-in effects.

Overall, this paper concludes that although contemporary transport systems are inherently characterised by significant risks and uncertainties, a variety of approaches are available to policy makers that may facilitate the development of effective and efficient policy interventions which minimise the propensity for unintended, adverse effects. Given the strong emphasis placed upon *ex-ante* and *ex-post* activities it is acknowledged that we have here advocated a particularly comprehensive, challenging and resource-intensive policy-making process. Clearly, in the current economic climate, this may struggle to gain practical legitimacy, regardless of its theoretical strengths. As a result, it is perhaps advantageous to reiterate what is perhaps the core consideration that emerges from this work: the importance of adaptive and flexible policy-making. Indeed, without such flexibility, *ex-post* activities such as monitoring or remedial action simply become worthless and obsolete, respectively. As noted, coping with complexities plays a crucial role in planning process; the more complex a system, the greater its associated uncertainties, and thus the greater need for flexibility to be embedded in the design of policy measures. Flexibility is thus both important in the context of policy intervention irreversibility (e.g. investment in heavy infrastructure) or irreversibility associated with the problem that the policy package itself aims to mitigate (e.g. anthropogenic climate change).

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