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ENVIRONMENTAL POLICY INSTRUMENTS AND INDUCED INNOVATION: THE EU DIRECTIVE ON END-OF-LIFE VEHICLES

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ABSTRACT

The paper addresses the dynamic-incentive effect of environmental policy instruments when innovation is uncertain and occurring in very complex industrial subsystems. The case of end-of-life vehicles (ELVs) is considered, focusing especially on the effects of a European Union Directive, adopted in 2000, which stipulated economic instruments of a free take back type, and on the voluntary agreements now in place in many EU countries. The systemic and dynamic features of the innovation process stimulated by policy, and aimed at reducing ELV externalities, are highlighted. Coherent sequences of single innovations taking place in both upstream (car making) and downstream (car recycling/recovery) of the ELV system can give rise to different innovation paths that are sensitive to cost-benefit considerations and technological options by industrial actors. The impact of economic instruments, in particular free take-back and recycling fees, on the choice of the innovation path is considered. Economic instruments initially allocate incentives to one specific phase of the ELV innovation chain. However, technological and economic flexibility available to actors may make individual cost-benefit conflicts prevail over inter-industry cooperation for innovation, and the system may even be induced along an "undesired" innovation path. Furthermore, the system may be characterised by "incentive dissipation" at some stage of the innovation process. The lack of incentive transmission between different industries can in fact prevent the creation of new recycling/recovery/reuse markets giving rise to outcomes unexpected ex ante. The effect of economic instruments on technological dynamics is highly uncertain.
The implication for policy is a need for an integrated approach, through enforceable VAs, in order to create a shared inter-industry interest for innovation, while reducing the risk of adversely influencing by economic instruments the cost-benefit considerations of single industries. Integrated Product Policy, together with best practice approaches at the technical level, is therefore suggested as the most promising framework for systemic problems such as ELV.

JEL: L620, O130, O310, O380

Keywords: ELV, Environmental innovation, environmental policy, recycling/recovery/reuse

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1. Introduction

Despite their insightful suggestions on dynamic-incentive effects of specific policy instruments, mainstream theories of environmental policy did not go beyond a "black-box" approach to dynamic-efficiency effects or policy-induced innovation. The analysis of innovation impacts of environmental policy, therefore, is attracting an increasing number of works addressing, *inter alia*, the role of institutional processes and industrial actors in policy making, the role of different policy instruments in stimulating innovative responses, and the detailed account of technological and organisational innovations attributable to policy impulses[1].

Dynamic-incentive analysis assumes a critical role for at least two reasons: (a) technological and organisational innovation is the main response to most environmental policies addressing emissions and waste from industrial activities whereas the level of activity is little affected; innovation must be considered as a primary impact, and not a by-product, of policy; (b) the evolution of environmental policy theory and practice is partly blocked by a fundamental mismatch still existing between mainstream theories of environmental policy -which are mainly deductive in nature, static-allocation oriented, and optimisation dependent - and the economic analysis of innovation - which is system-analysis oriented, evolutionary minded, and empirical-evidence dependent[2]. An approach integrating the two can be, therefore, a key to better policy making.

This paper addresses the way a specific class of policy instruments, i.e. economic instruments, can influence innovation when they are included in a policy requiring a complex adaptive response by a system of industries. Although adopting a systemic and evolutionary approach, the paper highlights the role of actors' cost-benefit considerations in making innovative choices in response to policy. One specific aim is to suggest that, even in the *ex ante* perspective, the features of the innovation process and economic interactions between industrial actors must be made explicit and addressed first in order to define the impact of economic instruments. The case study considered is EU policy on end-of-life vehicles (ELVs). After the very controversial process leading to the EU Directive 2000/53 and the experiences of national/industrial voluntary agreements during the 1990s, ELV policy is now at the stage of Directive transposition in Member States.

The ELV case is interesting for four reasons: (i) the innovation process is complex and systemic because, in order to attain policy targets, it involves interdependent innovations by

[1] See, in particular, Hemmelskamp, Rennings and Leone (2000), Hemmelskamp and Leone (1998), Klemmer (1999), Kemp (1997), Kemp, Becher and Smith (1999), Hahn and Stavins (1992).
[2] See, among others, De Liso and Metcalfe (1996), Dosi et al. (1998), Leoncini and Montresor (1999), Lundvall (1992).

different industries that give rise to alternative and uncertain adaptation paths; (ii) direct technical regulation, economic instruments, and voluntary agreements have been considered as both alternative and complementary approaches/instruments in both policy debate and practical experiences, and they are all included in the EU Directive as a result of political compromises; (iii) the ELV case has been analysed from the perspective of voluntary agreements (see Aggeri and Autchel 1997, EEA 1997) with a minor attention to innovation or, conversely, from the perspective of company-level innovation capabilities (see in particular Den Hond 1996); economic instruments, instead, received a minor analytical attention while the policy debate on ELV has been largely focused on them; (iv) the ELV case has many similarities with the case of electric and electronic waste (E&E) on which a EU directive, very similar to the ELV Directive, is being introduced (see European Commission 2000).

After presenting the essential facts about ELV problem and policy in the EU, we will depict the systemic and dynamic features of the innovation process. In particular, we will highlight that technological responses to policy by individual industries are interdependent along different "innovation paths". Economic variables can influence the choice among the latter and then we shall focus on the role of economic instruments in influencing the choice among innovation routes. Finally, some implications of combining economic instruments and VAs, as in the EU Directive 2000/53, are discussed.

The still open state of ELV policy and innovation do not allow a truly ex post impact analysis. However, as suggested by the extensive evidence presented in Zoboli et al. (2000), the set of possible innovations is well defined, and detailed evidence on some on-going innovations is available. Similarly, evidence exist on the working of some instruments in practice while the expected impact of other instruments has been extensively discussed before their recent introduction. The level of analysis is, therefore, a mixed ex ante/ex post one.

2. The problem of ELVs and policy responses

2.1. The situation in the EU

The exact number of ELVs to be treated in Member States is still uncertain. The figure adopted in drafting the EU Directive proposal, i.e. 8-9 million ELVs (1994 estimate), is questioned because of the great number of ELVs deregistered in EU countries and exported mostly to non-EU countries for treatment or re-use as second-hand cars. The actual number of ELVs to be treated domestically in EU countries could be 7,5 million units in 1998.

ELVs can have an economic value to last owners ranging from positive to negative according to various factors. When deregistration and delivery of the ELV to a dismantler implies a payment, an incentive to abandon the car in the environment can arise for the last owner. There are not reliable figures on the number of ELVs abandoned in the environment, but the phenomenon is clearly significant in some countries.

The estimates on the rates of ELVs recycling/recovery/reuse (RRR) in the EU are still rough. The overall rate of RRR is generally estimated at 75% of the car weight that corresponds to the metal (ferrous and non-ferrous) content usually recovered by dismantling (spare parts) and shredding activities. The automobile-shredding residue (ASR) is assumed to correspond to the remaining 25% of car weight (an estimated 2.2 million tons in the EU). ASR is generally landfilled and represents a major externality addressed by both ELV policies and industrial agreements. The presence of substances as PCB makes the environmental impact of ASR a critical issue despite the not-too large quantities. Classifications of ASR are still non-homogenous across countries but a procedure for including it in the European Hazardous Waste list is under way. The presence of plastic residues contributes to the relatively high calorific value of ASR-derived fuel.

Parts and materials from ELVs give rise to reusing/recovery/recycling chains that have different degrees of actual development, innovation opportunities, and constraints. Car production is an important market for some reusable/recycled/recovered materials.

Significant changes in car material regime occurred during the last few decades and the material composition of new cars produced in late-1980s and early-1990s (i.e. ELVs of the next decade) shifted further towards polymeric materials and aluminium. Compared to their extensive role of in car making, many plastics have significant difficulties in recycling from ELVs. Aluminium is the main metal having an increasing share in car material mix and the automotive sector is the main market for recycled aluminium. These trends for material composition clearly affect the recovery and recycling possibilities and, then, technical and-economic implications of different policy provisions (see Zoboli 1998 and Zoboli et al. 2000 for details).

2.2. The EU Directive on ELV

ELVs were identified as a "priority waste stream" by the Commission's "Community Strategy for Waste Management" (1989). After many-years of problem definition and proposed solutions, the Commission produced an ELV Directive proposal in 1997 (European Commission 1997). The latter addressed ELV as a waste-management problem to be faced on the basis of financial "extended producer responsibility" and it involved product making to a large extent through: quantified targets on RRR of ELVs; technical/environmental standards for dismantling and treatment operations; limitations on some heavy metals in car materials and components; limitations on ASR energy recovery; the obligation of industry to take back free of charge ELVs from last owners; the future direct regulation of car "recyclability/reusability/recoverability" (RRR-ability); and the implicit exclusion of national/industrial voluntary agreements.

Industries opposed most of the provisions as they were formulated, and in particular: free take-back; the timing of targets as applied to cars already on the market (the so called "retroactivity"); the limitations on energy recovery of ASR; the limitations on heavy metals in alloys, the exclusion of VAs. The preference of most industries was for "shared responsibility" and industrial voluntary agreements. A very controversial process of adoption went on during 1998 and 1999. The ELV Directive was finally adopted by the Council and the Parliament in September 2000 after the conciliation procedure[3].

The main provisions of the Directive 2000 are (see European Parliament and Council of the European Union 2000): (a) Collection/dismantling facilities must be authorised; last owners will receive a certificate of destruction; treatment facilities must fulfil requirements specified in the Annex I; many components must be removed; (b) By 1st January 2006 the recovery/reuse rate of all ELVs will have to achieve 85% in terms of weight and recycling/reuse 80%; by 1st January 2015 the reuse/recovery rate of all ELVs will have to be 95% of the weight and reuse/recycling 85%; energy recovery is allowed up to 5% of weight by 2006 and up to 10% of weight by 2015; (c) Amendments on car type-approval regulation will be prepared to ensure that vehicles will be reusable/recyclable to a minimum of 85% and reusable/recoverable to a minimum of 95% of weight; (d) Annex II specifies a list of materials and components exempted from the limitations on the content of lead, chromium, and mercury; (e) End-of-life vehicles shall be delivered to dismantling without any cost for the last owner (free take-back) and producers shall meet "all or a significant part" of the cost of implementation; (f) Member States may transpose key provisions by means of agreements between the national authorities and industries; agreements shall be enforceable and, in case of non-compliance, Member States must implement the Directive by legislation.

2.3. National policies and industrial VAs

In 2000, 10 EU Member States (Austria, Belgium, France, Germany, Italy, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom) had specific regulations and/or industrial voluntary agreements (VAs) for ELV. Other three countries were discussing industrial agreements (Finland and Ireland) or introducing legislation (Denmark). Six countries (Austria, Belgium, Germany, Italy, the Netherlands, and Sweden) combine VAs with pieces of legislation directly addressing ELV. Austria, France, Italy, and the Netherlands introduced voluntary agreements or countrywide initiatives in the early 1990s before the drafting of EU Directive. VAs and legislation in the other countries (Belgium, Germany, Portugal, Spain, and Sweden)

[3] For an analysis of the legal and policy background of the ELV Directive proposal see Onida (1999).

were established in 1997-99 during the debate on the EU Directive proposal but, in some of the latter, ELV has been high in domestic policy agenda for many years.

In particular, a process of integration between industrial agreements and legislation occurred in Germany and Sweden after a long confrontation between industry and policy-makers based on diverging views on responsibility distribution (i.e. "shared responsibility", or cost distribution on all the industries involved, Vs "extended producer responsibility", or financial responsibility of the car industry). The result in both countries is legislation including environmental and technical requirements for dismantling/shredding operations and the commitment by the car industry to apply free take-back subject to specific conditions.

In other large countries (France, Italy and the United Kingdom), ELV policy is largely based only on VAs promoted by the car industry and involving a number of other industries. One major feature of these VAs is the absence of specific economic instruments of the FTB-type and the prominence of free-market relationships. Agreements are mainly based on contractual arrangements aimed at distributing the costs and advantages arising in ELV management, with the car industry assuming the role of coordinator.

In the agreement implemented in the Netherlands, a "recycling fee" is levied on new car prices and redistributed to dismantlers and recyclers. Specific mechanical recycling targets are established. The Dutch scheme is an alternative approach compared to that preferred by carmakers and raised a strong debate on market vs administered schemes (see Zoboli et al: 2000 for details)[4].

3. Policy-making process and induced innovation

The long and controversial process of ELV policy making stimulated and influenced innovation responses in two general ways: (a) through expectations/threats about the introduction of a regulation, and (b) through the establishment of specific RRR targets.

National VAs and industrial networks for ELV management mostly developed as the attempt by industry to prevent a EU detailed regulation after the inclusion of ELVs among "priority waste streams"[5]. The "anticipation game" was driven by diverging views on the relative merits of VAs and direct regulation. The result has been that actual innovations in ELV management in some countries occurred *before* the most important regulation impulse at EU and national level was actually introduced. Furthermore, the change in regulation expectations occurring during the debate on EU Directive reinforced some directions of innovation, e.g. the

[4] There are not operational proposals for the introduction of ELV regulation in the United States and Japan. However, carmakers in these two countries are developing voluntary and/or industrial initiatives to cope with the regulation developments in the EU market and the evolution of their domestic waste policies.
[5] For the role of legislation threats in stimulating agreements, see Segerson and Miceli (1997).

increasing emphasis on dismantling networks with the expectation on FTB introduction (see Zoboli et al. 2000 for details).

The second general way of influence has been the complex process of RRR targets definition that assumed the features of a strategic game imbedded in innovation expectations. If RRR target-rates are viewed in terms of ASR non-landfilling rates, there is a significant similarity between the rates established by EU Directive and those adopted by industrial or national VAs. The latter, however, do not generally specify mechanical recycling targets and they originate from industry-level discussions of early 1990s when little experience and actual results in ELV management were available. They reflect technological expectations and strategic propositions by industry and they were mostly considered as targets to be achieved by "shared responsibility". Regulators assumed the targets were feasible and made them legally binding, introduced targets for mechanical recycling rates, and imposed a target timing that involves "retroactivity". Furthermore, regulators considered the VAs in force at mid-1990s as ineffective and placed RRR target-rates in the framework of a "direct regulation" approach *with* economic instruments.

The consequences of these general policy impulses for innovation are twofold:

(i) Innovation responses by industry started, evolved and reached some results even in the absence of precise legal frameworks and specific regulation in most countries, and mostly without regulation-imposed economic instruments at work; the features of the innovation process and technological options for ELV are, therefore, well defined but they are neither completed nor constrained to a specific dominant choice by the industrial sub-system involved; at the same time, these developments are the terms of reference for the innovation impact of EU regulation after the Directive of 2000;

(ii) The policy targets on RRR, as well as other provisions, make the actual results of industrial initiatives insufficient, thus paving the way to two key issues: (a) single specific innovations in ELV management are unable to achieve the RRR targets and *interdependent* innovations in the different phases of the ELV system must be developed in a coherent way; (b) the achievement of RRR targets implies an "economic-value deficit" by imposing incremental costs without a corresponding profit in the short run; therefore, incentives must be introduced into the system but the best approach to allocate the economic-value deficit in order to stimulate appropriate innovative reactions remains a moot point.

We shall analyse these consequences by addressing:

(a) the features of the innovation process in ELV, and in particular its systemic and dynamic profile;
(b) the innovation- or dynamic-incentive properties of economic instruments in presence of an innovation process having such features.

4. The innovation process

4.1. Specific innovations

Some developments occurring in Europe-based car companies are summarised in Figure 1.

The creation of networks of dismantlers/shredders linked to individual car companies has been a major organisational innovation given the limited relationships existing before between the car industry and post-consumer ELV operations. The specific technical and environmental requirements as well as the contractual arrangements between the actors involved (i.e. carmakers, dismantlers, shredders, and recyclers) differ from company to company and from country to country as they are tailored to specific operational and legal contexts.

Innovative developments in design for dismantling (DFD) are occurring in all car companies. DFD may consist of small changes in the part-assembling systems or it may imply changes/adaptations of components and parts. The boundaries between DFD and design for recycling (DFR) are not clear-cut.

DFR requires definition and measure of "recyclability". European carmakers work on the development of "recyclability coefficients" for materials and components and produce lists of substances/materials that are not admitted or undesired as part of technical specifications for component suppliers. In this way, "responsibility transfer" between industries occurs. DFR is increasingly linked to Life-Cycle Analysis (LCA). Most carmakers are investing in LCA at the R&D level and, in many cases, they are transferring results in practical choices. LCA is generally still limited to specific materials or car components[6]. DFR pushes most carmakers to pursue a simplification of the material regime. "Easily" (i.e. economically) recyclable materials are favoured and, as a consequence, the trend favourable to some polymers and composite materials is weakening. There is a propensity to reduce the number of polymers in favour of those having the best recycling possibilities and a process of inter-polymer substitution is under way.

The search for recyclability can favour "recyclable" metals as aluminium and significant research efforts are going on to exploit the properties of AL as a structural material. AL is mainly a substitute for steel or fully-recycled metals, however, and this can reduce its contribution to overall car recyclability.

The amount of recycled materials used in new car manufacturing is increasing. Recycled plastics in new cars sometimes come from ELV recycling loops in the form of "cascade recycling" (i.e. the use of recycled plastics in decreasingly critical components at subsequent rounds). The increase of plastic recycling from ELVs has been addressed by a number of initiatives by carmakers and plastic producers but mechanical recycling at the industrial scale is

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[6] For an analysis of the shortcomings of the present state of LCA see Ayres and Ayres (1998 and 1999).

limited to specific polymers from specific car components (e.g., bumpers). Economic balances of car plastic recycling are weak for many polymers due to high dismantling and logistic costs[7]. The potential for "cascade recycling" is considered to be limited.

Energy recovery of ASR in waste incineration plants and cement industry attracted innovative efforts and investments. Positive environmental results of ASR energy recovery emerge from various LCA analyses produced by industry but other studies produced by EU policy institutions give opposite results. Attempts are underway to separate and recover the materials in ASR (non-ferrous metals and plastics) and to recycle them.

4.2. Innovation paths

Some of the above specific innovations have systemic aspects in themselves, as in the case of DFD/DFR. However, the most important systemic feature arises at the inter-industry level. None of these innovations taken alone has the potential to attain the RRR targets and innovations with the highest potential, e.g. plastic recycling, are the less developed ones for technical and/or economic reasons.

The innovation process in ELV, therefore, must be considered as composed of alternative/complementary sequences of interrelated innovations that should be able to achieve RRR targets. We define these sequences as “innovation paths” or “vertically-integrated innovation options” and take them as reference for evaluating the possible impacts of ELV policy and instrument choice.

Three main innovation paths can be identified that can be defined as (Figure 2)[8]:

(a) “material-market creation path”;

(b) “energy-market creation path”; and

(c) “radical substitution path”.

4.3. Material-market creation path

Taking as given the current car material composition, the sustainable achievement of a reduced amount of landfilled ASR require market creation for the parts, components and materials currently not recovered, reused and recycled (RRR). This is only partly a problem of incremental RRR at the margin for materials that already have a well-developed secondary market (e.g. ferrous metals). In the case of new markets for recycled plastics, for example, innovations are required for the technical suitability of recycled plastics in existing or new uses, both outside and inside the car industry (i.e. open- and closed-loop markets). This is not

[7] For an analysis of factors limiting the development of recycling industry see Bontoux et al. (1996).

[8] Due to its still dubious implementation potential, we do not consider “metallurgical recycling”, an innovation developed by Mercedes-Benz in the early 1990s, that have “radical” features compared to other solutions and can be considered as a specific innovation path in itself (see Zoboli 1998).

enough, however, to achieve economic suitability of innovative uses. Appropriate (innovative) changes in dismantling activities are required to provide the materials at the "right" quantities, qualities and costs. The latter achievements can be favoured by innovations in car making through developments in DFD/DFR. This can push in the direction of inter-polymer competition and selective polymer substitution. At the end, the process requires interdependent changes in different industries while the increasing recycling rate achieved for some polymers might have adverse impacts on other polymers in the material mix. In general, by preserving the role of polymers as a material group in car making, this path can be non-detrimental for energy-emission saving in transports to which the lightness of plastics do contribute. Technologies leading to material recovery of ASR can be considered as a form of material markets creation, and require the same type of interrelated changes. The material-market creation path can combine relatively high ELV "recyclability" with relatively small and/or well-focused car-design changes.

4.4 Energy-market creation path

An alternative route of market creation is the development of energy recovery of ASR. It has specific features in terms of innovative adaptations. Markets for automobile shredding fuel (ASF) are still very limited and should be created. This path mainly involves new relationships between shredders and energy consuming industries, or other sectors possibly using waste-derived fuel, that are mostly external to the ELV system. Specific economic and technical constraints may arise, e.g. competition with other waste-derived energy feed-stocks. The feedback created along the ELV chain would be less complex than in material-markets creation, although some specific requirements for dismantlers do arise in terms of preparation of the material stream becoming ASR.

The important fact is the limited feedback on car material mix and design because the energy potential of ASR largely depends on the presence of polymeric residuals. The air emission implications of the energy route to ASR recovery should be obviously weighted against the emissions from conventional energy it can substitute for. It does not imply trade-offs with energy-emission requirements in car making by allowing the current trend towards composites and polymer-based light materials to continue. Although the EU policy targets allow energy recovery to be half of the incremental non-landfilling rate of car waste, the pursuit of energy recovery path is policy-constrained by the provisions of the EU Directive and it remains an open issue in the debate between regulators and industry.

4.5 Radical substitution path

The possible difficulties in pursuing "material market creation" and "energy market creation" paths, both allowing a relatively stable material-groups mix, can stimulate more radical adaptations of design and material choice in the upstream part of the ELV system. Let us define this path as "radical substitution ". Leaving aside the possible regulatory constraints on the use of specific materials (e.g. lead) and the associated material substitution impulses, a radical design choice could be to reduce materials *currently* having weak recycling markets. The substitution process should be considered as a reduced propensity to introduce complex and advanced materials not technically and/or economically suitable for recycling. It can lead to the interruption of the trend favourable to (composite) polymer-based materials/components in car material mix. Further to counterbalance the trend towards increasing average car weights, thus helping the trajectory of low-emission car, polymer-based materials contributed to assembling simplification and assumed a significant role in the present organisation of car production. The possible trade-off between increased recyclability on the one hand, and simplification of production and lower emission levels on the other hand, suggests that this innovation path can influence other car innovation trajectories. The "radical substitution path" can also change the problem of markets creation for recycling: it can reduce the need for developing "new" recycling market (e.g. some plastics) and can create, instead, a problem of marginally increasing quantities in well-established recycling markets (e.g. some metals). The "radical substitution path" also reduces the need for innovations in ASR energy recovery.

4.6. Preferences, degrees of freedom, and constraints

Policy makers, especially at the EU level, demonstrated a strong preference for "material-market creation", whatever the implications or trade-offs in car design, while they are adverse to "energy-market creation". Carmakers have a preference for a combination of "energy-market creation" (most preferred) and "material-market creation", and try to avoid the adverse implications of "radical substitution" on car making. Dismantlers, shredders, and material producers/recyclers have differentiated preferences for the three paths, and some of them (e.g. shredders and metal producers) might even benefit from "radical substitution". The latter would be, in general, the most problematic one because it can imply a loss of innovative opportunities, increasing costs, and adverse environmental implications.

Inside each of three paths there are various technical and economic degrees of freedom and constraints. A degree of freedom, for example, is the creativity that the chemical industry often demonstrates in designing and adapting materials; a specific constraint can be represented by the limitations on closed-loop markets for recycled plastics in car making. Different carmakers, industrial networks, and national situations are differently advanced along one or more of the three paths, and have different capabilities to pursue them. Finally, the three paths can be alternative, as sketched above, but can also be pursued by selective combinations to achieve RRR targets.

Environmental, technological, and economic results associated to the innovation paths are not completely known in advance and various specific innovations composing the three paths are not at advanced stages. The uncertainty about results, in facts, becomes evident during the same process of path selection, depending on the specific innovative steps and constraints along one or more paths. For example, the efforts on plastic recycling encountered economic-organisational difficulties and suggested to invest in dismantling networks development (material market creation path), and/or to develop energy recovery of ASR (energy market creation path), and/or to slowdown composite-materials introduction (possibly radical substitution path). The features of a knowledge and capability-creation process in an evolutionary framework clearly emerge (see in particular Den Hond 1996).

5. Economic instruments and innovation paths

To what extent policy instruments can influence the selection of the innovation path? The "partial" analysis of single instruments has methodological limitations. The EU Directive and country-level regulation/VAs are complex policy packages including a combination of heterogeneous instruments, thus it can be very difficult to isolate the impact of specific instruments because of their extensive cross-influences[9]. The most appropriate approach would be to consider different policy packages (including VAs) already implemented and to evaluate their ex post performance. This possibility is still limited because most ELV policy schemes at national level, as the German and the Swedish ones, have a too short history and record of achievements. Furthermore, some national policies and VAs are based only on contractual agreements without direct regulation and/or economic instruments.

The extensive debate on ELV regulation coupled with evidence from their halfway implementation, however, provide useful suggestions for analysing the implications of different economic instruments for ELV innovation. Taking into account the above-mentioned limitations, we simply attempt to define, on mixed ex-ante/ex-post grounds, the impulse of instruments on innovation *given* the features of the ELV innovation process.

The framework of externalities, actors and impact innovation *directly* addressed by economic instruments is described in Figure 3.

The main ELV-related environmental impacts/externalities are:

(a) The dumping of ELVs in the environment;

(b) The release of pollutants in treatment operations, and
(c) The landfilling of ASR.

The incentive effects and the actors economic instruments may address are:

(a) Disincentives to the dumping of ELVs in the environment by addressing last owner of ELVs;
(b) Incentives to increase the rate of RRR and reduce landfilled ASR by addressing one or more industrial sectors;
(c) Incentives to improve dismantling techniques and increase the dismantling rates by addressing dismantlers/recyclers;
(d) Incentives to increase the recovery of ASR by addressing the shredding industry;
(e) Incentives to increase car RRR-ability through DFD and DFR by addressing the car-industry.

Three main groups of economic instruments that have been (or can be) considered in ELV policy are:

(a) Free take back (FTB), recycling credits (subsidies), and deposit-refund systems;
(b) Increasing or specific landfill taxes;
(c) Virgin-material tax or recycled-material subsidies.

The instruments in the group (a) have been introduced, with different formulations, in some national policies and in the EU Directive. Landfill taxes are normally applied on ASR as a waste streams but they have not been used specifically for ELV waste management. Virgin material taxes or recycled materials credits have not been considered so far[10].

In the *direct-effects framework* of Figure 3, the choice on economic instrumentis instrumental to stimulate externality-reducing innovations, and corresponds to *separate* the different components (i.e. actors, industries, and phases), to address those considered as the most critical ones, first assigning them the initial incentive impulse, then expecting the sequence of innovative reactions which will take place in the rest of the system. In other words, economic instruments make explicit the economic-value deficit (missing markets), and they allocate the value deficit to a specific phase and/or actor(s). To achieve integrated or closed-loop innovations defined by the innovation paths, which are *complete-effects sequences* including indirect effects, the incentive should be "transmitted" through markets to other actors of the ELV chain playing a role in innovation. The transmission/spreading of incentive across the ELV system, however, has been *assumed* to occur rather than being explicitly analysed in

[9] At the theoretical level, although it may exist an "optimal instrument" if considered alone in a non-systemic setting, it can be sub-optimal when integrated in a whole-policy perspective (see Kolstad, Ullen and Johnson 1990).

[10] The condition that can make upstream or downstream taxes alternatively preferable in waste policy are examined, among others, by Calcott and Walls (2000), and Vatn (1998).

ELV policy making. This is mainly due to the difficulty in deploying full information on technological and economic relationships inside the system.

The features of the ELV innovation process, as described above, are complex enough to suggest that the closed-loop transmission across the whole system of the incentive placed at specific stage/actor cannot be taken for granted as it depends on uncertain and possibly conflictual mechanisms. The set of preferences for the different innovation paths is characterised by an high degree of heterogeneity. Preferences of agents with respect to the alternative innovation paths vary according to the associated cost-benefit balance.. Nevertheless, the emergence of one path cannot be decided by one actor alone because it depends by the *simultaneous* propensities and actions of different actors. Furthermore, the innovation paths are still incompletely defined and partially uncertain as their exact final shape depends on the choices made by agents at different stages of the process.

In such a dynamic framework of multiple options and constraints, we expect that incentives deriving from economic instruments will be transmitted in a way different from what assessed by partial equilibrium static analysis; moreover, theoretically similar economic instruments might influence innovative reactions in different ways. In particular, economic instruments which share similarities regarding to their ex ante theoretical effect, could push the system towards different innovation paths according to: the cost-benefit balance of the agents *directly and indirectly* affected, the structure of the markets involved in the *incentive-transmission process*, the *stage of the chain* at which the *initial* incentive impulse is placed, as well as other technological *and* economic degrees of freedom and constraints prevailing inside the system.

We shall discuss these issues by considering expected/observed impacts of two instruments in the group (a) above, i.e. free take-back and recycling fees[11].

5.1. FTB and recycling fees: apparent similarities and different innovation incentives

Free take back (FTB), recycling fees and deposit-refund systems have been discussed in the ELV case as they could be good substitutes. They should provide incentives: (a) to eliminate the dumping of ELVs into the environment; (b) to increase the rate of post-consumer RRR; (c) to increase RRR-ability at the car design stage. They address the same actors in the "consumer-dismantler/recycler-carmaker" sub-system and share various features. Each of the three instruments actually contains, both in theory and practical formulations, some element of the other(s).This seems to fit theoretical suggestions that neutrality of the chosen instrument with respect to outcome exists under some assumptions, and this opens the way to some degrees of

[11] Deposit-refund systems will not be explicitly discussed in that the essential elements of this instrument are contained in both free take-back and recycling fee schemes.

substitutability between instruments because they should create the same set of incentives even when targeting different (sets of) actors (Pearce and Brisson 19995, DETR 1993)[12].

However, even a simple analysis of the static allocation properties of FTB and recycling fees reveals that they can have quite different incentive structures for the choice of the innovation path because they modify in different ways the working of the ELV market, especially in terms of uncertain price effects (see Zoboli et al. 2000)[13].

With the FTB mechanism included in the EU Directive proposal 1997, the last car-owner can deliver his/her old car to a dismantling facility at zero cost. If the ELV has a negative value, i.e. dismantler ask money to accept the car for dismantling, last owner can be reimbursed by the car dealer or carmaker. An incentive to reduce the number of old cars abandoned in the environment (i.e. externality of the type a. above) arises.

As dismantlers can freely establish the price for ELVs they receive (i.e. FTB level) and last-owners will be fully reimbursed by the carmaker, dismantlers have the interest to pay negative prices for ELVs, last-owner become indifferent to ELV price, and car industry do not participate to the transaction. With this sort of "free" FTB, the possibility of a transfer to dismantlers in excess of incremental dismantling costs cannot be ruled out, in particular if the existence of a great number of non-professional dismantlers in Europe is considered. Furthermore, last-owners (i.e. consumers) may have an opportunity cost from "free-FTB" as far as the starting situation (before FTB) is one in which average positive ELV prices do prevail, as is the case in various Member States, while "free FTB" creates a pressure towards negative ELV prices.

For the other externalities and incentives (type (b) and (c) above), therefore, "free FTB" allocate the whole incentive (i.e. the economic-value deficit of incremental car RRR) to the automobile industry. The policy view, in fact, is that policy-induced costs of incremental RRR should not be supported by dismantlers/recyclers because high costs are a consequence of car-making choices, i.e. design and material mix (see Onida 1999). The final targeted actors are carmakers but the incentive impulse starts in the transactions between ELV last-owner and dismantler with the expectation that it will be transmitted to both upstream and downstream parts of the ELV chain. FTB total effect is then based on *expected* economic reactions and inter-industry incentive transmission mechanisms.

In terms of innovation, the possibility that a "material-market creation path" is stimulated by "free-FTB" cannot be ruled out, but the cost allocation associated of the instrument creates

[12] The role of a deposit scheme in reducing car abandonment is analysed by Greaves and Sexton (1992). The generalisation of a deposit-refund system up to the equivalence to a pigouvian tax system is proposed by Fullerton and Wolverton (2000).

[13] Arguments in favour of different implications of the two instruments are also proposed by Palmer and Walls (1999).

various uncertainties about the most likely outcome. Different reactions by industrial actors are possible and they as depicted in Figure 4 in the case incentives from FTB are transmitted downstream by dismantlers to recyclers. If FTB reduces the costs and increases the economic quality of materials coming from incremental dismantling (case A), then innovation can proceed along the “material market creation path” by creating more recycling/reuse of parts and materials. The new recycling/reuse markets are incentive-based, however. Self-sustained markets require innovations in recycling/reuse technologies for parts and materials. If innovations on recycling/reuse actually take place, carmakers can make selected adaptations in design/material mix and the cost of FTB can be gradually absorbed, i.e. carmakers can pay decreasing amounts of FTB due to increasing car recyclability/recycling.

A less optimistic possibility is that innovations in recycling are insufficient to create self-sustained markets (case B). FTB-based incentives become permanent subsidies to dismantling/recycling activities. Carmakers can then make different choices according to their technological capabilities and FTB costs they have to support. The first possible choice is to preserve material mix and related advantages while accepting high FTB costs (case B.1). In this case, FTB is likely to be passed on to consumers through higher new-car prices. Innovation incentives will be low and the main result could be new recycling markets steadily subsidised by consumers. The second possible choice for carmakers is to increase their economic involvement in downstream operations to "control" FTB (case B.2). In this case, the “power” of car industry on dismantling/recycling can become structural and greater with FTB than with VAs. The third choice for carmakers could be to make radical design/material adaptations in favour of easy-recyclable (traditional) materials thus reducing FTB costs but pushing innovation along the “radical substitution path” (case B.3).

In essence, FTB can have different innovation outcomes: (i) innovations in recyclability and new self-sustained recycling markets; (ii) modest innovation impacts on car design together with new recycling markets subsidised by the consumers; (iii) “backward-oriented” innovations, based on the interruption of trends towards advanced polymer-based materials.

The possibilities sketched in Figure 4 are based on the assumption that the resource transfer initially allocated to dismantlers is re-distributed along the downstream part of the ELV chain. However, “free FTB” does not guarantee that very low (or "zero”) costs of incremental dismantling are transmitted to the recovery/recycling industries (recyclers, shredders, material industries) through very low (or zero) prices for dismantled materials and parts. If incremental "zero costs" arising to dismantlers from FTB are not shared with other downstream industries, the creation of new recovery/reuse/recycling markets could be difficult[14].

[14] Other transaction costs can be associated to FTB (see Palmer and Walls 1999).

In principle, a “recycling fee” scheme, that addresses the same externalities and subset of actors, can mitigate some shortcomings of “free FTB”. In the Dutch scheme, the recycling fee on new cars is established by the fund administrator at a level corresponding to estimated (net) incremental dismantling costs. Furthermore, the recycling subsidy is distributed to recycling industries other than dismantlers; the sharing of benefits increases the possibility that new recycling markets actually arise. Finally, in the Dutch scheme only consumers (i.e. first-owner registering a new car) pay the financial transfer while carmakers do not pay for ELVs. The reasons for a distribution conflict between carmakers and dismantlers/recyclers emerging with “free-FTB” is weakened.

Since carmakers do not bear costs with FTB, it may seem paradoxical that German carmakers - the most active in the debate on ELV regulation -are strong opponents of the Dutch recycling-fee scheme while preferring a form of FTB even though, at the same time, they oppose the “free-FTB” of the EU Directive Proposal 1997 (Schenk 1999).

German carmakers’ preference are explainable if we observe the ways the two economic-instrument schemes could be implemented in practice. In particular, the preference arises from the alleged adverse implications of the recycling-fee scheme implemented in the Netherlands, and the alternative possibility to arrive at forms of “controlled FTB” schemes inside VAs.

The weaknesses of the Dutch recycling fee are alleged to arise from the fully administered working of the system, the creation of subsidised recycling markets, and their potential disincentive for innovation. FTB can be more flexible in its actual implementation. Instead of being freely established by dismantlers, FTB may be subject to a “conditional application” depending on the features of ELVs to be dismantled. Two examples are the condition about the age of the ELVs (i.e. less than 12 years old) included in the German VA and the conditions about the technical state of delivered ELVs in both the German and the Swedish schemes (and partly in the EU Directive 2000). These conditions create a form of “controlled FTB” that could reduce some possible distortions of “free FTB”, although they do not solve *per se* the issue of incentive-transmission process required by “material market creation path”.

While there is not extensive experience on the working of FTB, the Dutch recycling-fee demonstrated to be effective in achieving specific recycling targets. However, leaving aside its alleged high cost, the Dutch scheme is questioned for distortions it possibly creates on the European material market as well as its low level of integration with the automobile industry. Furthermore, although a recycling-fee scheme fulfil the EU Directive requirement that the last owner have not to pay for ELV, the first car owner (i.e. consumer) will pay in an any case, and it might be questioned if such a scheme fulfils an "extended-producer-responsibility principle".

In essence, FTB and recycling fees represent different initial cost-benefit allocations that can give rise to different incentive impulses and innovative reactions by industrial actors.

In the case of FTB, a critical point is the possible difficulty in redistributing the incentive placed at the dismantling stage across the ELV chain so that the increasing recycling (downstream) and recyclability (upstream) required by “material market creation path” will be actually achieved. A sort of “incentive dissipation” mechanism may arise. Furthermore, according to its formulation and the degrees of freedom of actors, it can also push towards a “radical substitution path”.

In the case of a recycling fee of the Dutch type in which the car industry does not pay for ELV, the critical points can be the lack of upstream "recyclability" incentives on carmaking and the difficulties in creating a final market for additional recycled materials from old cars. Even in this case, the loop can remain open whereas a “material market creation path” requires a “closed loop” innovation process.

6. Voluntary agreements and economic instruments: how can they coexist in ELV policy?

Economic instruments and VAs have been debated as *alternative* solutions to the ELV issue, the former being supported by policy makers and the latter by carmakers. However, the two approaches can be considered even *in combination* after the Art. 10 of the “compromise” ELV Directive 2000/53 which allows, *inter alia*, for Art. 5(4) on FTB -or equivalent measures- to be implemented by Member States within national enforceable agreements. How can the incentive effects of economic instruments change? VAs including forms of FTB, i.e. the German and the Swedish schemes, are too recent to supply sound evidence but the features of VAs for ELV (see Zoboli at al. 2000) can suggest some possible developments.

The incentive structure of VAs is not standardised as it derives from tailored contractual agreements. VAs for ELV suggest that cost-benefit considerations by participating industries are very important in the bargaining process leading to the agreement, but, when the latter is in place, it generally works in a cooperative way which is largely independent from the fact that the cost-benefit distribution between actors is the most “fair” one by some reliable standard (if any). In most VAs, cost-benefit distribution is, in fact, *implicitly* defined by the distribution of industrial and technical tasks. The possibility that any actor perceives to suffer from cost-benefit imbalances is generally faced by allowing forms of re-bargaining or side-arrangements. The apparently less critical role of precise cost-benefit considerations -or the prominence of strategic considerations- in VAs compared to economic instruments may depend on the fact that VAs are strongly focused on a combination of “material“ and/or “energy market creation path”. The latter can be successful *only if* integrated innovations by different industries do take place in a “capability creation” process (Den Hond, 1996).

As a consequence, the incentive property of VAs is that they can create a system of cross-controls between industries by putting in a framework of inter-industry cooperation a set of actual and potential economic conflicts over net cost distribution. Interdependency between "partial" innovations inside innovation paths, and in particular "material market creation", creates the shared interest that all the actors work in the most appropriate way. The weakness of one actor can impair common achievements and it is unlikely that one industry can participate to the agreement at zero cost or enjoying extra-profits at the expenses of other actors (see Zoboli et al. 2000 for a discussion).

These positive incentive properties for innovation, however, cannot be taken for granted for all VAs. Although all innovative developments on ELV emerged so far from different forms of VAs, many agreements did not yet achieve their own objectives. Furthermore, the variety of VAs and their incomplete deployment in various countries prevent from a rigorous assessment of which form of agreement can assure best incentives to innovation. Even company-level initiatives or country-level agreements with a weak regulatory framework have been able to reach practical achievements on recycling and recovery, but regularities on ex post performance and explaining factors are weak. The positive results seem to be related to a large industrial participation to the agreement, investments in DFD/DFR by the car industry, successful creation of dismantling networks, and a sufficient experience allowing a deeper learning process[15].

The way incentives from economic instruments, as FTB, will change in the framework of a VA will largely depend on the specific formulation of the national policy. Despite the difficulty in defining the range of possibilities, it is likely that forms of "controlled FTB", e.g. the German or Swedish approach, will prevail. The "control" arises on two grounds. The first is in the making of the VA through the contractual definition of the level of FTB and the cases in which it can be applied or excluded. The second one is the actual working of ELV management networks. Already at present, dismantlers and recyclers in many European countries are increasingly involved in VAs even without (explicit) economic incentives (or recently introduced forms of "controlled FTB"). In many countries, legislation allows car dealers to receive ELVs to be transferred for treatment at authorised dismantlers and a systematic preference for dismantlers in the carmakers' networks (or in the VA) can then arise.

In essence, the role of economic instruments could be reduced to that of "second level" instruments that enter into the fore only when specific or extreme circumstances create visible cost-benefit imbalances that must be corrected for a smoothed working of the agreement. Far from being the key of the cost-benefit distribution system, as in the EU Directive proposal of 1997, FTB can become the explicit cost element in a cost-benefit distribution which remains mostly implicitly defined by the assignment of industrial/innovation tasks. But different

[15] Similar requirements are also suggested, among others, by Delmas and Terlaak (1999) for innovation-oriented agreements.

propensities might prevail in country-level transposition, and the possibility that some countries will design the whole agreement around economic instruments cannot be ruled out. In any case, the *threat* of FTB or similar instruments can be significant in shaping the agreement.

7. Conclusion

Binding targets on incremental RRR included in the ELV Directive created the problem of an economic-value deficit associated to lacking markets for incremental recovered, recycled and reusable car materials and parts. The possibility to overcome the economic-value deficit through market creation strictly depends on technological and organisational innovation and the key issue become the choice of "right" incentives to innovate. The choice of EU policy makers has been to introduce economic instruments of the FTB form in the ELV Directive. Carmakers and other industries tried to solve the same problem by the alternative approach of voluntary inter-industry agreements they promoted in most European countries. Behind the different reference principle (i.e. "extended producer responsibility" vs "shared responsibility"), the debate between industry and policy makers largely remained ideological in nature whereas the evaluation of different approaches/instruments in terms of induced innovation remains weak.

We have proposed elements for such an analysis by highlighting dynamic-incentive properties of economic instruments in a systemic induced-innovation framework as the ELV issue.

The first conclusion is that, even in the ex ante perspective, dynamic-efficiency effects of economic instruments critically depend on the specific innovation system involved and it may be expected that the greater the inter-industry complexity of the process the greater the uncertainty about the impact.

Car RRR targets (as well as other EU Directive provisions) can be achieved by interrelated innovations to be undertaken by different industries giving rise to different innovation paths. The latter are marked by technological and organisational uncertainty as well as cost-benefit and strategic considerations by industrial actors, and they can even evolve endogenously during the innovation process. In such an induced-innovation framework, uncertain dynamic-efficiency effects can be expected for all economic instruments –in particular free take back and recycling fees, but also landfill taxes, and virgin-material taxes.

Introducing economic instruments corresponds to assume that a cost/price incentive exogenously allocated to a specific stage/actor will be "transmitted" through markets to other stages/actors having a role in innovation and, at the end, the "right" or desired innovation path will prevail. However, economic instruments exogenously modify the cost-benefit balance that actors associate to their own innovation choices and, given the inter-industry nature of innovation paths, the result can be unpredictable. The latter may depend on factors such as the specific industry/activity addressed, its position in the innovation process, its market relationships with other industries in the ELV chain, the technological and organisational capabilities of these industries, and their degrees of freedom and pay-off in contributing to specific innovations and/or innovation paths. Adverse selection might prevail and the innovation path may be different from "markets creation", i.e. closed loop incremental RRR of car materials and parts. This possibility also suggests that ELV Directive, despite its focus on product making, is mainly a waste policy rather than an "integrated product policy".

Furthermore, a mechanism of "incentive dissipation" may occur because of the inability (or unwillingness) by some involved actor to transmit the incentive to other stages. As a consequence, innovation process might stop at some intermediate stage/phase. Individual cost-benefit modifications induced by economic instruments can be such that inter-industry conflicts prevail over the technological and organisational cooperation required by systemic innovation. This risk emerges with both FTB and recycling fees, and it is at the root of the little consideration of virgin material taxes and landfill taxes for ELV. Incentive dissipation would increase the risk that an undesired innovation path will prevail[16].

The main policy implications are three.

Firstly, in a dynamic-efficiency perspective, economic instruments should be "de-linked" from the usual general reference principles, as Polluter Pays Principle or Extended Producer Responsibility, and they should be considered in an effectiveness perspective. The take-off and completion of a preferred innovation path should be the priority in choosing instruments while cost-benefit distribution and equity considerations should be instrumental to put in motion the appropriate sequence of innovative reactions (see Zoboli 2000).

Secondly, the analysis of the specific innovation process involved should come first relative to policy instruments choice. Despite their efficiency properties in theory, some instruments may be ineffective in practice because the "targeted disturbance" they introduce into the system may be "re-elaborated" by the system differently from expected. As a consequence, both instrument choice and instrument details must be based on a deep knowledge of the system addressed.

Thirdly, innovation uncertainties associated to economic instruments in complex inter-industry innovation may suggest that a "target-based" policy approach is preferable. Car RRR targets of EU Directive are able to define the whole profile of innovation by making the latter a targeted one while minimum technical/environmental standards can prevent from a "race to the bottom". Enforceable targets and minimum environmental standards may be sufficient for inducing innovation-oriented industrial actions based on self-organisation of contracts and

[16] On the effectiveness limitations of specific economic instruments even in the case of municipal solid waste see Zoboli (1994).

technical tasks distribution. Although “Coasian” approaches or VAs do not necessarily represent the optimal or fairest approach, in systemic problems as ELV the reciprocal commitments established by VAs can create a cross-industry control mechanism as well as a shared innovation interest. Policy-induced cost-benefit conflicts between industries, which possibly have adverse consequences on innovation, could then be reduced. These advantages should be taken into account vis à vis the emergence of Integrated Product Policy (IPP) as a leading concept of EU environmental policy (see European Commission 2001) and the associated shift from "extended *producer* responsibility" to "extended *product* responsibility"[17].

[17] For an extensive analysis of “product responsibility” principles see Davis et al. (1997).

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Figure 1. Activities on ELV by selected carmakers

Renault SA	• ELV collection, spare-parts recovery, material recycling, energy recovery, car recyclability • R&D efforts on plastic recycling • Dismantlers contracted by Renault in 1997 were 270 • An average reuse/recovery/recycling of 82.9% in the Renault system is calculated
PSA-Peugeot Citroen	• Design of vehicles to be 90%-recyclable from 2002 • Recycling of end-of-life parts and re-use of certain parts • DFR: reduction of the diversity of materials • Increasing use of recycled materials in new cars
Adam Opel AG	• ELV recovery and car design. • Network of 234 dismantlers in 1998 • DFR manuals for internal use • Recyclability coefficients calculated for internal use • Life Cycle Assessment (LCA) for materials and components
BMW	• ELV recovery and car recycling • Network of 90 associated dismantlers • DFR/DFD: "Dismantling parts charts" containing guidelines and recommendations • Recycling coefficients and indexes of "suitability for recycling" of components and parts
Daimler-Chrysler	• DFD/DFR guidelines for internal use • Simplification of material regime by reducing the number of plastics • LCA is made for evaluating material alternatives
Ford Motor Company	• Restrictions on hazardous substances DFR guidelines • Parts marking and material coding standards • Targets for recyclability of new models and use of recycled materials • Network of 170-180 dismantlers in Germany • LCA is used for material and component selection
FIAT	• FARE system on dismantling, the reuse of recycled materials and ASR energy recovery • Network of 312 associated dismantlers in 1998 • Recovery rate is calculated at 82% of car weight • Recyclability coefficients for internal use • LCA applied to materials and components
Volvo Car Corporation	• DFD/DFR together with car recycling and ASR energy recovery • Guidelines on design to be applied to the parts and components of new models • Cooperation on recyclability with component and material suppliers • Network of 70 dismantlers in Sweden

Source: adapted from Zoboli et al. 2000 based on direct interviews and information from companies.

Figure 2. Three main innovation paths

	Material market creation	*Energy market creation*	*Radical substitution*
Aims in terms of policy objectives	Increase RRR rates, especially material recycling and parts reuse Reduce ASR landfilling by preventing its production or by ASR-material recovery	Increase RRR rates, especially energy recovery and parts reuse Reduce ASR landfilling by developing its alternative use ***Can be either substitute for or complement to "material market creation"***	Increase RRR rates, especially recycling. by changing car material mix towards material easily (i.e. economically) recyclable Reduce ASR by reducing the share of materials difficult to recycle ***Can be substitute for both "material" and "energy" market creation" if they prove to be difficult to implement***
Specific innovations involved	ELV collection/dismantling networks Dismantling techniques Selective DFD, DFR, and LCA in carmaking Material-regime simplification in carmaking Innovations in plastic recycling Innovations in recycling of other car materials Innovative outlets for recycled car materials Innovations in material recovery of ASR Cooperative research	Energy recovery technologies for ASR Innovative energy uses in different industries Cooperative research	Change car material mix against (composite) polymeric materials or other materials difficult to recycle at present conditions Adaptations of other aspects of car design and making
Industrial actors most directly involved	Dismantlers Shredders Recyclers Material producers Components producers Carmakers	Shredders Industries using fuel form ASR	Material producers Components producers Some material recyclers Carmakers
ELV actors possibly having positive preference	Policy makers Carmakers Dismantlers Material recyclers Some material producers	Carmakers Plastics producers Shredders	Various non-plastic materials producers and recyclers
Trade-off with other car innovation trajectories	No trade-off with car lightness and energy/emission saving	No trade-off with car lightness and energy/emission saving	Trade-off with car lightness and energy/emission saving

Keys: DFD: design for dismantling; DFR: design for recycling; ASR: automobile shredding residue.
Source: adapted form Zoboli et al. 2000.

Figure 3. Expected direct impact of economic instruments

Economic instrument	*Externality addressed*	*Agents addressed*	*Markets affected*	*Potential impact on innovation*	*Possible side effects (negative)*
Landfill tax	Landfilled ASR	Shredders	ASR market	Technologies for energy/material recovery of ASR Dismantling organisation and techniques	Illegal ASR dumping
Tax on virgin materials Subsidies on recycled material	Landfilled ASR	Material producers and recyclers Car makers	Primary material markets Secondary material markets	Material substitution New uses for recycled materials Increasing rate of RRR	Distortions in primary material markets Subsidised markets for recycled materials
Recycling credit/fee	ELVs abandoned in the environment Pollution in dismantling operations Landfilled ASR	Car buyers and ELV owners Dismantlers Recyclers	ELV market Secondary material markets Spare parts market	DFD and DFR Material substitution and innovation Dismantling organisation and techniques	Subsidised markets for recycled materials Oversupply of recycled materials Cost shift to consumers
Free take-back	ELV abandoned in the environment Pollution in dismantling operations Landfilled ASR	ELV owners Dismantlers Car makers	ELV market Secondary material market Spare parts market	DFD and DFR Material substitution and innovation Dismantling organisation and techniques	Cost shift to consumers
Deposit-refund system	ELV abandoned in the environment	Car buyers and ELV owners Dismantlers	ELV market	Dismantling organisation and techniques	

Keys: DFD: design for dismantling; DFR: design for recycling; ASR: automobile shredding residue
Source: adapted from Mazzanti and Zoboli 1999.

Figure 4. Alternative expected effects of "free FTB" in terms of innovation paths

<table>
<tr><td>Starting impact (by assumption)</td><td colspan="4">FTB-related incentive is transmitted to recycling activities through reduced costs and increased economic quality of materials from incremental dismantling. New recycling markets are incentive-based, and innovations in material recycling and car recyclability are required to have self-sustained markets. Two alternative outcomes are possible:</td></tr>
<tr><td>First-round transmission</td><td>A
Recycling innovations do occur downstream
Selective innovations in DFR and DFD occur upstream to help recycling</td><td colspan="3">B
Innovations in material recycling are not enough to create self-sustained markets for recycled materials. FTB-based incentives become subsidies to dismantling and recycling activities

According to levels of FTB and their technological capabilities, carmakers (i.e. the payer) can:</td></tr>
<tr><td>Other-rounds transmission</td><td>A.1.
Creation of a closed material loop, i.e. increased use of recycled materials in car making and other industries
Carmakers can pay decreasing amounts of FTB due to the value of additional recycled materials
Carmakers can pay decreasing amount of FTB by making only selective adaptations in car design and material mix</td><td>B.1
Preserve the advantages of unchanged material mix and pay high FTB costs.
FTB is likely to be passed to consumers in new-car prices</td><td>B.2
Downstream integration by the car industry may occur to control FTB costs</td><td>B.3
Make radical design/material adaptations in favour of easy-recyclable traditional materials thus reducing FTB costs</td></tr>
<tr><td>Prevailing innovation path</td><td>Innovation may go along "material market creation path"</td><td>Incentive dissipation: innovation chain interrupted at the recycling level
New recycling steadily subsidised by consumers</td><td>Innovation may go along "material market creation path" with a change in the structure of the ELV system</td><td>Innovation may go along the "radical substitution path"</td></tr>
</table>

Source: adapted form Zoboli et al. 2000.