Economic Instruments and Induced Innovation: The Case of End-of-Life Vehicles European Policies

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Summary

The paper addresses the dynamic-incentive effect of environmental policy instruments when innovation is uncertain and occurs in very complex industrial subsystems. The case of end-of-life vehicles (ELVs) is considered focusing predominantly on the effects of the European Directive adopted in 2000 which stipulated economic instruments as free take-back, and on the voluntary agreements in place in many EU countries. The ELV case study is an example of a framework where policy-making faces an intrinsic dynamic and systemic environment. 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”, in accordance with cost-benefit considerations, technological options and capabilities associated to the different industrial actors involved. The impact of economic instruments on innovation paths, in particular free take-back, is considered. Deficiencies or difficulties concerning the transmission of incentives between different industries can prevent the creation of new recycling/recovery/reuse markets, giving rise to other less preferable and unexpected outcomes. The implication for policy is a need for an integrated policy approach, as enforceable VAs, in order to create a shared interindustry interest for innovation and to reduce the possible adverse effects which economic instruments exert on innovation through cost benefit impacts on key industrial and waste-related agents involved in the ELV management system. 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 and the associated shift from "extended *producer* responsibility" to "extended *product* responsibility".

Keywords: ELV, Induced innovation, Dynamic efficiency, Economic instruments, Recycling

JEL Classification: L620, O130, O310, O380

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1. Introduction

Dynamic-incentive effects of environmental policy are attracting an increasing research interest. Innovation is often the main response to environmental policies, and policy instruments may matter for 'induced innovation' effects, but shared conclusions about various theoretical and empirical issues are still lacking. An extensive review of theories and evidence on technological change and the environment, including the role of policy instruments, is presented in Jaffe et al. (2003), who distinguish between analyses of 'induced innovation' and 'evolutionary' approaches. Requate (2005) gives account of the present state of theoretical research on the dynamic incentives of different policy instruments, in particular economic instruments (EIs). Recent contributions address the determinants of 'environmental innovation', including policy instruments, on econometric grounds (for example, Brunnermeier and Cohen, 2003; Jaffe and Palmer, 1997; Mazzanti and Zoboli, 2005). A growing stream of evolutionary-minded applied research projects addresses technological and organisational innovations associated to policy experiences, and in particular the role of institutional settings, observed industrial strategies, and policy-design approaches in influencing innovation (see, among others, Hemmelskamp et al., 2000; Klemmer, 1999; Kemp, 1997; Rennings et al., 2003).

Most of available contributions do not go beyond a 'black-box' representation of dynamic-efficiency mechanisms stimulated by policies and their instruments. The works on 'induced innovation' based on neoclassical production functions and optimising behaviour on R&D investments, have difficulties in dealing with systemic uncertainties and 'on-the-path' adjustments typically characterising agents' behaviour in real innovation processes. Evolutionary approaches able to deal with this kind of systemic uncertainties and adaptations, sometimes have difficulties in dealing with the *ex ante* representation of how agents' cost-benefit considerations can guide innovation responses to policies and their instruments, thus limiting their usefulness to ex post comprehensive, multi-faceted interpretations of what actually happened. Therefore, the way EIs can work in favour or against innovation through agent reactions to EIs themselves is often left without a realistic *ex ante* representation. Furthermore, most part of research on EIs and innovation deals with pollution and climate change policies, also with the aim of modelling 'endogenous technological change', whereas other important policy areas, in particular waste and recycling, are still disregarded.

The aim of this paper is to make a step inside the 'black box' of 'induced innovation' and dynamic efficiency when innovation in response to EIs depends on the decisions of interdependent industrial actors[1]. More specifically, by taking an evolutionary perspective, we address the ways specific EIs reflecting the 'producer responsibility principle' (PRP) in waste and recycling policy can influence innovation when the relationships between various manufacturing industries with different interests about innovation are involved[2].

We analyse a specific case study, the EU policy on End-of-Life Vehicles (ELV hereafter), that can be representative of this class of 'multiple industry – PRP instrument' dynamic efficiency problems. After the controversial policy process leading to the EU Directive 2000/53 and various experiences of voluntary agreements (VAs) during the 1990s, ELV policy is now (beginning 2005) at the stage of Directive transposition in Member States. The ELV case can be a representative one for four reasons: (i) innovation is the *only way* to attain policy targets, and the innovative response should be systemic because, to attain those targets, it must involve interdependent innovations

[1] Here we will use a very general concept of '(policy) induced innovation' that includes any kind of technological and organisational innovations that would not take place without policy and it is, therefore, 'induced' by policy itself. Our use of the concept is not limited to biased technological change in response to a change in relative factor prices caused by a price-based policy instruments.

[2] See Stevens (2004) for a general framework of the relationships between '(extended) producer responsibility principle' and innovation.

generated by different industrial agents; (ii) the superiority of EIs over VAs or *vice versa* has been the source of a many-years debate between industry and policy-makers, but it has never been studied on a sound analytical basis; EIs and VAs were both finally included in the Directive 2000/53 as a 'political' compromise; (iii) the ELV case has been analysed from the perspective of voluntary agreements (Aggeri and Autchel 1997; Aggeri, 1999; EEA 1997) with a minor attention paid to innovation or, conversely, from the perspective of company-level innovation capabilities (Den Hond 1996); EIs, instead, received minor attention while the policy debate has been largely focused on them; (iv) it shares similarities with other EU policies, in particular packaging policies and the EU Directives on electric and electronic waste – WEEE (see European Commission, 2000).

Although the still open state of ELV policy implementation does not allow us to perform a true ex post analysis on EIs and induced innovation, extensive information exists about policy-induced industrial innovation efforts, about industrial actors' views and strategies on the (expected) impacts of EIs, and about some impacts of specific EIs' at a certain implementation stage (generally early stage)[3]. From this mixed ex ante/ex post knowledge base, we shall propose an *enlargement of theoretical hypotheses* and *model-making assumptions* about EIs and dynamic efficiency for a class of policies characterised by: (a) the use of EIs reflecting the 'producer responsibility principle', also in combination with other instruments aiming at the same policy objectives; (b) the involvement of many industries with very different technological profile and capabilities, market position and power, and economic interests towards the investments stimulated by policy; (c) innovation is the only or the critical factor for achieving policy targets.

[3] After a preliminary work on the ELV issue (Zoboli, 1998), the research work presented in Zoboli et al. (2000) was based, *inter alia*, on an extensive set of interviews carried out in 1999-2000, i.e. the most critical phase of the policy debate in Europe. The 43 interviews included: 23 interviews with car makers (10), materials and car-component industries, and managers of ELV agreements in 6 European countries; 9 interviews with European professional associations of material and recycling industries; 11 interviews with officers of the European Commission in 3 different directorates (Enterprise, Environment, and Research). We monitored the development of ELV policies and industrial initiatives for the subsequent years, and we carried out a specific research work on Sweden (Zoboli et al., 2003) based on direct interviews.

The paper is structured as follows. Section 2 introduces the ELV case study focussing on the development of the EU Directive and national policies. Section 3 presents the features of ELV-related innovation, outlining different 'innovation paths'. Section 4 addresses the role of economic instruments in orienting ELV-related innovation. Section 5 concludes and highlights some policy making issues. The Appendix illustrates the basic economics of the free take-back instrument.

2. The ELV problem and policy responses

The exact number of old cars deregistered in EU Member States and becoming ELVs to be treated (dismantling, de-pollution, reuse of parts, wreck shredding, recycling of materials, energy recovery or landfilling of final residues) is surprisingly still uncertain. The estimate given in a draft of the EU Directive proposal in 1997 was of 8-9 million automobiles, but it was questioned given the high number of ELVs deregistered in EU countries and exported to non-EU countries for treatment or re-use as second-hand cars. The number of ELVs to be domestically treated in EU countries was roughly 7,5 million units in 1998 (our estimate, see Zoboli et al. 2000), a figure confirmed by the latest ACEA (Association of Car Manufacturers Europe) surveys, which indicate around 7.7 million units to be treated in EU15 and Norway out of 11.5 million cars de-registered[4].

The economic value of an ELV to final owners may be either positive or negative. When car deregistration and delivery involves a payment to a dismantler, because there are few or none valuable parts to reuse, an incentive to illegally abandon the car in the environment arises. There are no reliable figures on the number of ELVs abandoned in the environment, but it is a recurring phenomenon in some countries (see Lee et al., 1992).

[4] The huge difference between the number of de-registered cars and those treated in Member States is due to shredding without pre-treatment, illegal treatment, abandoned vehicles, and export. A large part of the whole difference for EU15 is due to Germany (3.2 million de-registered and only 1.2 million treated domestically in 2000), Italy (1,8 million de-registered and 915,000 treated domestically), and France (1.8 million de-registered and 1.3 million treated).

The estimates on the rates of ELVs recycling/recovery/reuse (RRR) in the EU are still inaccurate[5]. The overall rate of RRR is generally estimated at 75% of the car weight that corresponds to the metal (ferrous and non-ferrous) share recovered by dismantling (spare parts) and shredding. 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 ELV policies. The presence of substances such 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 as an energy feed-stock.

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

Significant changes in car material regime have occurred during the last few decades and the material composition of new cars produced during the 1990s (i.e. ELVs of the present decade, assuming a life of approximately 10-15 years) further shifted towards the use of polymeric materials and aluminium. Even though they are used extensively in car making (also reducing pollution by decreasing weight), many plastics have significant difficulties in recycling from ELVs. Aluminium, on the other hand, is the main metal used increasingly in car material mix and recycled AL is extensively used car making. These trends for material composition clearly affect the recovery and recycling possibilities which in turn have an impact on the technical and-economic implications of different policy provisions.

ELVs were identified as a priority waste stream by the Commission's "Community Strategy for Waste Management" in 1989. After many-years of problem definition and

[5] The definitions of 'recycling', 'recovery', and 'reuse' are those of the Directive 2000/53.

proposed solutions, the Commission produced an ELV Directive proposal in 1997 (European Commission, 1997). The latter addressed ELV as a waste problem to be faced on the basis of "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 final owners; the future direct regulation of car "recyclability/reusability/recoverability"; and the implicit exclusion of national/industrial voluntary agreements (VAs hereafter).

Industries opposed most of the provisions as they were formulated, in particular: free take-back; the timing of RRR targets 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. The ELV Directive was finally adopted by the Council and the Parliament in September 2000 after a conciliation procedure[6].

Summing up, the main provisions of the Directive 2000/53 are: (a) Collection/dismantling facilities must be authorised, final owners will receive a certificate of destruction, treatment facilities must fulfil specific requirements. Many car components must be removed by dismantlers; (b) the recovery/reuse and recycling/reuse rates of all ELVs will have to respectively achieve 85% and 80% in terms of weight by January 2006; then, the reuse/recovery rate of all ELVs will have to be 95% of the weight while reuse/recycling 85% by January 2015; energy recovery is thus allowed up to 5% of weight by 2006 and up to 10% 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

[6] See Onida (2000) for an analysis of the legal and policy background of the ELV Directive proposal.

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 for dismantling without any cost to the final 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 (voluntary) 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.

During the last few years, other pieces of secondary legislation regarding ELVs have been produced mostly regarding the application of Directive articles, in particular Annex II on materials.[7]

Before the adoption of Directive 2000/53, 10 EU Member States (Austria, Belgium, France, Germany, Italy, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom) had specific regulations and/or VAs for ELV. Three other countries were discussing industrial agreements (Finland and Ireland) or introducing legislation (Denmark). Six countries (Austria, Belgium, Germany, Italy, the Netherlands, and Sweden) combined VAs with sections of specific legislation. Austria, France, Italy, and the Netherlands introduced VAs or countrywide initiatives in the early 1990s before the first draft of the Directive[8]. An extensive description of the national schemes and policies at the time of the Directive's introduction, which are still the basis of the national policy approaches, is presented in Zoboli et al. (2000) while a bi-annual update of the details of ELV policy implementation in EU countries is produced by

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[7] In particular: Commission Decision 2003/138/EC establishing component and material coding standards; Commission Decision 2001/753/EC regarding a questionnaire for Member States reports on the implementation of Directive 2000/53/EC of the European Parliament and of the Council on end-of-life vehicles; Commission Decision 2002/151/EC on minimum requirements for the certificate of destruction issued in accordance with Article 5(3) of Directive 2000/53/EC of the European Parliament and of the Council on end-of-life vehicles; Commission Decision 2002/525/EC amending Annex II of Directive 2000/53/EC of the European Parliament and of the Council on end-of-life vehicles.

[8] For the role of legislation threats in stimulating voluntary agreements, see Segerson and Miceli (1997).

ACEA (www.acea.be)[9]. The main feature of most national voluntary policy schemes is the absence of economic instruments (a partial exception are Germany, Sweden, and the Netherlands, see text): VAs are mainly based on formal and informal contractual arrangements aimed at sharing/distributing tasks according to single industries role in the ELV chain, alleged solution capabilities and, inevitably, market power, with the car industry usually playing the role of coordinator. Free market relationships are emphasised in opposition to top-down regulatory actions associated to EU policies (see also Par. 4.4).

3. The induced innovation process

From a technical point of view, both the compliance with the provisions the Directive 2000/53 and the commitments included in VAs involve an extensive set of technological and organisational adaptations by different industrial actors in the car making (upstream) and ELV treatment chains (downstream, post consumer). The complexity of the industrial interrelationships involved by the ELV issue can be evident in Figure 1.

During the 1990s, the options for innovation became well-defined even in the absence of precise legal obligations and economic instruments in most national schemes (see Zoboli, 1998). After the EU Directive, the level and the legally-binding nature of policy targets on RRR determined the insufficiency of actual and expected results of industrial initiatives and multi-sector VAs. Two key issues emerge: (a) any single specific innovation is unable to achieve RRR targets set by Directive 2000/53; as a consequence interdependent inter-industry innovations (from car design to ASR treatment) must be pursued; (b) the achievement of the RRR targets implies an 'economic-value deficit' in the short run, because there are underdeveloped markets for

[9] To our knowledge, there are not operational proposals for the introduction of EU-type 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 in the EU export market and the evolution of their domestic waste policies.

the additional flow of materials and energy feed-stocks deriving from higher RRR rates. We shall analyse these issues by addressing:

(a) the features of the innovation process in the ELV case;

(b) the dynamic-incentive properties of economic instruments in such a process.

3.1. Specific innovations

Some specific innovations pursued by Europe-based car companies during the last decade are summarised in Figure 2.

The creation of networks of dismantlers/shredders linked to individual car companies has been a major organisational innovation given the previously existing limited relationships between the car industry and post-consumer ELV treatments. However, contractual arrangements between the main actors (carmakers, dismantlers, shredders, and recyclers) differ from country to country.

Innovative developments concerning design for dismantling (DFD) are taking place in all car companies. DFD may consist of small changes in the part-assembling systems or it may imply changes and 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 include lists of not admitted or undesired substances/materials in the technical specifications imposed to component suppliers. Thus, a "responsibility transfer" between industries takes place. DFR is also increasingly linked to Life-Cycle Analysis (LCA). Most carmakers are investing in recycling-oriented LCA at the R&D level and, in some case, they are transferring results to practice. LCA is generally still limited to specific materials or car components[10]. 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 toward the use of certain 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 amount of recycled materials used in new car manufacturing is increasing. Recycled plastics in new cars often come from ELV recycling loops in the form of "cascade recycling" (i.e. the use of recycled plastics in decreasingly critical car components). Economic balances of car plastic recycling are nevertheless weak for many polymers due to high dismantling and logistic costs[11].

The energy recovery of ASR in waste incineration plants and the cement industry have attracted innovative efforts and investments. Positive environmental results of ASR energy recovery emerge from various LCA analyses offered by industry but other studies offered 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.

3.2. Innovation paths

None of above-mentioned innovations has the potential to attain the RRR targets of Directive 2000/53 if taken alone. Innovations with the highest potential contribution (plastic recycling) are the less developed for technical and/or economic reasons.

The innovation process, therefore, must be composed of alternative/complementary sequences of *interrelated innovations,* that should allow the achievement of defined 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 policies.

Three main innovation paths can be identified (Figure 3):

(a) "material-market creation path";

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[10] For the shortcomings of the present state of LCA see in particular Ayres and Ayres (1999).

(b) “energy-market creation path”;

(c) “radical substitution path”.

3.2.1. Material-market creation path

Taking as given the current car material composition, the sustainable achievement of a reduced amount of land-filled ASR is only partly a problem of incremental RRR at the margin for materials that already have a well-developed secondary market (ferrous metals). Instead, it requires market creation for the parts, components and materials currently not recovered, reused and recycled. This can be thought as an upstream-oriented series of necessary (but not sufficient) innovations in the technical viability of recycled metals in existing or new uses, innovative changes in dismantling activities, innovations at the upstream car making stage through developments in DFD/DFR. In the end, the process requires interdependent changes in different industries. Technologies leading to material recovery of ASR can be considered as a form of material markets creation. The material-market creation path can combine relatively high ELV “recyclability” with relatively small and/or well-focused car-design changes. This is the path more desired by EU policy makers that draw Directive 2000/53.

3.2.2. Energy-market creation path

An alternative route of market creation is the development of the energy recovery of ASR. Markets for ASR as an energy feedstock are still very limited and should be created. This path mainly involves new links between shredders and energy consuming industries, or other sectors possibly using waste-derived fuel, that are mostly external to the ELV-related industries. Specific economic and technical constraints may arise, for instance competition with other waste-derived energy feed-stocks. The feedback created along the ELV chain would be less complex compared to the material-market

[11] See Okö Istitut (2003), for a detailed analysis of plastics recycling from ELVs based on LCA and ‘eco-efficiency analysis’.

creation. It does not imply trade-offs with energy-emission requirements in car making because it allows for the continuation of the current trend towards composites and polymer-based light materials. Though EU policy targets allow energy recovery to be a share of incremental RRR rates, the pursuit of an energy recovery path is constrained by the provisions of Directive 2000/53.

3.2.3. Radical substitution path

The difficulties in pursuing "material market creation" and/or "energy market creation" paths, may stimulate more radical adaptations of design and material choice in the upstream part of the ELV system. A radical design choice is one associated to the reduction of car materials *currently* having weak recycling markets. The substitution process should consist of a reduced propensity to introduce complex and advanced materials not technically and/or economically suitable for recycling. 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-related innovation trajectories. It reduces the need for developing "new" recycling markets (some plastics) and can create, instead, a problem of marginally increasing quantities in well-established recycling markets (some metals). It also reduces incentives for innovations in ASR (energy) recovery.

3.3. Selection uncertainties

The "selection" of a dominant innovation path is still marked by uncertainties associated to the following factors:

1. *Technological uncertainty and learning*. Environmental, technological, and economic results associated to each innovation path are still not completely known and various specific innovations composing the three paths are not at advanced stages. The (un)certainty about results, in fact, emerges and evolve during the same process of path selection. The process is clearly an evolutionary one based on cumulative knowledge

and capability-creation through both focused R&D and learning by experience (Den Hond, 1996).

2. *Different national environments for innovation.*. Different carmakers and industrial actors can have different capabilities in pursuing one or more paths, or their combinations, also depending on national (or even local) industrial and innovation 'environments', which are not under their full control. For example, in some countries there is shredding industry highly integrated with steel production that might take a pivotal role in the process; in some countries there are experiences in automotive plastic recycling due to a very active chemical industry; the development of car-parts reuse is favoured in some countries where a well-established secondary markets for car parts already exists.

3. *Expected cost-benefits and preferences of industrial actors*. Industrial actors (carmakers, dismantlers, shredders, component producers, material recyclers, etc.) have heterogeneous preferences for one or more paths, because different paths imply different cost-benefits balances for them[12]. Even though technological uncertainty also makes cost-benefit balances somewhat uncertain and evolving with research/experience, there are clearly diverging and converging interests by different industries about different technological options and innovation paths (see Zoboli et al. 2000). This makes the selection process a very interactive one even without introducing EIs that necessarily impact the cost-benefit balances of the different actors.

4. Economic instruments and the selection of innovation paths

The Directive 2000/53, as well as some national VAs, adopted an '(extended) producer responsibility principle' and introduced forms of EIs. Generally speaking, the EU policy approach to ELV has been not too different from that characterising

[12] It can be noted that no formal cost benefit analysis has been performed by policy makers before the introduction of ELV regulation. The scarcity of formal and transparent cost benefit estimates also applies to industrial stakeholders. The issue of (lacking) ex ante regulation impact analysis for ELV directive and the lack of transparent cost-benefit estimates by industry is discussed in Onida (2000) and Zoboli et al. (2000).

packaging waste, in which the 'producer responsibility principle' has been the cornerstone to achieve higher RRR targets[13].

We will address the possible role of EIs, focussing in particular on the free-take-back (FTB) mechanism introduced by Directive 2000/53, in pushing the ELV system toward the innovation paths we have defined above[14]. We aim at highlighting that the extent to which EIs stimulate (policy-desired) innovation path(s) can be different from what expected, as result of: (a) the systemic features of the inter-industry innovation process and the cost-benefit considerations by single industrial actors; (b) the difficulties in giving the instrument the best configuration in practice in terms of effectiveness[15].

4.1. Policy making and instrument choice

The policy-makers objective is to minimise the three main ELV-related sources of environmental externalities: (a) The dumping of ELVs in the environment; (b) The release of pollutants in ELV treatment operations, and (c) The landfilling of ASR at the final stage of treatment (see Figure 1). The usual reason underlying the introduction of

[13] An extensive discussion of the economics of 'extended producer responsibility' is presented in OECD (2004) and in particular in the work by Walls (2004). The Directives 1994/62 on packaging and packaging waste did not explicitly mention a 'producer responsibility principle' but gave rise, *de facto*, to a major case of PRP application in EU environmental policy. The Directive 2004/12/EC emending the 1994 directive on packaging and packaging waste, instead makes extensive reference to 'producer responsibility', also in terms of 'financial responsibility'. The Commission is currently producing an *ex post* evaluation of the 1994 packaging Directive.

[14] FTB impose car producers to take back free of charge the ELVs of their own make, and its inclusion among economic instruments might be questioned by a rigid reference to standard classifications. Though the price incentive is not clear cut as for Pigovian taxes and market permits, FTB obligations introduce a cost for carmakers that is an incentive to produce more recyclable and recoverable cars, i.e. to produce less externalities in the post consumer treatment/disposal, in order to reduce the burden of FTB itself. Thus, the incentive mechanism of FTB is similar to a tax on externalities when the 'producer of the good' is assumed to be the 'producer of the externalities' associated to the post-consumer stage of the good itself. Furthermore, FTB is applied to each ELV even after policy targets on RRR are attained, which is a common incentive feature of economic instruments, e.g. Pigouvian taxes. The difference with CAC and regulatory standards is clear in any case. See also Par. 4.2 and 4.3 and the Appendix for a more detailed explanation.

[15] As stated in the Introduction, our main aim is to highlight the mechanism by which EIs can influence induced innovation in specific class of policies applied to specific industrial/innovation settings. We are not performing an ex post evaluation of policy instruments cost-efficiency/effectiveness. Therefore, we think we are not incurring in the methodological limitations characterising the impact analysis of a single policy instrument outside its policy package. For a methodological note on *ex post* policy effectiveness evaluation see Mazzanti et al. (2003).

EIs is the expectation that they are more cost-effective for the achievement of objectives (a), (b), (c) as above, in comparison with other instruments. During the ELV policy-making process (1989-2000), neither EU/national regulators nor industrial stakeholders have performed analyses on the possible superiority of EIs over CAC and other instruments. However, there are *reasonable* advantages on the EIs side.

Concerning externality (a), it is *reasonable* to expect that reducing or eliminating the cost of delivery (by FTB or other instruments, see below) will increase the delivery rate to dismantlers. As regards externality (b), the reduction of externalities during ELV dismantling and treatment can be pursued by CAC regulation - and it is so in Directive 2000/53 and all national VAs/regulations. However, by using EIs to cover (part of the) additional costs of environmentally-safe ELV dismantling and treatment, the development of 'clean' and efficient dismantling activities can be promoted, and it is the first stage of the 'market creation path' we depicted[16]. As regards externality (c), in a material balance perspective, a reduced landfilled amount of ASR necessarily corresponds to higher RRR rates and *vice versa*, and a *reasonable* way to achieve it is to push industrial actors towards innovation efforts in the upstream phases *preceding* ASR landfilling. However, the achievement of higher RRR rates implies an 'economic-value deficit' due to missing or very underdeveloped markets for the additional materials. No involved sector/industry will voluntarily support it. Therefore, EIs can be introduced to reveal and allocate the economic-value deficit to *one or more* actors. The addressed industrial actor(s) should be stimulated to undertake innovation efforts that should contribute to achieving RRR targets and, *at the same time*, to absorb the economic value deficit, possibly along the innovation paths depicted above.

4.2. Which economic instrument?

[16]The main business of car dismantlers is the recovery of high-value spare parts for 'reuse'. Used reconditioned spare parts compete, in a very complex way, with new original spare parts (Zoboli et al., 2003).

We assume that the depicted framework (Figure 4) summarises the 'average knowledge' of policy makers concerning the impacts of different EIs. Which are the best economic instruments among those in Figure 4 to achieve objectives (a), (b), (c)? Even in this case, neither EU/national policy makers nor industrial stakeholders produced rigorous economic analyses demonstrating the superiority of the specific EI they have chosen in practice (or the superiority of VAs promoted by industrial stakeholders).

Policy makers necessarily have only a partial knowledge of the full impact (direct and indirect, short term and long term) of specific instruments either because the policy is completely new or because they did not perform a complete ex ante analysis of expected impacts[17]. Furthermore, the same externality can be addressed by different EIs imposed on different actors and markets; and one instrument can address more than one externality due to inter-industry technical/economic relationships. Finally, each instrument is expected to stimulate specific innovations, which are not full innovation paths. Therefore, chains of reactions to the chosen EI should be considered, and the 'average knowledge' could be not complete concerning them, especially for indirect effects.

While *ex ante* there is an over-choice of instruments, the range considered in ELV debate and in practical applications has been restricted to: (1) free take back (FTB), (2) recycling fees, and (3) deposit-refund systems. They share various features and each of the three 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 there may exist a certain degree of substitutability between different instruments targeted to waste-

[17] In the case of ELV, this 'average knowledge' may dynamically evolve in parallel with policy making processes and industrial responses (Den Hond, 1996) but we simply assume it as given at the time of policy design.

related objectives[18]. We think, instead, that instruments have very different features and implications in terms of *cost-benefit distribution between actors* and, *as a consequence*, in terms of induced innovation and our 'innovation paths'.

Free take back (Directive 2000/53/EC). The FTB mechanism implies that the consumer, i.e. the final car owner, can deliver his/her car to a dismantling facility for free. The producer (carmakers) are responsible for the cost of ELV management. Through FTB, dismantlers receive, *de facto*, financial resources from car makers to perform additional dismantling for providing more materials to recyclers in the downstream part of the RRR chain (see the Appendix for more details). Therefore, FTB could be, ex ante, a good candidate as the best EI. In fact, a FTB allocating the costs to the car industry creates: (a) incentives to final car owners to deliver ELV to dismantlers (without payment); (b) financial resources (from carmakers) for dismantlers and possibly other industries in the RRR chains; (c) incentives to improve recyclability, recoverability and reusability (RRR-ability) at the car-design and car-making level in order to reduce the burden of FTB (the easier it is to RRR a car, the lower the cost of FTB). Therefore, it potentially addresses all the three objectives of ELV policy described above. Actually, the key policy concept behind the FTB of ELV Directive proposal of 1997 has been that the costs of higher RRR rates should not be supported by consumers and/or dismantlers/recyclers because the high costs of car RRR are a consequence of car-making choices at the upstream level of the chain, i.e. design and material mix (Onida, 2000).

Recycling fees (the Netherlands). The approach to ELV management and EIs developed in the Netherlands during the 1990s is based on a 'disposal fee' paid by the first owner of a new car registered in the country, coupled with a 'recycling premium'

[18] See Pearce and Brisson (1995) and DETR (1993). A static-oriented neoclassic analysis of waste policies leads to a theoretical equivalence in terms of welfare and innovation effects of different instruments implemented at various levels of the waste production/management chain. The approach can be valuable when dealing with relatively simple systems of agents and innovations, e.g. municipal waste management systems. It can loose explicative power for highly complex issues characterised by a significant diversity of industries, technical complexity of the

paid to dismantlers, transporters and recyclers for the extra-cost they support in increasing RRR rates according to planned targets. The system is managed by a private company, the ARN, acting on the provisions of Dutch legislation. Although this form of recycling fee formally fulfils the requirement of EU Directive 2000/53 that the final owner have not to pay for ELV management, the first car owner will bear the cost, and he/she is generally also the final owner of an ELV in normal sequence of new-old cars rotation. Furthermore, such a scheme does not fulfil the '(extended) producer-responsibility principle' of Directive 2000/53 as car makers do not pay for ELV management. Nevertheless, the Dutch recycling fee addresses all the three main externalities and objectives of an ELV policy, and reflects the idea that, in a country without a nationally-based car industry, the dismantling and recycling activities must be financially supported to be viable. The Dutch scheme has been adapted to Directive 2000/53/EC in terms of targets and their timing (see www.arn.nl) and, recently, it has been recently questioned as possibly implying state aid to dismantlers and recyclers. The Decision 2002/204/EC concluded that there is not state aid[19].

Deposit-refund system (Sweden). The use of a deposit-refund system for cars disposal in Sweden started as early as 1975 according to a specific regulations then amended several times. The producers and importers of new or old cars have to pay a 'recycling fee' on behalf of the potential buyer, when the car enters the Swedish market. The fee is then included in the price of the new car. The amount of the fee is fixed by the Government and it is paid to the Vehicle Disposal Fund. The revenue of the Fund is then used for paying 'scrapping premiums' to the final car owner in conjunction with the deregistration of the vehicle for scrapping. The value of the ELV is determined by negotiations between the final owner and the dismantler. Even though dismantlers ask for money to the final owner in order to dismantle old cars of very low value (thus enjoying, de facto, part of the scrapping premium) they do not receive a scrapping

goods and externalities involved, and where industrial innovation is the key for achieving policy targets.

premium directly from the Fund. Instead, if the dismantler buys the car before deregistration, then he receives the premium as being the final owner. While waiting the EU Directive, after an heated debate between regulators and the Swedish car industry, in 1997 the Ordinance on Producers Responsibility for Vehicles created a recovery system wherein car manufacturers had to organise the car scrapping of their cars and pay for the corresponding costs. This did not eliminate the previous system, however, and 'producer responsibility' coexists with a deposit refund system at the consumer level[20].

The three EI formulations sketched above suggest that the EI is directly applied to some economic actors, but it is expected (by policy makers) to generate spillovers on other actors due to technical or economic (market) links among them, as drawn out in Fig.1, and then to develop an "innovation path". In other words, the EI-based incentive placed at one stage/industry *have to be transmitted* to other parts of the ELV chain to stimulate a set of innovative reactions that contribute to policy objectives, in particular those of type (c), i.e. to increase RRR. However, in systemic innovation settings where industrial actors possess some degrees of freedom for choosing innovative reactions according to their cost-benefit balances, this incentive-effect transmission cannot be taken for granted *ex ante*.

This key issue of the relationship between EIs and innovation can be highlighted by looking at the implications of an EI configuration in terms of induced innovation paths. We shall analyse the implications of a specific FTB configuration.

4.3. FTB and innovation paths

The Appendix illustrates a simplified competitive market for ELVs (supply by final owners and demand by dismantlers) and the comparative statics of the FTB configuration of the 1997 Directive Proposal. The final car-owner is allowed to deliver

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[19] Arguments in favour of different implications of FTB and recycling fee are proposed by Palmer and Walls (1999).

his/her old car to a dismantling facility at zero cost. It means that, if he/she has to pay the dismantler for delivering the car (i.e. the value/price of ELV is negative), he/she can be fully reimbursed by the producer of his/her car. The key point is that, in this form of FTB, dismantlers can freely establish the price for the ELVs they buy from final owners. As shown in the Appendix, it is in the dismantlers interest to pay negative prices for ELVs, while the final owner is fully reimbursed by the carmaker and then it is likely he/she becomes indifferent to ELV prices. The car industry bears the full cost without participating in the transaction.

This is equivalent to a tax on ELV paid by carmakers, of which the revenue is recycled to dismantlers, who establish the tax level. Within this form of "free price - full reimbursement" FTB (FPFR-FTB), the possibility of a transfer to dismantlers in excess of the actual incremental dismantling costs cannot be ruled out, in particular if the existence of a great number of non-professional dismantlers in Europe is considered. In other words, they might enjoy a 'regulation-induced rent'. Furthermore, in as far as the starting situation (before FTB) is one in which average positive ELV prices do prevail in the transactions between final owners and dismantlers, as is the case in various Member States, final-owners (i.e. consumers) may have a net opportunity cost because FPFR-FTB creates pressure on negative ELV prices[21].

In terms of innovation, FPFR-FTB may stimulate the 'material-market creation path', i.e. the path preferred by EU policy makers, *both* if the incentive from the EI would be 'internalised' upstream in car design/making in order to save FTB costs, *and* if dismantlers transmit part of the monetary incentives from FPFR-FTB to downstream recyclers. Therefore, the influence of FPFR-FTB on the policy-desired innovation paths depends on *inter-industry incentive transmission*. Industries, however, are not passive actors. They have the possibility to pursue alternative market actions and innovation options, in order to (re)allocate costs and capture benefits associated to the instrument.

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[20] See Zoboli et al. (2003) for details of the Swedish scheme.

The possible different reactions are shown in Figure 5. In case A, innovation can proceed along the “material market creation path” by creating more recycling/reuse of parts and materials. The new recycling/reuse markets, however, can be self-sustained if innovations on recycling/reuse actually take place. Carmakers can make selected adaptations in design/material mix favourable to recycling. The cost of FTB can be gradually reduced by the innovation process.

A less optimistic possibility is that innovations in recycling are insufficient to create self-sustained markets (case B). Carmakers can then make different choices according to their technological capabilities and the FTB costs they have to support. The first possible choice is to preserve the material mix and the present car design/assembling approaches while accepting high FTB costs (case B.1). Innovation incentives in the ELV system will be low and the main result could be new recycling markets steadily subsidised by consumers through higher new-car prices. The second possible choice is to increase their economic involvement in downstream operations to "control" FTB prices applied by dismantlers (case B.2). In this case, the “power” of the car industry on dismantling/recycling can become structurally significant with FPFR-FTB (why not greater than within VAs ‘dominated’ by the car industry?). The third choice for carmakers (case B.3) may be to make radical design/material adaptations in favour of easily-recycled (traditional) materials thus reducing FTB costs but pushing innovation along the “radical substitution path”.

Essentially, *even in the ex ante perspective*, a FPFR-FTB mechanism may have different outcomes in terms of innovation and innovation paths: (i) innovations in car recyclability and new self-sustained recycling activities (‘material market’ and ‘energy market’ creation); (ii) little innovation impacts on car design together with new recycling markets indirectly subsidised by the consumers; (iii) “backward-oriented”

[21] The final owner actually pays nothing because the car dealer/maker will reimburse for the negative price, but he/she is suffering a loss if a positive price for his/her ELV prevailed *before* FPFR-FTB.

innovations, based on the interruption of trends towards advanced polymer-based materials difficult to recycle.

In at least one case, there is an 'innovation incentive dissipation', because the allocation to the car industry of the economic-value deficit of higher RRR rates does not give rise to the *expected* incentive transmission and innovation path and, instead, only leads to higher car prices[22].

The final version of the Directive 2000/53 seems to take into account the possible shortcoming of a FPFR-FTB by establishing a sort of 'cost-sharing FTB', which paves the way to contractual agreements between dismantlers and car makers not yet fully clear in terms of induced 'innovation paths'[23].

4.4 EIs performance with voluntary agreements

EIs and VAs have long been debated as *alternative* approaches to ELV policy, the former being supported by policy makers and the latter by carmakers. The two approaches should be considered *jointly* after the Art. 10(3) of the ELV Directive 2000/53, which allows for Art. 5(4) on FTB -or 'equivalent measures'- to be implemented by Member States within national *enforceable* agreements[24]. How can the incentive effects of EIs change? VAs including forms of FTB, as the German and the

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[22] Other transaction costs possibly associated to a FTB instrument are suggested by Palmer and Walls (1999).

[23] Art 5(4) states: "Member States shall take the necessary measures to ensure that the delivery of the vehicle to an authorised treatment facility in accordance with paragraph 3 occurs without any cost for the final holder and/or owner as a result of the vehicle's having no or a negative market value. *Member States shall take the necessary measures to ensure that producers meet all, or a significant part of, the costs of the implementation of this measure and/or take back end-of life vehicles under the same conditions as referred to in the first subparagraph*. (…)." (our Italics)

[24] Art. 10(3) states: "Provided that the objectives set out in this Directive are achieved, Member States may transpose the provisions set out in Articles 4(1), 5(1), 7(1), 8(1), 8(3) and 9(2) and *specify the detailed rules of implementation of Article 5(4)* by means of agreements between the competent authorities and the economic sectors concerned. Such agreements shall meet the following requirements: (a) agreements shall be enforceable; (b) agreements need to specify objectives with the corresponding deadlines; (c) agreements shall be published in the national official journal or an official document equally accessible to the public and transmitted to the Commission; (d) the results achieved under an agreement shall be monitored regularly, reported to the competent authorities and to the Commission and made available to the public under the conditions set out in the agreement; (e) the competent authorities shall make provisions to examine the progress reached under an agreement; (f) *in case of non-compliance with an*

Swedish schemes, are too recent to supply sound evidence, but the features of VAs can suggest some possible implications for innovation.

The incentive structure of VAs is not standardised because it derives from tailored contractual agreements. In most VAs, cost-benefit distribution is, in fact, *implicitly* defined by the distribution of industrial tasks and, because of the uncertainties still associated to some innovations, they are not fully accountable even by industrial actors themselves. In principle, given the features of the ELV problem, VAs can be good for innovation if they are shaped to reflect interdependency between innovations inside an innovation path, in particular a 'material market creation' path, and the contractual agreements reduce the probability that one industry enjoys extra-profits or free-rides at the expenses of other actors. In practice, these positive properties are not yet demonstrated for all VAs and observed regularities are weak (see Zoboli et al., 2000).

According to the formulation of Art 10(3) of Directive 200/53/EC, VAs can be a way 'producer responsibility', or the FTB of Art 5(4), is implemented. At the same time, the introduction of FTB-like instruments by direct regulation is threatened in the case VA's do not comply with Directive's objectives. The two provisions *together* can give rise to balanced effects in terms of cost distribution and innovation. On the one hand, the burden of a FTB inside a VA can be lower for the car industry than the FTB would be imposed by direct regulation (as in our analysis of Par 4). The car industry, therefore, seems to be worse-off in those countries without VAs, where Art. 5.4 must be implemented by direct regulation. On the other hand, to avoid EIs be introduced directly by policy makers, the VA must be effective in terms of targets and objectives achievement. This can prevent a too much unequal cost distribution inside a VA, possibly reflecting industrial and market power, because unequal distribution can impair cooperative actions aimed at targets achievement. Therefore, the car industry cannot avoid the responsibility of a significant part of the burden in order to escape a

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agreement Member States must implement the relevant provisions of this Directive by legislative, regulatory or administrative measures." (our Italics).

FTB introduced by direct regulation. All in all, the combination between VAs and Eis, which has been a 'political compromise' in Directive 2000/53, seems to be favourable to effectiveness and innovation on technical grounds because it reduces the possibility policy-induced unsatisfactory cost distributions push actors to deviate from cooperation.

5. Conclusion

The case of end-of-life vehicles (ELVs) can be representative of a class of policy issues in which the dynamic-incentive effect of EIs takes place in very complex industrial systems. To achieve policy objectives and targets, interrelated sequences of single innovations in both upstream (car making) and downstream (car recycling/recovery) of the ELV system, which give rise to different 'innovation paths', should take place. Our main aim was to explore how the introduction of EIs can influence the behaviour of industrial actors towards different 'innovation paths'. This is equivalent to explore if the chosen EI and/or its practical configuration can be considered as being neutral with respect to dynamic-efficiency. The possible impact of a free take-back (FTB) instrument on innovation paths has been considered.

Our main conclusion is that, when EIs are introduced inside complex and systemic industrial settings, their dynamic efficiency can critically depend, even *ex ante*, on which *specific industry/activity* the EI is directly applied, on its *position* in the innovation process, on its *market power and* its *relationships* with other industries, on the technological and organisational *capabilities* of these industries. In other words, different innovation paths, including paths not preferred by policy makers, may emerge from the matching of actors' innovation role and actors' (expected) share of the policy-induced cost/benefit impact. Differently from static neoclassical approaches, where the cost/benefit impact of the EI and its formulation is neutral with respect to policy effectiveness, the effects of EIs in systemic and dynamic settings critically depend on *where*, along the 'production chain', and *how*, in terms of net cost allocation, the incentive is introduced. Consequently, it is also relevant the extent to which the incentive allocated to a certain industry is transmitted to other industries thus generating second-order effects downward or upward along the chain, i.e. whether a cooperative or a conflicting behaviour towards innovation is stimulated. Disregarding these effects can imply a 'dissipation' of innovation incentives, and possibly the generation of 'regulation-induced rents' for some actors.

Some policy implications may be sketched. Firstly, dynamic-efficiency effects of EIs must be the core of policy concerns when objective achievement depends on innovation. EIs choice should be 'de-linked' from standard general principles, as Polluter Pays Principle or Producer Responsibility Principle, and it should be considered in an effectiveness perspective. The take-off and completion of a preferred 'innovation path' should be the priority in choosing and configuring instruments while cost-benefit distribution and equity considerations should be *instrumental* to put in motion the appropriate sequence of innovative reactions by the economic actors.

Secondly, despite their ex ante efficiency-related properties, some EIs may be ineffective when implemented because the 'targeted disturbance' they introduce into the system is re-elaborated in unexpected ways by actors' behaviours, including 'innovation-incentive dissipation', 'regulation-induced rents', and cost transfer to final consumers through prices. Then, the analysis of the innovation process involved, of the elements of market power, and of economic-value flows inside the system should come *before* the choice of policy instruments.

Thirdly, PRP policies that involve many industries in interrelated innovation processes should consider EIs in conjunction with 'enforceable' inter-industrial agreements. This is the final choice of Directive 2000/53/EC on ELVs. Although VAs do not necessarily represent the most efficient/equitable approach, in high-interdependency settings the reciprocal commitments established by VAs can create a cross-industrial control mechanism as well as a shared interest towards effective innovations. Policy-induced cost-benefit conflicts between industries, which may be stimulated by certain EIs formulations or direct-regulation, could then be reduced by using EIs as a threat in properly designed VAs.

These conclusions might be relevant vis à vis other policies addressing ‘multiple industry – PRP’ problems, as the implementation of the 2004 Directive on packaging waste, the directives on waste of electric and electronics equipments (WEEE), and the on-going development of Integrated Product Policy (IPP), which shifts the policy perspective from “extended *producer* responsibility” to “extended *product* responsibility”.

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APPENDIX: The market for ELVs and the comparative static of FTB

Figure A.1 and A.2 illustrate, in a simplified way, the comparative statics of free take-back (FTB) in the market for ELVs. We assume that (i) ELVs arising at a specific time are homogenous in terms of “age” and technical features, (ii) there is just one (national) competitive market, and (iii) one equilibrium price for ELVs, at which all transactions take place exists [26]. The number of ELVs

[26] The scheme may nevertheless approximate a market for one specific category of ELVs of the

delivered to dismantlers by final-owners is represented on the horizontal axis. The negative part of the cost/price vertical axis is placed upside in figures.

Figure A.1 describes a market with a negative equilibrium price *before* FTB (e.g. the German market). The supply curve for ELVs by final owners (So) is downward sloping for negative prices (i.e. the propensity to deliver ELVs increases for decreasingly negative prices) and become vertical for zero to positive prices at the maximum number of cars becoming ELVs at that time (i.e. final-owners will be ready to deliver all their ELVs for non-negative prices). The cars not delivered are illegally abandoned into the environment, thus accepting the risk of fines and legal costs against the cost of car delivery. The demand curve for ELVs by dismantlers (Do) is upward sloping, starting from a positive price. The dismantling industry has marginal increasing costs in terms of number of treated cars. Dismantlers are willing to pay a positive price for ELVs for a relatively low number of ELVs, but, in order to treat an increasing number of ELVs, they are willing to pay lower and lower positive prices, until they are wiling to pay negative prices for large quantities[27]. The equilibrium price (-po) is initially negative (by assumption) and the quantity of ELVs treated (qo) is less than the maximum available number (i.e. some ELVs will not be delivered and then illegally dumped into the environment).

We assume that FTB reflecting 'producer responsibility' consists of a full reimbursement from a carmaker to final owners for negative prices the latter receive for an ELV of the carmaker's brand. It is introduced together with the obligation for dismantlers to attain higher dismantling rates in terms of car weight (i.e. incremental costs per each car treated) in order to arrive at higher RRR rates. Let us assume for simplicity that incremental dismantling costs are net costs, i.e. additional dismantled parts/materials have not a market value. As in the FTB included in EU Directive proposal of 1997, dismantlers are free to establish demand prices for ELVs. The FTB scheme is a "free price – full reimbursement" one (FPFR-FTB). With FPFR-FTB, both supply and demand curves shift. The possibility of full reimbursement for the costs of ELV delivered induce final-owners to deliver all their ELVs and the supply curve will shift rightward to become SFTB (i.e. vertical at the maximum number qFTB, completely inelastic to paid or received prices). Given demand prices for ELVs are freely established, the change of the demand curve of dismantlers cannot be defined ex ante. The increasing costs of incremental dismantling would surely shift the demand curve upward in order to cover the incremental costs, and the willingness to pay positive prices decreases. FTB affects the price at which ELVs are accepted by dismantlers: this price is likely to become increasingly negative.

Figure A.1. FTB introduction with initial negative equilibrium price for ELVs

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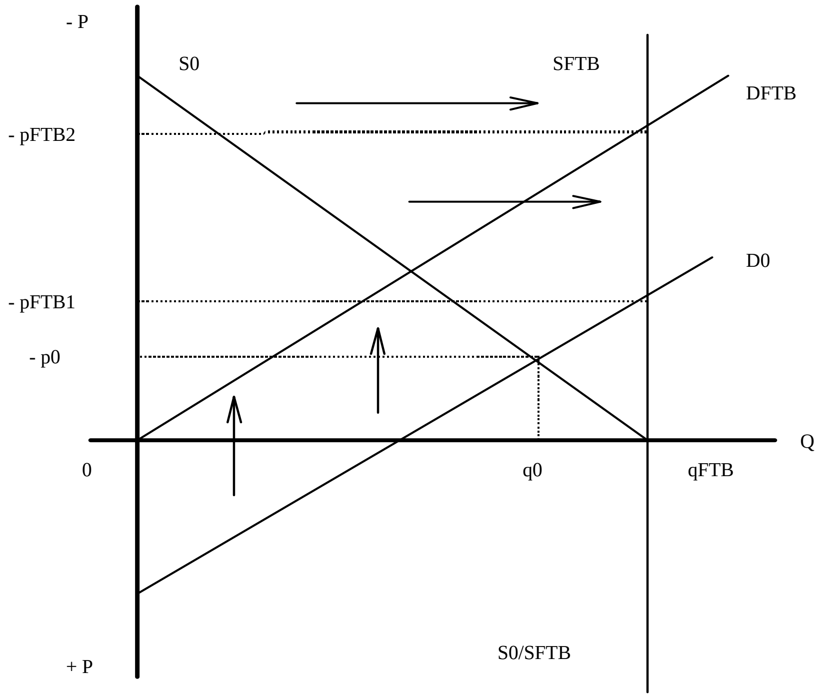
same age where competition between dismantlers pushes towards one single equilibrium price.

[27] A slightly more realistic interpretation is that the curve represents the demand by a very large number of very small dismantlers with different efficiency in treating the same cars. The more efficient dismantlers have low treatment costs and are ready to pay positive prices whereas marginally arising quantities of ELVs will be treated by less efficient dismantlers with higher operating costs, the latter being ready to buy ELVs at negative prices only (i.e. they receive ELVs *and* money from final owners). Transactions take place at the equilibrium price.

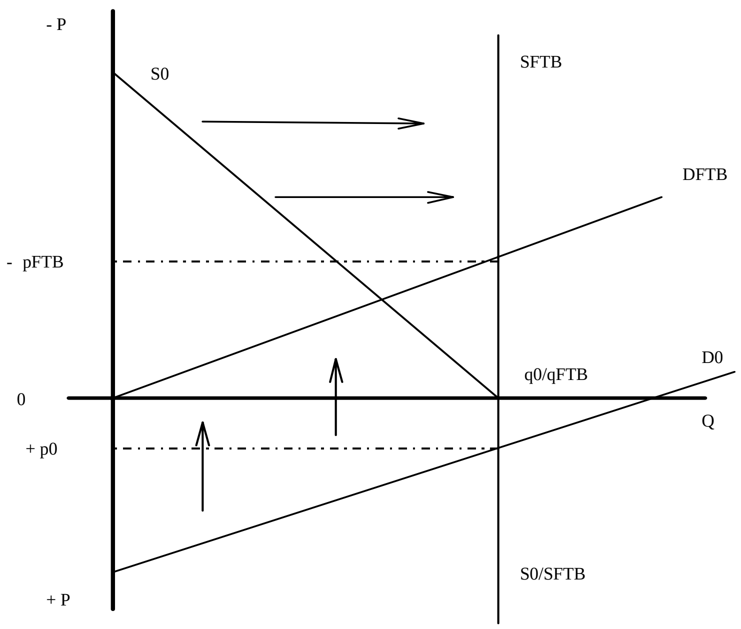


It is likely that the demand curve starts at zero prices because, with the introduction of FTB, no dismantler is ready to pay a positive price for ELV. The demand increases as a consequence (in the negative price space) for increasingly negative prices (DFTB). Provided that final owners are reimbursed for whatever price they have to pay to dismantlers, and that carmakers do not participate in the transaction, there are not boundaries to the upward shift of the demand curve. The exact position and slope of the demand curve is therefore not defined ex ante regardless the component related to actual incremental costs of dismantling. The equilibrium price might be -pFTB2, while the equilibrium quantity is qFTB (the maximum number of ELVs available at that time).

In terms of cost-benefit balances, FTB improves the environmental performance because it is reasonable that no car will be abandoned and an increasing amount of materials/parts will be dismantled (and hopefully recovered/reused/recycled). The dismantlers see all their incremental costs covered by payments they receive from final-owners (area -pFTB2 x qFTB), thus the possibility that they can enjoy extra-profits by establishing high negative prices cannot be ruled out. They might actually enjoy a ‘regulation-induced rent’ corresponding to the part of the producer surplus exceeding total incremental costs and a normal profit on them. Final owners are better off compared with the non-FTB situation (when they paid area po x qo) because they are fully reimbursed and do not pay whatever negative price established by dismantlers. Carmakers support all incremental costs and possible free lunches (if any) through transfers to dismantlers (area -pFTB2 x qFTB).

Figure A.2 illustrates the same mechanism for initial market equilibrium at positive prices for ELVs before FTB is introduced (e.g. the French market). Two main differences arise compared with the previous situation: (a) The demand curve for dismantlers is flatter because we assumed they are willing to pay higher prices for ELVs (i.e. positive prices even for large quantities); (b) The equilibrium quantity treated is presumably at the maximum level qo/qFTB even in the initial situation (i.e. ELVs are not abandoned given a positive equilibrium price).

Figure A.2. FTB introduction with initial positive equilibrium price for ELVs



FPFR-FTB works as above, but cost-benefit implications are different. The environment gains only as a consequence of an incremental dismantling of each ELV (and reuse/recovery/recycling), since all ELVs were already delivered before FPFR-FTB. The transfer to dismantlers will be paid by both final-owners and carmakers. If, as depicted above, with FPFR-FTB and increasing dismantling costs, the dismantlers are not willing to pay positive prices to car final-owners; then final-owners face an opportunity cost (corresponding to the area +po x qFTB) which is essentially a transfer to dismantlers. Carmakers pay a transfer to dismantlers corresponding to the equilibrium negative price -pFTB applied to the number of cars accepted for dismantling (qFTB).

To simplify the analysis, we have not considered that higher dismantling rates of each car may give rise also to direct benefits for dismantlers (together with higher costs) if they are able to sell additional dismantled components and materials at positive prices. Although it does not change the mechanism depicted for FTB, this enlarges the uncertainty on its cost-benefit implications. In a first scenario, FPFR-FTB covers all the incremental costs of dismantling and, then, dismantled materials/parts are offered at “zero prices” to the downstream recycling industries. Another scenario is that FPFR-FTB does not cover all incremental dismantling costs, and the ‘normal’ loss to dismantlers is only reduced. Another possibility is that, although FPFR-FTB covers all the incremental costs, dismantlers are able to extract positive prices for dismantled materials/parts. With a complete freedom of establishing FPFR-FTB levels, all possibilities emerge; as a consequence the implications for the development of recycling chains along the “material market creation” path are highly uncertain.

Figure 1. A sketch of the ELV system

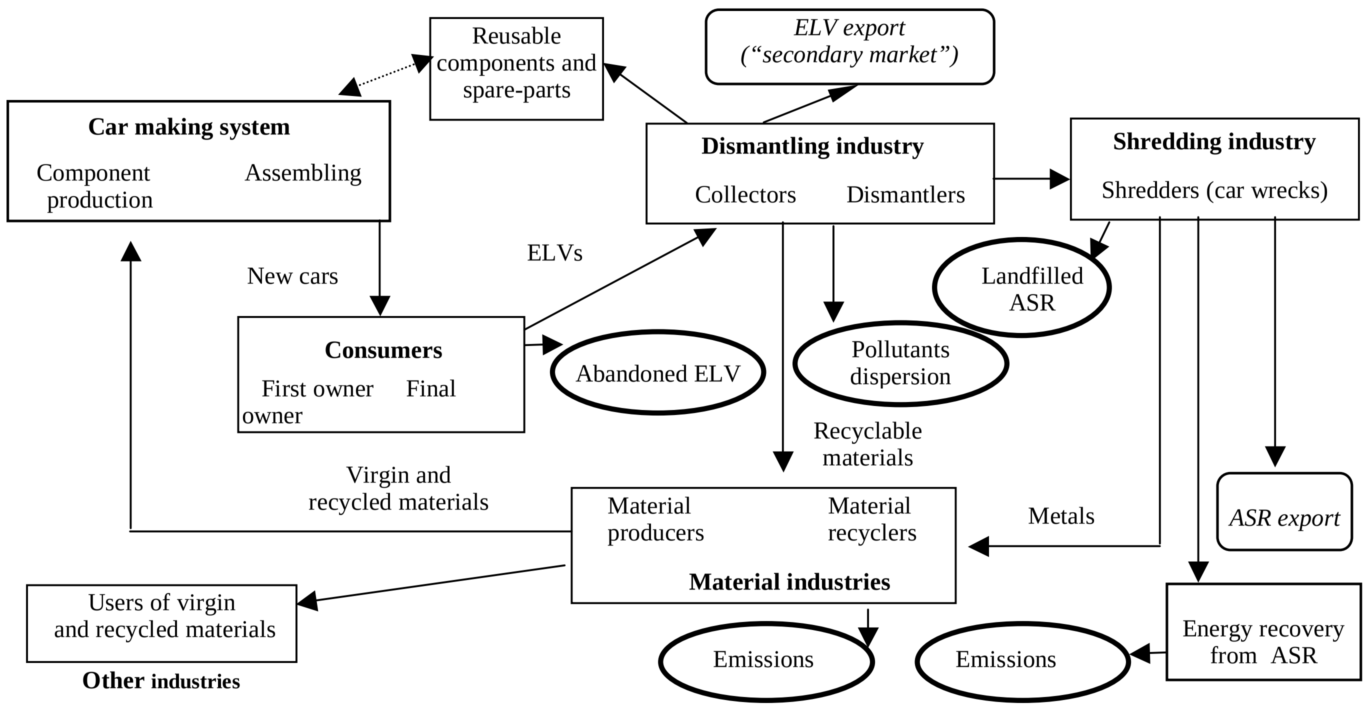


Figure 2. Examples of innovative activities on ELV by selected European carmakers

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), direct interviews and information from companies.

Figure 3. Innovation paths

	Material market creation	*Energy market creation*	*Radical substitution*
Implications 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.

Figure 4. Expected 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	(less) Landfilled ASR through increased recycling	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 (less) Landfilled ASR through increased recycling	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 (less) Landfilled ASR through increased recycling	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

Figure 5. Alternative expected effects of "FPFR-FTB" in terms of innovation paths

Starting impact (by assumption)	Carmakers pay for FTB and dismantlers receive the corresponding flow of economic resources through last car-owners. 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 necessary to have self-sustained markets. Two alternative outcomes are possible:			
First-round transmission	A Recycling innovations do occur downstream Selective innovations in DFR and DFD occur upstream to help recycling	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:		
Other-rounds transmission	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	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	B.2 Downstream integration by the car industry may occur to control FTB costs	B.3 Make radical design/material adaptations in favour of easily-recycled traditional materials thus reducing FTB costs
Prevailing innovation path	Innovation may go along "material market creation path"	Incentive dissipation: innovation chain interrupted at the recycling level New recycling steadily subsidised by consumers	Innovation may go along "material market creation path" with a change in the structure of the ELV system	Innovation may go along the "radical substitution path"

Source: elaboration from Zoboli et al., 2000.

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