The International Journal of Life Cycle Assessment (2018) 23:2217–2247
https://doi.org/10.1007/s11367-018-1439-7

POLICIES AND SUPPORT IN RELATION TO LCA

From value-added tax to a damage and value-added tax partially based on life cycle assessment: principles and feasibility

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Received: 25 January 2017 / Accepted: 5 January 2018 / Published online: 25 January 2018

Abstract

Purpose The purpose of this article is to examine the arguments in favor of a shift from value-added tax (VAT) or sales tax to a *damage and value-added tax* (DaVAT) partially based on the life cycle assessment (LCA) of goods and services. With this shift, goods and services that seriously harm the environment and human health will be priced up, those that impact them less will be priced down. The paper recalls the proposal made by De Camillis and Goralczyk (Int J Life Cycle Assess 18:263–272, 2013) to differentiate the VAT rate associated with products according to their environmental impacts over their life cycle. The paper suggests a new way to convert VAT into DaVAT, examines the operating principles of such a system, and considers its practical feasibility. The new policy tool based on LCA presented is intended to be applied to every country wishing to reform its consumption tax system in order to strive for a more sustainable future. Some aspects specific to countries having the same currency, notably the Euro zone, are also discussed.

Methods The proposal of De Camillis and Goralczyk is discussed from the perspective of both environmental performance and compliance with LCA standards. To overcome the identified difficulties, a new way of adapting VAT (or consumption taxes in general) according to LCA is suggested. The proposal relies on three essential points: (i) apply VAT (or consumption taxes in general) to *all* goods and services and reduce its multiple rates to one single low rate (e.g., 3%) called *uniform VAT* (UVAT); (ii) add to UVAT a per-unit tax called *global damage tax* (GDT) calculated on the basis of environmental impacts assessed by means of specific or generic LCAs. In the case of potentially high-polluting products or industries, a specific LCA will be automatically imposed. The obligation to assess high-polluting activities already exists in many countries with, e.g., environmental impact studies, but the impacts are not necessarily evaluated by LCA; (iii) in order to reflect environmental, social, or ethical concerns specific to a country, another damage tax termed *specific damage tax* (SDT) is proposed that extends beyond LCA. DaVAT is the sum of UVAT, GDT, and SDT. DaVAT is conceived not as an additional burden but rather as a shift of taxation, as the rate of the old consumption taxes can decrease proportionally to the increase of GDT. DaVAT is also designed in such a way that the erosion of tax revenues, when pollutant would decline, is offset by the extension of the tax to all goods and services and by the possibility to gradually re-increase the UVAT rate when the number of highly polluting products decreases.

Results and discussion The proposal is examined first from a theoretical point of view by considering which principles should be used to comply with LCA standards and general requirements of (environmental) tax policies. Four general principles emerge: *consistency* in the choice of the functional unit and in the characterization, normalization and weighting methods, *transparency* of information about the environmental score of the product, *evolution capacity* of the levers of the tax and of the assessment methods, *respect for national sovereignty* concerning the setting of the tax price. The proposal is also examined from a practical point of view by asking how the DaVAT system would work in practice. The answer takes into account *associated costs*, *risks of fraud*, *price changes*, and *acceptability* of the proposal. The issue about price changes is addressed on the basis of a simulation drawn from six published LCA studies on different products.

Conclusions The proposal to replace most of the VAT or sales tax with a unitary global damage tax based on LCA of goods and services seems to meet expectations not only in terms of

Responsible editor: Alessandra Zamagni

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s11367-018-1439-7) contains supplementary material, which is available to authorized users.

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theoretical consistency and practical feasibility but also from the perspective of income tax consolidation, environmental efficiency, and sustainable growth. The study concludes by pointing out the limits of an LCA-based tax and by suggesting a framework for a closer examination of the DaVAT system in order to verify that it would provide the intended incentives and to explore the modalities of its implementation.

Keywords Damage and value-added tax · Environmental taxation · Green consumption tax · Green VAT · LCA as a policy tool · LCA-based tax · Sustainable growth

1 Introduction

It is needless to say that environmental problems increasingly threaten our societies. IPCC warns in its last report that limiting warming to 2 °C above pre-industrial levels is "inconsistent with both long- and short-term trends," "from the way that we produce and consume energy to how we use the land surface" (IPCC 2014, 418). Climate change is not the only danger. The current extinction rates of species, likely still underestimated, are about 1000 times the natural background rate of extinction and expected to increase in the future (Pimm et al. 2014). The additional amounts of nitrogen and phosphorus activated by modern agriculture already erode the resilience of important earth subsystems (Galloway et al. 2008). Ocean acidification, changes in land use, global freshwater use, stratospheric ozone depletion, chemical pollution, and atmospheric aerosol loading could also have disastrous consequences if some biophysical thresholds were crossed (Steffen et al. 2015). Steffen et al. (2015, 7–8) emphasize the "severe implementation gaps in many global environmental policies relating to planetary boundaries issues" and "the need to address multiple interacting environmental processes simultaneously." In the fight against these problems, the *polluter-pays principle* plays a key role for already a long time (OECD 1972; European Union law 1992). According to this principle, the polluters should pay the costs associated with the environmental damages they create. However, the implementation of such a principle (for instance in the form of gas guzzler tax, road haulage charges, fuel excise duties, prepaid waste bags) encounters difficulties from an environmental, legal, and socio-economic point of view.

From the environmental perspective, it is difficult to find coherent and comprehensive criteria to measure different kinds of pollution and damage. As a result, taxes are often limited to specific products[1] or qualities of existing products or to one aspect of environmental issues, which favors windfall effects, emission leakages, or displacement of pollution in time and space (Fullerton 1996; Fowlie 2009; Fullerton et al. 2010; Bosco and Altomonte 2013). This problem concerns not only environmental taxes but many other environmental measures. The phenomenon is well known with regard to carbon leakage (Kuik and Hofkes 2010; Monjon and Quirion 2011). It also affects many other releases and impact categories, as the life cycle assessment experts are well aware of.

From the legal point of view, the polluter-pays principle requires to charge the actors responsible for pollution proportionally to the damage they cause (OECD 1972). Some presentations of the principle also recommend to allocate the revenue of the charge "preferably" to environmental measures and policies rather than to general State budget (Council of the European Communities 1975, 4.b). This can cause some problems. Firstly, because pollution is often a multifactorial phenomenon to which several actors can contribute. Secondly, because the costs of the damages are not always easy to determine. Thirdly, because "allocating charge revenues to a dedicated fund does not conform to the principle of universality, according to which tax revenues should not be used for specific expenditure" (De Sadeleer 2014, 61). To overcome these limitations, a broader framework allowing to "use revenues to finance reductions in incentive-distorting taxes such as income tax or corporation tax" (Pearce 1991, 940) has been developed under the name of *Ecological (Budget and) Tax Reform* (Von Weizsäcker et al. 1992; European Environment Agency 2000; Milne and Andersen 2012; UNEP 2015). In this framework, the environmental tax measures simply need to comply with the *proportionality* and *non-discrimination* principles. The principle of proportionality requires that each taxation measure pursues a legitimate aim (e.g., preventing harm to the environment) and uses adequate means to achieve this aim. Typically, a tax that does not prevent harm to the environment while pursuing that aim will be deemed disproportionate. The principle of non-discrimination implies that a system of differentiated taxation must be based on objective criteria, similar for all products concerned. Typically, a tax is discriminatory if it protects products not concerned by the legitimate aim of the tax (Davey 2012; De Sadeleer 2014; Rolim 2014).

From the socio-economic perspective, environmental taxes may also raise difficulties because of compliance and administration costs (Pavel and Vitek 2012), risks of eroding the taxation base (Kosonen 2010), and slump in economic growth (Barker and Köhler 1998). Other challenges include difficulty in "identifying the appropriate rate to levy" the tax (Mankiw and Taylor 2014, 249), distortions of competition (Vogelaar 1994; Bovenberg and Goulder 1996), and the apparent

[1] In this article we use the term *product* in the sense defined by ISO 14040 and ISO 14044 (2006, 3.9), i.e. as "*any goods or service*".

regressivity of the tax (Ekins and Dresner 2004; Fullerton et al. 2010; Kosonen 2012).

These difficulties naturally emerge in one way or another when a concrete proposal is put forward. For instance, in 2008, the European Commission was asked to examine the possibility of introducing differential VAT rates to promote "green products" (Oosterhuis et al. 2008, 27). This possibility was not selected for the following reasons: no consistency in the definition of the "green" criterion and of the limits of the system; risk of rebound effect; risk of public loss of revenue; products evolution; risk of distortions between States; risk of non-integration of the tax in the prices; insufficiency to change behaviors (elasticity) (Naess-Schmidt et al. 2008; Oosterhuis et al. 2008; Oosterhuis and Schaafsma 2010). We will return in our conclusion to the issues raised with regard to this concrete proposal.

The original contribution of this paper is to present a new environmental taxation scheme likely to overcome the environmental, legal, and socio-economic difficulties mentioned above and outlined below. Our leading hypothesis is that a life cycle-oriented tax properly configured is able to reduce the leakage and displacements of pollution, comply with the general taxation principles of proportionality and non-discrimination, prevent erosion of the taxation base, protect competitiveness, and meet the requirements of equity and social justice. De Camillis and Goralczyk (2013) proposed to adapt the value-added tax (VAT) rates on goods and services on the basis of their life cycle assessment (LCA). At a time when environmental problems increasingly threaten the future of our societies and when very few countries have successfully implemented a coherent and efficient system of environmental taxes, we think that the framework designed by De Camillis and Goralczyk goes into the right direction. Building upon this framework (Sect. 2), we discuss the possibility and the way how to adapt the consumption tax system by shifting to a new *damage and value-added tax* (DaVAT) partially based on the LCA of the goods and services (Sect. 3). The proposal is discussed both from a theoretical and practical point of view. From the theoretical perspective (Sect. 4), the question raised is how LCA can be used coherently in the framework of a consumption tax. On what principles should an LCA-based tax be founded? In particular, how can the variance of the LCA results be reduced in this context? From the practical perspective, how will the DaVAT system work in practice (Sect. 5)? What will be its implementation, maintenance, administration, and compliance costs? What about the risks of fraud associated with it? What price changes can it bring (Sect. 6)? Is it socially acceptable (Sect. 7)?

Let us start by (i) briefly recalling what LCA, VAT, and sales tax consist in; (ii) defining what we mean by *damage* in the expression *damage and value-added tax* (DaVAT); (iii) exploring the works on this topic.

LCA is a method assessing potential environmental impacts along all stages of the life cycle of, e.g., a good or service (extraction of resources, manufacturing, distribution, use, and disposal). Impacts are assessed on three areas of protection: ecosystem diversity, human health, and natural resources. These impacts may include climate change, stratospheric ozone depletion, human toxicity, ecotoxicity, ionizing radiation, photo-oxidant formation, acidification, eutrophication, land use, and fossil energy demand. The results of an LCA can be aggregated and weighted to obtain a single environmental score (not necessarily expressed in monetary terms) characterizing the all-quantified impacts of a specific good or service. De Camillis and Goralczyk (2013) have proposed to use this single score to raise or lower the VAT rates.

Value-added tax (VAT) and sales tax are the two main forms of consumption tax. Sales tax is only collected at one stage of the supply chain, i.e., at the final sale to the consumer. VAT is collected at successive stages of production and distribution, each time a product (or material) is sold. However, the burden of VAT does not rest on businesses, as producers, intermediaries, and retailers deduct the VAT they collect on their sales from the VAT they pay on their purchases. The mechanism of this deduction may vary (effective refunds or accounting transactions), but the basic principle is always the same—namely that VAT is ultimately paid by the end-consumer only. Figure 1 shows how VAT works in general. The procedure described in Fig. 1 is a simplified example of non-distortionary tax, i.e., with no imbalance between supply and demand. There can be more market participants than the four ones depicted in Fig. 1. For ease of reading, sales taxes are mentioned in this article only when the VAT and the sales tax regimes are treated differently in the DaVAT system. Apart from these cases, what is said about VAT applies to consumption taxes in general.

The term *damage* is used in this paper in a much broader sense than the way it is usually understood in LCA, or in law, or in economy. In LCA, the *damage approach* refers to the definition of endpoint category indicators, i.e., indicators close to areas of protection such as human health, ecosystem quality, and natural resources (Guinée et al. 2002, 110). In law, a distinction is commonly made between, on one hand, damage to persons and goods and, on the other hand, environmental damage, which concerns only the natural elements (Kurukulasuriya and Robinson 2006, 52). In economics, there is no universally accepted method of monetary valuation of environmental damages (Ierland et al. 2001; Kumar and Thiaw 2013). In this article, the term *damage* means not only a physical harm impairing a person or a thing but refers to any loss of something desirable whatever the setting, whether individual, social, economic, or otherwise.[2] This suggests that the damage associated with production and consumption may

[2] Collins English Dictionary. Complete and Unabridged. HarperCollins Publishers, 2003. Collins Thesaurus of the English Language. Complete and Unabridged 2nd Edition. HarperCollins Publishers, 2002.

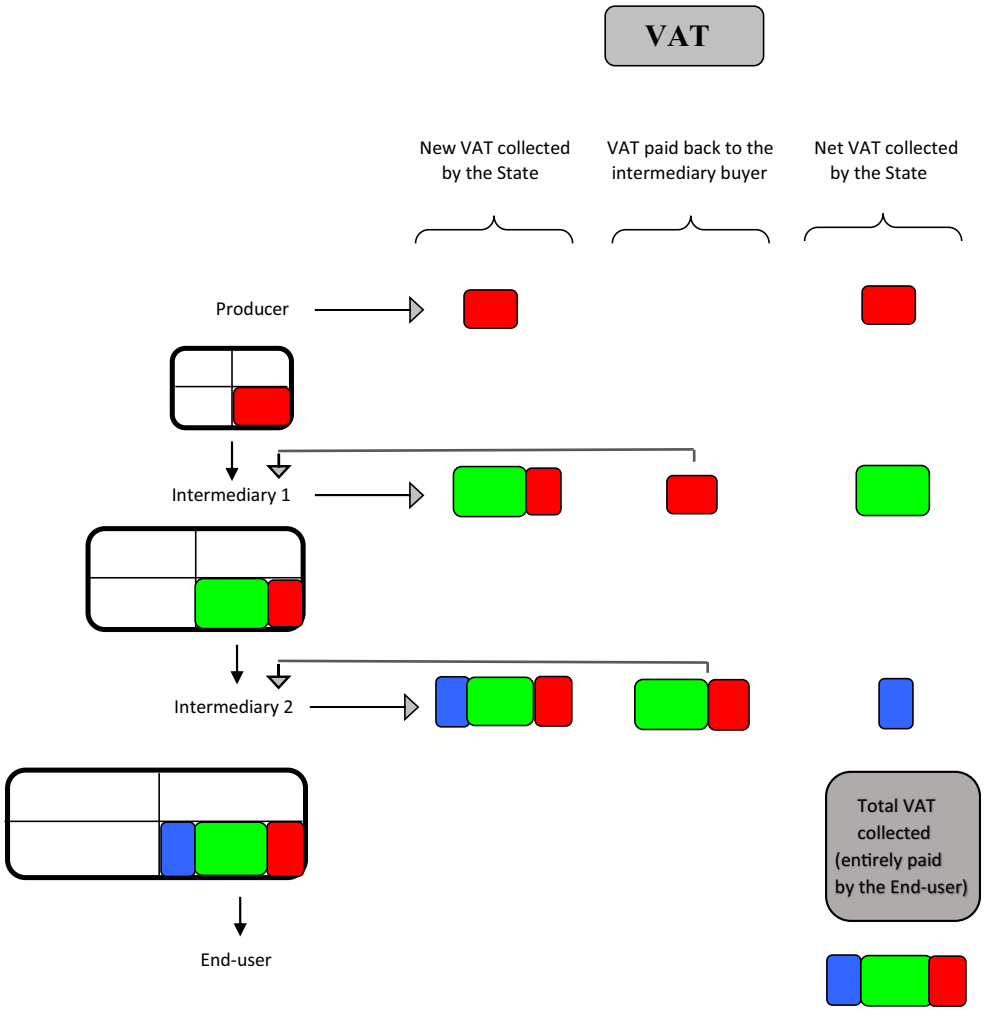

Fig. 1 How the VAT works. The *area of the figures* depicts the *price* paid for a good or service. The *colored surfaces* represent the *value-added tax* included in the amount paid for a product. This tax is a *fraction* of the product's *price* (e.g., here, 25%). The *vertical arrows* represent the *supply* of a good or service. The *horizontal arrows* represent money transfers for *tax collection* or *refund* by the State

have an economic or social dimension that goes beyond the framework of classical LCA. We conceive the damage and value-added tax (DaVAT) as a consumption tax based only partly on LCA methods. As every tax is the result of a human decision, a damage and value-added tax cannot and should not be based on scientific grounds only. It also has to be based on decisions at the local level of each country and to take into account the aspirations of this country's population. We will keep in mind this dimension in the construction of the DaVAT concept.

The term *damage-added tax* was first used in 1972 by Jürgensen who immediately ruled it out as "unworkable, owing to the insolubility of the imputation problem and in some cases lack of certainty of the fundamental relations of the damage" (Jürgensen 1972, 17). One of the challenges of the present article is to determine whether this argument still holds today. Since the advent of the polluter-pays principle, and even much earlier, many authors argued for a consumption tax levied on negative externalities (Pigou 1920; Sandmo 1975; Gorz 1988, 321; Daly and Farley 2010, 444) without specifying how the externalities would be calculated. Courchene and Allan (2009) suggest to create an "international carbon-added tax" applied to the cumulative carbon footprint of a product at the time of its implementation. Stiglitz (2013) and McAusland and Najjar (2015) propose a "carbon-added tax" levied at each stage of the production and transportation process to finally pass on to consumers. As their names imply, these taxes are based only on carbon emissions. Morrison (2007) recommends an "ecological-added tax" based on pollution, depletion, and ecological damage.[3] Albrecht (2006) and Oosterhuis et al. (2008, 5) suggest recourse to LCA to differentiate the products subject to "green consumption taxes" but do not specify how that could be done. Several LCA weighting methods emphasize the need to express the results of an LCA in monetary terms (see

[3] Morrison proposes that the "*Ecological Added Tax*" (E-VAT) levied on all goods and services replaces income taxes. E-VAT would be associated with the introduction of "a negative income tax to maintain tax equity after the abolition of income taxes" and with the creation of "a National Trust to invest in sustainability to overcome institutional barriers" (Morrison 2007, 8).

Pizzol et al. 2015 for a recent review). In the Netherlands, Croes and Vermeulen (2015) are currently developing a valuation method inspired by Vogtländer and Bijma (2000) by which every supply chain actor collects the upstream hidden environmental and social costs of its products and adds to them its own contribution. In France, the *Fondation 2019* is developing a research program on the possibility of correcting the final price of goods and services through significant variations in VAT based on a "life cycle externalities assessment" (Fondation 2019 2011; Thi et al. 2016). However, although LCA is one of the tools used for strategic environmental assessment of new tax policies (Nilsson et al. 2005; Seidel 2016), none of these weighting methods have yet resulted in the development of a new LCA-based tax. De Camillis and Goralczyk (2013) are the first, to our knowledge, to specify *how* the VAT could be based on LCA. Our paper primarily builds on their work that is critically reviewed, thereby identifying needs for improvement. It then suggests a new LCA-based taxation scheme likely to meet the criteria of environmental efficiency, compliance with LCA standards and general taxation principles, as well as practical and economic feasibility.

2 Proposal of De Camillis and Goralczyk

De Camillis and Goralczyk propose to adjust the current VAT rate of a product in accordance with its environmental performance[4] compared with the annual average of its category. The new tax would be specifically calculated as follows:

$$VAT_x = \frac{VATsr - (I_a - I_x)}{I_x}$$

with:

VAT_x	VAT rate (expressed in decimal form) of the product x in the year n
$VATsr$	VAT standard rate (expressed as a decimal)
I_x	single score environmental indicator (dimensionless) of the product x in the year n
I_a	single score environmental indicator (dimensionless) as reference environmental performance in the year n-1 for the product category a to which belongs the product x (benchmark).

Although De Camillis and Goralczyk start a very interesting line of reasoning, adjusting the VAT rate of a product according to its environmental performance *compared with the average of its category* might pose problems, which the authors recognize themselves as well. By addressing these difficulties, we contribute to the further development of an LCA-based environmental tax.

The first difficulty concerns consistency in taxation. The relative environmental performance of different products will differ between different product categories. For example, the proposal by De Camillis and Goralczyk does not prevent a car with a lower environmental impact score than the average score of its category to be taxed less than, for instance, a dinner at a restaurant—which has, however, a lower impact than the car. This will occur *if* the restaurant has a *higher* environmental impact score than the average score of its own category (yet less polluting than that of the cars). This goes against the principle of non-discrimination, which requires to use similar and objective criteria for all products concerned by the aim of the tax (i.e., here, lowering environmental impacts). Furthermore, in this system, some products belonging to high-polluting categories will become cheaper (e.g., as in the example of the car above). This contradicts the principle of proportionality, which requires to use adequate means to achieve the aim of the measure (i.e., here, discouraging environmentally harmful consumption and production habits). De Camillis and Goralczyk are aware of this danger, as they suggest the possibility "to integrate into the equations a set of multiplicative factors to overtax environmentally damaging products" (De Camillis and Goralczyk 2013, 267). Imposing higher charges on more environmentally impacting products requires a common valuation method for all product categories. Our analysis examines the principles and the feasibility of such a method in a consumption tax framework.

The second difficulty concerns the incentive aspect of an environmental tax that continues to depend on the product's price. In this respect, the tax is likely to be absorbed in the variations of the product's basic price. In other terms, as the tax is a fraction of the price, reducing the basic price also reduces the amount of tax to be paid. This may encourage some producers to slightly lower their profit margin so that the price for the end-consumer remains unchanged—which makes the tax less effective. Here again, the risk of absorbing the tax in the basic price can be reduced by overtaxing the most polluting products. But this brings us back to the issue of a common valuation method for all goods and services.

The third difficulty relates to the priority of scientific approach and the expectation for transparency in LCA. The magnitude of the tax conceived by De Camillis and Goralczyk is fixed by *comparison* between the single environmental scores of different products. In LCA, such scores result from a weighting of the various impact categories. But the standards require that weighting is not used for *comparative* assertions intended to be disclosed

[4] De Camillis and Goralczyk consider a scenario 1 where the environmental performance is calculated by LCA and a scenario 2 where it is calculated by carbon footprint. The first two difficulties we point concern both scenarios, the third one concerns scenario 1 only.

to the public (ISO 14044 2006, 4.4.5). A first reason of this is that a single score can hide large variations of releases and resource uses in some impact categories. A second reason is that, in general, the limitations inherent to any LCA[5] require additional information (such as sensitivity and uncertainty analysis of the results) to compare products and make informed choices. Finkbeiner (2014) has brought this point to attention in the context of a discussion on the European product environmental footprint initiative (PEF).[6] Galatola and Pant (2014) replied that "there are numerous examples of situations where weighting is already used by policy makers and LCA practitioners in the context of comparative assertions. A public, open and transparent discussion on this issue should be held" (Galatola and Pant 2014, 1357–1358). We would like to contribute to this discussion. The recommendation of de standards is interpreted by Guinée et al. (2002) as follows: "According to ISO 14042 [revised in the meantime by ISO 14040 2006 and ISO 14044 2006], weighting is not allowed for comparative assertions disclosed to the public. One must therefore decide whether to ignore the ISO principles, keep results internal, or refrain from weighting" (Guinée et al. 2002, 93). However, the requirement of ISO 14042/14040 and ISO 14044 may be read differently. According to us, the weighting and the use of an aggregated score *may be made public*, *provided that* (i) data prior to weighting (i.e., characterized data and normalized results) remain available together with the weighting results (ISO 14044, 4.4.3.1, and 4.4.3.4.3); (ii) it is clearly communicated to the public that the single aggregated weighted score does not express the environmental performance of the product because such performance is multidimensional, i.e., must be analyzed category indicator by category indicator (ISO 14044, 4.4.5) and by using additional information such as described in sections 5.1, 5.2, 5.3 of the ISO 14044 standard (e.g., detailed sensitivity analysis and critical study). The proposal of De Camillis and Goralczyk certainly does not include the *claim* of the environmental superiority of a product based on its single score I_x. In that respect, it does not contradict the standards. The problem, however, is that a comparison is used to set the amount of the tax. This seems to us neither consistent (see the first difficulty mentioned) nor efficient (see the second difficulty), nor justified by an ISO standardized approach. We will return (in Sect. 4.1.3 *Consistency in weighting*) on the possibility of using a single aggregated weighted score to set an environmental tax. For the moment, we note that the recommendation of the standards is not only due to the limitations inherent to any LCA, but also to the requirement to lead the assessment with objective, non-discriminatory, and transparent criteria—as must be the case in a taxation context. In ISO 14040/44 standards, transparency is defined as "open, comprehensive and understandable presentation of information" (ISO 14040/44 2006, 3.7). ISO 14040 emphasizes the fact that "due to the inherent complexity in LCA, transparency is an important guiding principle in executing LCAs, in order to ensure a proper interpretation of the results" (ISO 14040 2006, 4.1.6). It seems to us that it is precisely this requirement of transparency that explains why "weighting, as described in 4.4.3.4, shall not be used in LCA studies intended to be used in comparative assertions intended to be disclosed to the public" (ISO 14044, 4.4.5). Even if international standards are not to be confused with legal principles of taxation, we believe that a tax complying with these standards is more likely to flourish. On the other hand, it is clear that the benchmarking dimension included in the proposal of De Camillis and Goralczyk (making the tax rate dependent on the relative performance of the product with respect to its category) would provide the incentives for firms with products belonging to the same category to perform better than their competitors in environmental terms. We will bear in mind this important aspect of the proposal in the subsequent part of our analysis.

3 A new proposal to convert VAT into DaVAT

To overcome the difficulties discussed in Sects. 1 and 2, we propose a new way to adjust VAT according to, inter alia, LCA. Figure 2 represents the general structure of this new taxation system.

As shown in Fig. 2, our proposal relies on three essential points:

1. Apply VAT to all[7] goods and services and reduce its multiple rates to a single very low one (about 3%) called *Uniform VAT*[8] (UVAT). Contrary to what one might think, consumption taxes do not apply to all consumed goods and services. Across the European Union for instance, the amount of consumption not subjected to VAT represents on average 48% of the gross domestic product per country (from 19% in

[5] "Value-choices, exclusion of spatial and temporal, threshold and dose-response information, relative approach, and the variation in precision among impact categories are examples of such limitations" (ISO 14044, 4.4.5).

[6] The possible linkage between our proposal and PEF is evoked in Section 4.1.4. It should be noted, however, that this issue goes beyond the scope of this article.

[7] Except the second-hand products, for which the tax has already been paid by the consumer.

[8] This name has been proposed by one of the reviewers of this article. We would like to thank her/him for that. The term *Damage and Value Added Tax* also grew out of several comments made by the reviewers.

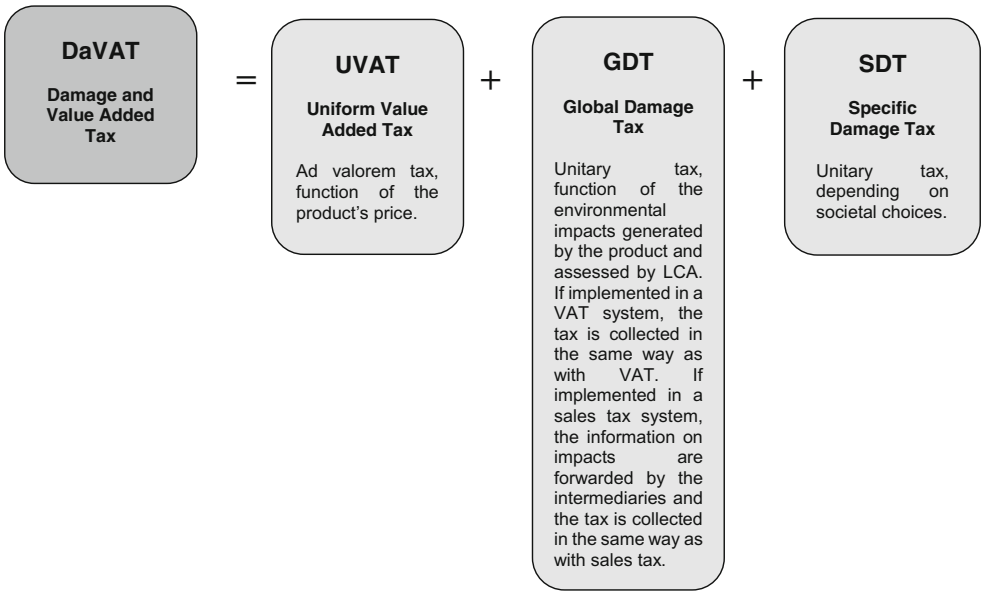

Fig. 2 General structure of DaVAT

Luxembourg to 59% in Italy according to Lejeune 2011 and OECD 2008, 69). The goods and services exempt from VAT belong mainly to the sectors of health, education, travel, sport, leisure, culture, antiques, financial services, and insurance. There are three rationales for the broadening of VAT to all goods and services in the framework of an LCA-based tax. First, maintaining a single-rate residual VAT applied to all goods and services is a way of preventing a collapse in State revenues. The current VAT or sales tax regimes guarantee an important source of revenue for States (17.3% of all taxes raised in Europe, 21.7% in the USA, 24% in China, according to TAXUD 2010; US Government Revenue 2013 and China.org 2013). Replacing this revenue with an environmental tax constitutes a risk to sustainable public finances, as environmental taxes tend to decline when their goal (i.e., here, preventing the environmental impact altogether) is reached (Kosonen 2010). Here, the erosion of the tax revenue, as harmful releases are declining, is offset by the broadening of the taxation base and by the possibility to gradually reincrease the UVAT rate. This capacity to preserve State revenue is all the greater given that the UVAT rate is low and the taxable base is large. The broadening of VAT to all goods and services is largely recommended because of its potential to reduce tax rates, simplify the tax system, and increase the revenue collection (OECD 2010; European Commission 2013). The second reason is that reducing the VAT rate will allow producers to offer their low-polluting products previously subject to VAT at a lower price. This meets one of the objectives of the tax, and also has redistributive properties. The third reason is that the broadening of the taxable base to all goods and services ensures that, in principle, none of them be exempt from the polluter-pays principle, which complies with the principles of non-discrimination and proportionality.

2. A *global damage tax* (GDT) is added to the UVAT. This amount is calculated from the life cycle impacts of the good or service up to the moment that it is delivered, whether it be to an intermediary or to the end-user. The LCA of the product is thus split as many times as there are purchases in the supply chain. If the product is purchased for final use, the normal or average use of the product until its end of life is also taken into account. All the goods and services will not necessarily be subject to an LCA. In the case of potentially high-polluting products or industries, an LCA will be automatically imposed (see Sect. 5.1 for more details). For the other products, each producer or intermediary will have the choice, either of accepting the product-class generic default LCA score or commissioning a specific LCA. Note that GDT is not an *ad valorem* tax but a per-unit tax: it is not a ratio (relative for instance to the price of the product or to the average environmental performance of its category) but a measurable and additive quantity (a financial amount). In other terms, as two products with the same function and environmental performance have twice the impact of one of them, this implies that the tax paid on both products will be double of that on one product. So, the amount of the tax is determined neither by comparison with environmental scores of other products (as in the proposal of De Camillis and Goralczyk), nor as a proportion of the product's price (as in the VAT), but only on the basis of the environmental

impacts presumed or actually measured of the product itself. This overcomes the two difficulties described above concerning the proposal of De Camillis and Goralczyk (consistency in taxation and risk of absorption of the tax in the product's basic price). In GDT, the environmental impacts of all products, even those of different categories such as a car and a dinner at restaurant, are calculated on the basis of a common metric, and the resulting tax cannot be smoothed or hidden by decrease in the product's price. Regarding the third difficulty evoked above (the issue of comparison between single environmental scores), although the *amount* of the GDT does not depend on a comparison between different products of the same category, the producers, intermediaries, and consumers are incentivized to carry out their own benchmarking by contrasting the GDTs (i.e., the financial amounts) attached to the products available to them. As the LCA of a product is split as many times as there are purchases in the supply chain, even the default LCA score of the intermediary products can differ, because two similar end products can be made using different intermediary products, with different environmental impacts. Each intermediary is incentivized to minimize these impacts, in order to decrease the final price of its product and/or to raise its profit margin. This form of benchmarking should therefore be conducted by all the intermediaries throughout the whole production and supply chain. This system also incentivizes substantial innovation and discourages greenwashing, for negligible differences have little or no impact on LCA results. Let us note straight away that the LCA considered here has a specific form: its *goal* and *scope* is to assess the human health, environmental and resource depletion impacts of a good or service *in order to contribute to setting its tax in accordance with the polluter-pays principle, without claiming the environmental superiority of the product comparing to others*. It has to be clear that this does not mean that LCA has to be more standardized in general. It, however, means that the application of LCA for taxation purposes involves common principles and rules for *that* LCA's use. Section 4 of this paper establishes the principles of an *LCA for DaVAT*.

3. In order to reflect environmental, social, or ethical concerns specific to a country, another damage tax termed *specific damage tax* (SDT) is proposed that extends beyond LCA. The purposes, procedures, and calculation modes of this tax attached to a particular category of goods or services can be highly variable (e.g., taxes on fattening food, sugary beverages, unrecyclable packaging waste, waste water, pesticides, biofuels detrimental to food supply) and will not be discussed here. SDT may be levied locally and does not necessarily rely on LCA. It is optional, but far from incidental. Its main reason for being is that the damage of a production and consumption process cannot be reduced to its impacts evaluated by LCA. A society may want to express, through its own taxation system, specific concerns for the environment, but also in the areas of health, social development, as well as ethics. These concerns can of course be expressed through the way tax revenue is used. For example, specific aids to certain sectors previously exempted from VAT (education, culture, etc.) can be implemented (see more on this in Section 7 *Acceptability of the proposal*). Concerns can also be reflected in the way the tax itself is levied. For instance, if the production of some biofuels threatens food security by increasing competition for limited resources such as land or water, it is important to go beyond the perspective of the LCA to include those social, economic, or even political issues (Weidema 2005; UNEP-SETAC 2009). In other cases, it can happen that a society just wants to overtax an impact category already included in LCA, e.g., the climate change impact category. For instance, a State or a group of States can decide to tax more heavily greenhouse gas (GHGs) emissions by adding a surcharge in the SDT of the products concerned. This operation will be made easier by the fact that GDT already provides the information about the GHG emissions related to these products. However, there is a need that SDT should not be absorbed in the variations of the basic price (it should be a per-unit tax rather than an *ad valorem* one) and that the taxed substances be easily traceable (signaled by intermediaries). In the DaVAT system, excises levied on specific commodities such as alcohol, tobacco, petroleum products, luxury goods, etc. are not (necessarily) removed, but (most often) gathered under the name of SDT.

Thus, in the expression *global damage tax*, the term *global*, meaning both *comprehensive* and *worldwide*, refers to the fact that the damage evaluated by GDT covers both all the impact categories taken into account by LCA and the entire life cycle of the product, likely to unfold anywhere in the world. In this respect, GDT is determined in a way that can be adopted by every country worldwide. In the expression *specific damage tax*, the term *specific* refers to the fact that the damage considered expresses concerns specific to one country, and that the product categories to which SDT is applicable are more restricted than those covered by GDT. We propose to refer to the sum of UVAT, GDT, and SDT as the *damage and value-added tax* (DaVAT). If DaVAT is implemented into a VAT system, the VAT-specific repayment mechanism of the intermediaries is maintained, as far as UVAT and GDT are concerned.[9] UVAT and GDT are paid by intermediaries (for the goods and

[9] SDT may also be concerned if it is useful to trace the taxed item (e.g. biofuel detrimental to food supply) throughout the supply chain, but it is not concerned if the taxed item (e.g. sugary beverage) does not require this.

services they buy), then paid back to them by the State up to the amounts collected, though not to the end-user. For example, a consumer buying an ink cartridge will pay, e.g., 33 € (pre-tax price) + 1 € (3% of the pre-tax price) + 4 €s + 3 € + 2 € (=9 € per unit) if 4, 3, and 2 € correspond, respectively, to the prices of the damages associated with the production, intermediary, and use and end-of-life phases of the product, and if UVAT is set at 3%. DaVAT can also apply to the sales tax regime. In that context, the intermediaries neither pay the tax nor are reimbursed, but forward to the buyer the information on the environmental impacts of the good or service they sell. Figure 3 describes how UVAT and GDT work in the framework of a VAT system.

As a result, the DaVAT for a good or service x_i bought at one stage i of its sales path (without considering reimbursements by the State to the intermediaries) is calculated as follows:

$$DaVAT_{x_i} = UVAT.P_{x_i} + GDT_{x_i} + SDT_{x_i}$$

With

$$GDT_{x_i} = \sum_{s=1}^{i} I_{x_s}.Fp.Fca$$

where:

$DaVAT_{x_i}$ Damage and value-added tax: all of the tax payable on purchase of a good or service x_i (in currency c) bought at one stage i of its sales path. The final selling to the end-user is denoted hereafter by $i = f$.

$UVAT$ Uniform value-added tax: single rate (dimensionless) applied to the pre-tax price of the good or service x_i. Intuitively, the difference between this rate and the original VAT rate indicates the potential for a drop in the price of the least polluting products: the greater the difference between the original VAT and UVAT, the greater the potential is.

P_{x_i} Pre-tax price of the good or service x_i (in currency c).

I_{x_s} Single environmental score of the product x_i (dimensionless[10]), aggregating values over all LCA impact categories at each stage s of the sales path of the product x_i. The summation index s takes the integer values between 1 and i and depends only on i. It numbers the different purchases from 1 to i, the purchase in the supply chain for which the tax is calculated. Intuitively, this environmental score is similar to the dimensionless weighted results provided by several LCA weighting methods (Eco-indicator 99 2000; Frischknecht and Knöpfel 2013; SM 2013), even though those results are often identified in units such as Eco-points, Millipoints, etc.

Fp Pricing factor fixing the actual amount of GDT (in currency c[11]). Intuitively, this factor means to put a price on the dimensionless weighted results mentioned above (Eco-points, Millipoints, or whatever one wishes to call them). In other terms, it indicates the price of damages in a given country: the higher it is, the more expensive are the environmental, human health, and resource damages. Fp is country dependent,[12] as the fixing of the Fp level results from a political decision. However, some decision-support tools for assessing the Fp value and estimating its impact on economic operators are described in Sect. 4.4, Sect. 6, and Electronic Supplementary Material.

Fca Currency area adjustment factor (dimensionless). This factor, normally equal to 1, can take another value if several States share a single currency (as for instance in the Euro-zone) and wish to limit disparities in the damage's price Fp. In that case, adjusting Fca is one way of modifying all the Fps to the same extent across all the monetary zone, rather like a common central bank can affect the economy of several countries by modifying its policy rate. Fca is a means to foster cooperation among States belonging to the same currency area despite their differences in the capacity to tax pollution. These States, in accordance with their respective capabilities, social and economic conditions and political choices, can fix a GDT amount (i.e., the value of Fp) different from that of other States of the same area. They can nevertheless cooperate in deciding, in some cases which require common agreement, to jointly increase (or decrease) their respective GDTs in the same proportion by modifying Fca. This kind of cooperation strengthens the influence and

[10] More precisely, the dimensionless score I_x is obtained by i) multiplying each normalized midpoint impact category result by a weighting factor specific to the impact category in question and canceling the dimensions of the normalized results; ii) adding the values obtained thereby (more details in Section 6). Weighting is dimensionless when it results from a ratio between two physical quantities of the same kind, e.g. the ratio of the environmental load of a region to that of one average inhabitant (Eco-indicator 99 2000; SM 2013), or the ratio of current to critical flows (Frischknecht and Knöpfel 2013). In this study, the dimensionless character of the weighted results is simply assumed, without specifying which weighting method will be used in the DaVAT framework (more details in Section 4.1.3).

[11] Fp is the conversion factor between I_x (dimensionless) and $GDTx$ (in currency c). It has thus the dimension of c. For more details on the transition from the dimensionless score I_x to the monetized value GDT fixed by Fp, and the possibility to relate this transition to other monetization methods, see Section 6 and Electronic Supplementary Material.

[12] By *country* we mean any legal entity in position to levy consumption taxes (including, for instance, provincial sales taxes in Canada). In the remainder of this article the terms *State* and *country* are used interchangeably to refer to those entities.

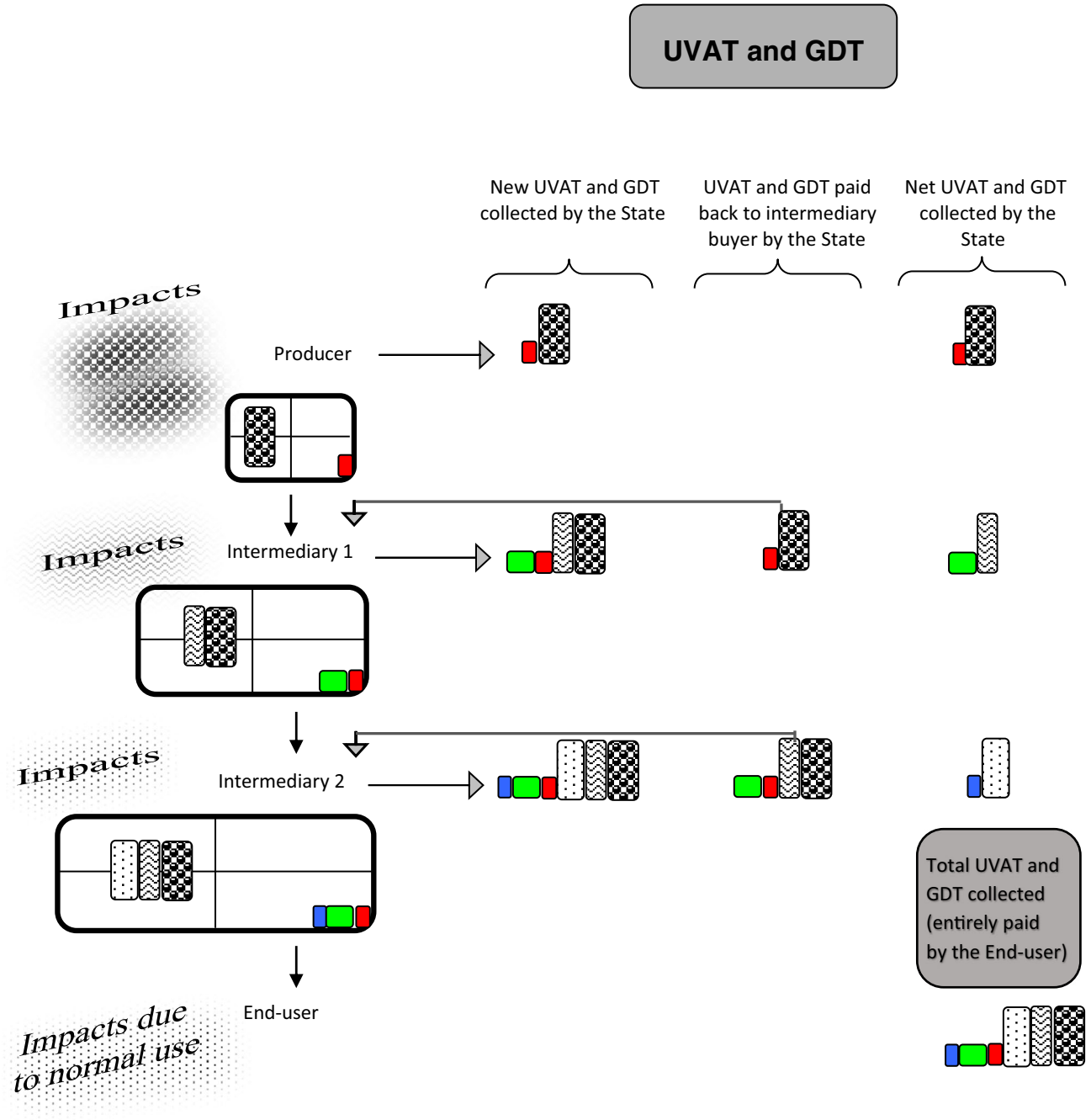

Fig. 3 How UVAT and GDT work in the DaVAT system. The *horizontal arrows* represent money transfers in case of implementation of DaVAT into a *VAT system* (not into a *sales tax system*). The *colored surfaces* depict UVAT (tax as a *fraction of the price* reduced to a *uniform low rate*). The *surfaces with points or geometric motifs* depict GDT (tax depending on the *cumulative environmental impacts* generated by the product at each stage of the supply chain). For more details on the meaning of figures and arrows, see caption of Fig. 1

credibility of the currency area, for instance in international negotiations on environmental matters.

GDT_{x_i} Global damage tax applied to the good or service x_i (in currency c). For each purchase i along the supply chain, the price $Ix_i \cdot Fp \cdot Fca$ generated by the environmental impacts of the last stage of the supply chain is added to the price of the previous stages: $Ix_{(i-1)} \cdot Fp \cdot Fca$, $Ix_{(i-2)} \cdot Fp \cdot Fca$, etc. As predicted by the LCA, the sum of the impacts $Ix_i + Ix_{(i-1)} + \ldots. + Ix_1$ can theoretically be negative. If it is so at the final selling to the end-user ($i = f$), $GDTx_i$ is set to zero, in order to minimize the risk of collapse in State revenues.

SDT_{x_i} Specific damage tax applied to the good or service x_i (in currency c). Depending on the items

taxed, SDT can be computed similarly to GDT (e.g., to overtax the climate impact category), or differently from it (e.g., to tax sugary beverages).

The DaVAT system should not be confused with the *differentiation of the rates*, often criticized as not very effective in achieving its objectives (in terms of environment, human health, or the like, notably owing to the absence of objective criteria) and as opening the door to lobbying and its administrative costs (Copenhagen Economics 2007, 71). Strictly speaking, DaVAT is *not* a system of differentiated rates as it only involves *two rates* applicable to all goods and services: a single very low one (about 3%) (*UVAT*), and the pricing factor *Fp* fixing the actual amount of GDT. Such a factor applies uniformly to the environmental scores I_x of all goods and services. *Fp* is not negotiable by product category and therefore closes the door to lobbying in that framework, though it is always possible to differentiate certain products by adding to them a specific tax SDT. The mechanism remains relatively easy for the everyday user, as there are no more *differentiated rates*, neither *special regimes*, nor *deduction coefficients*. In many countries, this should simplify the existing system.

Generally, our proposal is in line with the optimal taxation theory's recommendation that "only final goods ought to be taxed, and typically they ought to be taxed uniformly […] [with the] well-known exception [of] goods that generate externalities and that therefore justify corrective, Pigovian taxes or subsidies" (Mankiw et al. 2009, 2, 17). One may wonder why should damage be charged to consumers only. Why not levy direct taxes on producers or intermediaries? In practice, when the producers and intermediaries are taxed without being subsequently reimbursed, it is observed that they tend in one way or another to pass the cost of pollution on their products' prices so that, in the end, the person who really pays this cost is the consumer or user (OECD 1992). The difference is that, in cases where the tax is paid by producers or intermediaries without subsequent reimbursement, the consumers usually pay without being able to identify the damage included in the price. As a result, they cannot choose accordingly: the tax has been absorbed in the product's price. In this respect, VAT is probably the system paying the most attention to all the stages of the supply chain. In VAT, the tax collection is not concentrated on a single stage (sale to the final consumer) as it is the case in the sales tax system, but spread over all the sale transactions. This reduces risks of cheating because, as it is in the interest of all the intermediaries to be refunded of the tax they pay, they ensure that the latter is collected (Zodrow 1999). In a system where all stakeholders tend to minimize their costs and maximize their gains, any means to avoid paying negative externalities tends to be used. It is therefore coherent to tax negative externalities in a way that makes them as visible as possible at each stage of the economic chain and limits as far as possible the risk of leakage and cheating.

4 DaVAT operating principles

Is the LCA-based tax described above consistent, efficient, compliant with LCA standards and with the tax laws? The analysis of the challenges encountered in the implementation of environmental taxes in general (Sect. 1) and in the design of an LCA-based taxation framework (Sect. 2) has highlighted two elements. First, the importance of consistent criteria for taxation. Second, the fact that this consistency must be clear not only to scientists but also to the legislators and to the public in general. We suggest to address these issues by the principles of *consistency* and *transparency*. Furthermore, the theory of optimal taxation (Mirrlees 1971) generally recommends maximizing efficiency and equity of the tax. We propose to address these topics by two additional principles: *evolution capacity* and *respect for national sovereignty.*[13] Each of these principles is necessary to guide the implementation of the tax, but none of them is overriding or decisive in itself. This means that, as principles guide but not determine the choices, there may be cases where some competition arises between the principles without compromising their validity. An illustration of this is provided in Sect. 4.4 *Respect for national sovereignty.*

4.1 Consistency

The term *consistency* is intended to be understood here as it is in ISO 14040 (2006) and ISO 14044 (2006), i.e., in a threefold sense. First, conformity to the existing international standards on LCA (ISO 14044 2006, 3.45). Second, accordance of the assumptions, methods, and data of an LCA with its defined goal and scope (ISO 14044 2006, 4.5.3.4). Third, qualitative assessment of whether the study methodology is applied uniformly to the various components of the analysis (ISO 14044 2006, 4.2.3.6.2).

A goods or services production system can generate different products and environmental aspects (raw materials, intermediate products, co-products, and releases). Each of these products and environmental aspects can have a variety of uses. These uses can generate themselves a multitude of environmental, human health, and resource depletion impacts. How to consistently evaluate the damages generated by each element of the system? How to avoid omissions and double counting? How to concentrate in a single score the multiplicity of impacts on climate, ecosystems quality, resources, human health? These issues of definition (of the product system and the functional unit), allocation, double counting, and weighting are well known in the framework of LCA. They are the subject of recommendations in ISO 14040 (2006), ISO

[13] The issue of the efficiency of the tax is also addressed in Section 5.2 *Administrative costs* and Section 6 *Price changes.* The equity issue is also addressed in Section 7 *Acceptability of the proposal.*

14044 (2006), WRI, and WBCSD (2011) standards and are constantly being improved (Rack et al. 2013; Jolliet et al. 2014). A new standard *Requirements and guidelines for critical review processes and reviewer competencies for an LCA* has been published in 2014 (Finkbeiner 2013; ISO 14071 2014). In the DaVAT system, an independent regulatory agency, specially created for this purpose,[14] should verify the correct application of these practices in general, and in particular of the following four points.

4.1.1 Consistency in the definition of the functional unit and of the system boundaries

In the DaVAT system, any purchase of materials or of a good or service along the supply chain determines a functional unit (and the reference flows associated) corresponding to the purchased item such as it is specified in the purchase order. The *LCA for DaVAT* is thus fractioned in several assessments, each of which covering the process managed by each intermediary of the supply chain between its payment to the suppliers and its sale to the customer. In other terms, the DaVAT of each purchase bears the trace of the damage associated with the good or service bought. This is done without multiplying the analysis costs since the DaVAT system is designed to apply to all goods and services anyway. If the purchased item is sold to an intermediary for processing, its impacts are calculated till its delivery. If the product is sold for final use, the assessment also covers the normal or average use of the product until its end of life. Note that a product can be purchased for final use (i.e., the ultimate application for which it has been designed) not necessarily by consumers or individuals but, possibly, by intermediaries. For example, a farmer using a tractor and fertilizers until their end of life will pay (in a VAT context) or signal and forward (in a sales tax context) their impacts from cradle to grave, although, as an intermediary, the farmer will be reimbursed of the payment (in the VAT context) by the State. The functional unit of each LCA is thus defined here by *what is paid*, i.e., the good or service which is bought or, in the case of a default score, the product or service category of the item bought. As a rule, buyers never pay twice exactly the same good or service they buy: each new purchase always entails a process (or a part of a process) with its own impacts. In principle, the amount paid includes the entire process leading up to the product. That guarantees, to some extent, the consistency of the DaVAT system and the definition of its boundaries. Theoretically, the boundaries of an *LCA for DaVAT* can be indefinitely extended, as in the case of an ideal LCA. In reality, the boundaries of the LCA for DaVAT are simply the end of life of the product and the cut-off rules, i.e., the rules specifying which flows or levels can be excluded from the LCA. Still, it is necessary to agree on the meaning of *normal or average use*. The important thing here is not to extrapolate. For example, if the product purchased is a car engine, we will not consider that its normal use is to consume gasoline and to travel 200,000 km. The normal use of an engine is to be inserted into a car and, after a certain period, to be disposed of in landfills or recycled or possibly reconditioned. By contrast, if the product purchased is a car, its normal or average use is to consume, say, gasoline, and to travel, e.g., 200,000 km. The next section discusses how to clarify the definition of the normal use of products in general. As to the end of the car life, if the manufacturer can demonstrate an environmental gain (measurable by associated flows) in connection with the way the vehicle is recycled for its own production (closed loop recycling), this gain will be taken into account to reduce the DaVAT paid by the end-user. If the car is recycled or reused by another company in another sector or value chain (open loop recycling), the purchase of the recycled or reused product is simply exempted from the DaVAT as it is the case in the VAT system with all second-hand products for which the tax has already been paid by the first owner. So, the low cost of used products (exempt from DaVAT because already paid by the consumer) in comparison with the "extractive" ones (subject to DaVAT) should boost the recycling practices and the development of maintenance, repair, and recycling services when those are environmentally friendly (Iraldo et al. 2017).

4.1.2 Consistency regarding counting of emissions

It may happen that the normal use of a product A (e.g., a car) involves the purchase of another product B (e.g., gasoline). How to avoid counting emissions related to the use of product B twice, first in the LCA of A (including its normal use, i.e., fuel consumption), second in the LCA of B (also including its normal use, i.e., gasoline burning)?

At first sight, one might think that an LCA of A from cradle to the point of sale, and an LCA of B including its use phase, makes it possible to calculate the exact emissions of A throughout its lifetime. However, the emissions related to the product B may depend not only on the use of B (e.g., how much fuel is consumed), but also on the characteristics of A. For instance, different models of cars achieve, per liter of gasoline consumed, different emission performances regarding nitrogen oxides, reactive hydrocarbons, carbon monoxide (Innes 1996), and different services delivered (e.g., distance traveled). The levels of these emissions also tend to increase with the age of the car. The lifetime of the product A, as well as the conditions of its maintenance, recyclability, and recoverability, also determine the nature and the levels of its emissions throughout its life cycle (this is true not only for cars but also for, e.g., electrical appliances). Some studies have also highlighted a myopia phenomenon affecting consumers that

[14] The specific missions and responsibilities of this regulatory agency are detailed in sections 4.3, 5.1 and 5.3.

are not always aware of how much they will actually pay for the use of the car they are buying (Hausman 1979; Allcott and Wozny 2014). For all these reasons, it is recommended, at least in the case of automobile pollution, to combine a tax on A and a tax on B (Innes 1996; Fullerton and West 2003; Bjertnæs 2017). The tax on A relates to the potential deterioration of the environment caused by A as it can be anticipated at the time of the purchase of A. The incentives of this tax are the environmental performance, durability, recyclability, etc. of A throughout its whole life, from its manufacturing to its disposal or recycling. For example, it has been shown that a high registration tax on classical vehicles increases the market shares of alternative-fuel vehicles (Mabit and Fosgerau 2011). The tax on B relates to the effective use of A. It fosters a moderate use of A over time.

In the DaVAT system, attention is paid not to double count the emissions and to confront consumers with the consequences of buying each product. Accordingly, two cases are distinguished. In the first case, the emissions of a product B (product needed for the use of A) depend significantly on the characteristics of the product A. In this case, we recommend to split the emissions related to the average use of A and those related to the normal use of B so as the sum of the fractions equals 1. This allows to acknowledge the fact that the use of product A affects the consumption of product B. For example, emissions related to the average use of a car are halved, and emissions related to the normal use of gasoline are also halved, so that the sum of the two fractions equals 1. Fixing the fractions, i.e., setting the partition coefficient between the emissions related to the use of A and those related to the use of B, is beyond the scope of this study. The establishment of the partition coefficient should be discussed and decided at an international level (see Sect. 4.1.4). A list of product categories A and B subject to this coefficient (i.e., concerned by the first case) should also be drawn up. The list should also be the subject of an international consensus. In our opinion, motor vehicles, but also electrical appliances, are intended to belong to the list of products A. Therefore, fuels, but also electricity, should appear in the list of products B. In the second case, the emissions of a product B (e.g., tires, paints, shoe polish, cleaning products) depend little on the characteristics of the product A. We recommend not to include these products in the list of the articles subject to the emission reduction coefficient. For these products, the normal use is understood in a more restricted meaning than usual in LCA. The normal use of A is calculated without taking account of the emissions from other products purchased in addition to A (as DaVAT is already included in each of these purchases). The normal use of A is calculated on the basis of the use of the products B already associated with A at the time of purchase, but no more. For example, new shoes being sold polished, or a new car being sold with its tires, this is taken into account, but the subsequent operations of using new polish, or replacing tires, are not considered. Similarly, the normal use of a saucepan will not include the emissions related to use of washing-up liquid, cooker, water, etc. (already included in the purchases of these products). However, it will include, if applicable, the emissions related to the wear of the saucepan. As for the normal use of B (e.g., new polish or new tires), it will be calculated similarly on the basis of the total (unfractioned) emissions of B only. Finally, if a product purchased to allow the use of another product has other uses (as it is the case with some multiple-use oils for instance), its average use will be calculated by averaging the identified uses, except for the potentially high-polluting products or industries, for which a specific LCA will be automatically imposed (more details on this subject in Sect. 5.1).

4.1.3 Consistency in weighting

As stated in the ISO 14040 standard, "there is no scientific basis for reducing LCA results to a single overall score or number, since weighting requires value choices" (ISO 14040 2006, 4.3). Among the many methods of weighting, there is no consensus on the best one (Huppes and van Oers 2011a, b). This problem, which may seem insurmountable from a scientific point of view, takes on a particular form in a taxation context, where science does not have the last word anyway. In Sect. 2, we argued that using a single aggregated weighted score is not forbidden by the standards if it is clearly communicated to the public that this score does not express the environmental performance of the product (which requires additional information), and if data prior to weighting are also available. Environmental performance is multidimensional in nature. So, many expressions used in this article ("most polluting products," etc.) are, as the LCA specialists will know, imprecisions of language which do not fully reflect the complexity of reality. But if the single score does not express the environmental performance, why would we use it to tax goods and services? Here, we face probably the most challenging aspect of the DaVAT from an LCA perspective. Struggling with certain problems, one needs to be pragmatic. In economics, internalizing negative externalities, i.e., integrating the damages into the product price, necessarily implies reducing to a single dimension what depends, as such, on several dimensions. This kind of imprecision is not opposed to the general principles of law. In the European jurisprudence, the "imprecision of the results of studies," associated with the "likehood of real harm to public health," justifies (according to the precautionary principle) "the adoption of restrictive measures, provided they are nondiscriminatory and objective" (European Court of Justice 2010, § 93). Under US law, "the information is considered accurate if it is within an acceptable degree of imprecision or error appropriate to the particular kind of information at issue" and if it integrates "standard practices accepted by the relevant scientific and technical

communities" (Information Quality Guidelines 2002, 3.2.2). The World Trade Organization provides that "measures (…) necessary to protect human, animal or plant life or health" can be taken "in cases where relevant scientific evidence is insufficient (…) on the basis of available pertinent information (…). In such circumstances, Members shall seek to obtain the additional information necessary for a more objective assessment of risk" (WTO 1995, 2 §2, 5 §7).

So, the unscientific nature of weighting is not a sufficient reason for not using it in a taxation context. In the DaVAT system, weighting is a convention for action, a way to act on the material economy to limit its impacts on the environment, resource depletion, and human health. Introducing a tax is a human decision which will always be based on value choices, which should always be made collectively in a democratic framework. Remember that, in determining the tax, the LCA score I_x is actually fixed in currency c by factor Fp and possibly adjusted by the currency area factor Fca, each of these factors being chosen by the States. The amount of the DaVAT expresses both the degree of damage—imperfectly approached—associated with the product taxed, and the choice and needs of a country. In 1999, Finnveden wrote that "if we want changes to be made, we must learn to take decisions and act on a less rigid basis than full scientific methods" (Finnveden 1999, 37). In 2002, Guinée et al. "strongly recommend[ed] that a weighting set be developed covering all impact categories and approved by a panel having due international or national authority" (Guinée et al. 2002, 633). In 2016, Thi et al. highlighted the necessity of a consensus on a weighting scheme in a life cycle model internalizing externalities by means of either a corrective tax, or a reduced value-added tax rate. We concur with this conclusion. We leave open the question of which weighting method should be chosen to establish the DaVAT. The important thing, in our view, is that this method should be the subject of a consensus between the countries or regions using DaVAT and meets a fourfold requirement of transparency and consistency:

1. Transparency of the *arguments*: on what facts and values do we base our reasoning to give a particular weight to one impact category and another weight to another? (Finnveden 1997).
2. Transparency of the *environmental score*: from the single score, one must be able to know how it was calculated and the details of the various characterized and normalized results for each impact category.
3. Transparency about the *conventional and non-scientific nature of the weighting operation*: when presenting the weighted results, the public should be reminded that the complexity of the interactions between the impact categories cannot be accurately measured and that the question of the importance we attach to each of them cannot be eluded.
4. Consistency with the *goal of the LCA* and with the standard requirements for weighting: since the goal of the weighting process is here to fix a common framework for DaVAT on international level, valid in principle for all the countries of the world, it is important that the choice of the weighting factors can be made on the basis of sensitivity analysis assessing the consequences of the different weighting methods considered (ISO 14044, 4.4.3.4.2). The characterization, normalization, and weighting factors could also take regional or local specificities into account.

4.1.4 Consistency of the measures and controls. Reduction of the variance

To conclude on this first operating principle, it is clear that DaVAT will only be consistent if certain common rules are followed by all the stakeholders adopting the system. The DaVAT system should use common databases, apply the same inventory, characterization, normalization, and weighting methods,[15] as well as refer to the same impact categories, the same cut-off rules, and the same concept of normal use. While the amount of the GDT is specific to a country and a product x, the calculation of the environmental impacts associated with the product x, ultimately resulting in its environmental score I_x, is the same for all and shall be designed so that it may be adopted by every country worldwide. It is also desirable that the way to communicate DaVAT be subject to common rules (see the next operating principle: *transparency of information*). There is equally a need to implement in a standardized way the software tools for calculating DaVAT so as to reduce the variance of the LCA results as much as possible: the same data must produce the same results (Herrmann and Moltesen 2015). The variation in the data themselves, i.e., in the observations or in the measures, does not prevent us from drawing consistent conclusions. For instance, the recent discovery of a software altering the emission data of some products of a major automobile manufacturer[16] does not mean that the variance of measures is uncontrollable, but rather that cases of fraud can always be detected, even in a context where there is no unique standard measurement system. It is clear, however, that a common and standardized measurement method will make the controls easier and more efficient. Proposing an LCA standardized method for DaVAT is not the purpose of this study. Current efforts to improve and harmonize product category rules (Ingwersen and Stevenson 2012; Minkov et al. 2015) might be helpful in this respect. The

[15] Which does not necessarily imply the same characterization, normalization and weighting *factors*. These can be local- or regional-specific. See Section 4.1.3(4).

[16] Volkswagen had installed in some of its diesel cars a software limiting nitrogen oxide emissions when the car is undergoing an emission test.

choice of an *LCA for DaVAT* should, however, be made on the widest possible scale, i.e., by the largest number of countries likely to adopt the DaVAT system, on the basis of a consultation carried out by a recognized non-governmental institution such as the UNEP-SETAC Life Cycle Initiative.

4.2 Transparency of information

It is essential for an environmental tax to fulfill its informative and awareness-raising role. Each good or service purchased should bear, in a standard and visible way, an indication mentioning its share of global damage tax (GDT) expressed in monetary value and, if applicable, its specific damage tax (SDT). Whatever the pre-tax price of the good or service, its GDT will remain the same, thus keeping its signaling effect. We propose that these indications are accompanied by a QR code or a Flash code opening a website detailing the LCA results of the product (in compliance with trade secret laws) and indicating whether these results are the default ones or the values obtained by a specific LCA. The website should also mention the technical data of the tax calculation (factors *Fp*, *Fca*, start date of the cycle). It should allow an easier understanding of the results of an LCA (Nissinen et al. 2007), learn the terms and principles of the weighting method (as detailed in Sect. 4.1.3), and recall the precautions to be taken to make informed choices when comparing LCAs of different products (in accordance with ISO 14044, WRI, and WBCSD standards). This transparency and access to information, allowing for reproducibility, also provides an additional way to identify and combat misreporting LCA results (for other tools of this type, see Sect. 5.3 *Risks of fraud*).

4.3 Evolution capacity

Goods and services are constantly evolving, as is our understanding of their levels of harmfulness and toxicity. Our knowledge of the state of the environment, of natural resources, human health, and of the economic situation of the countries, is also steadily evolving. A system of damage taxation ignoring such changes is neither credible nor effective. The ability to evolve and the regular updating of the DaVAT is therefore an essential feature of DaVAT. Let us briefly list the DaVAT adaptation tools.

1. The *factors Fp* (fixing the tax price) and *Fca* (currency area adjustment) can and should be regularly indexed to inflation and adjusted within each State (for *Fp*), or possibly adjusted within the common monetary area (for *Fca*), depending on the environmental objectives of each State and on macroeconomics factors. If the socio-economic circumstances permit, and if scientific knowledge on the state of the environment warrants it, it is desirable that the price of damage be regularly increased by the State, e.g., by 1 or 2% per year (Ma and Grubler 2009). A tax whose amount remains unchanged could evolve towards a new status quo, where environmental innovation is no longer incentivized. Some decision tools to determine the level of *Fp* and its evolution are described in the next section: *Respect for national sovereignty.* Note that our proposal to regularly index and adjust the price of damages does not include discounting. The principle of discounting is that money earned today is worth more than money earned in the future. However, discounting applies to long-term investments whereas DaVAT, as a consumption tax, relates to the instant gratification of the consumer. Furthermore, several authors warned against the risks of discounting in LCA because, "when applying standard discounting-methods to long-term effects (…) what happens a few centuries from now hardly counts at all" (Bickel and Friedrich 2005, 31; Weitzman 1998; Hellweg et al. 2003).
2. As a reminder, switching from VAT to UVAT allows to lower the price of low-polluting products. If this lowering is progressive, it can accompany a gradual increase of GDT. What about the day when DaVAT efficiency has become so high that the environmental, human health, and resource depletion impacts are under control? Will an increase in the damage price still make sense? At that time, maintaining the tax revenue can be done by *gradual reincreasing* of the *UVAT rate*.
3. The *calculation method* of I_x (the environmental score of a good or service x) should be improved in light of the progress of knowledge and methods in LCA if and when there is a consensus on this issue. The same goes for the weighting method chosen. The variability of the results of LCAs is sometimes invoked as an argument against their reliability. One of the main causes of this variability is the low number of high-quality inventory data (Björklund 2002; Hauschild et al. 2013). As the DaVAT system will boost data collection as well as sensitivity and uncertainty analyses on them, it should contribute to decreasing this variability. The coordination of discussions about calculation methods of I_x will be entrusted to the DaVAT regulatory agency mentioned in Sect. 4.1.
4. The *setting and updating* (e.g., every 5 years) *of the default score* of each product category cannot be done merely on the basis of the average of the LCAs commissioned by the producers or intermediaries wishing to do so. Indeed, this average score (whatever its calculation mode) will be pushed down anyway by the voluntary LCAs. One cannot exclude that, within a particular category of goods or services, other companies that do not commission any LCA develop production systems more environmentally harmful than what is indicated by the default score of the category in question. If the calculation of the default score is solely based on voluntary LCAs, the evolution of such

score will not reflect the reality and will distort competition with the potentially high-polluting products or industries for which an LCA is automatically imposed. As a result, the calculation and updating of the default scores will also rely upon other data, notably those taken from hybrid input-output approaches, i.e., (here) classification of sectoral emission inventories by flows of goods and services between different lines of business (Suh 2005; Williams et al. 2009; Sengupta et al. 2015). The calculation can also be based on *documentary LCAs*, i.e., not aimed at setting the score of a specific product of a particular company, but at filling the gaps in our knowledge of the environmental impacts of some product categories. Here again, these tasks define one of the missions assigned to the international regulatory agency mentioned above.

So, the amounts of DaVAT will change over time, though in a foreseeable way for the economic actors. The price of the damage will gradually increase, not to offset the erosion of State revenues (which can be done by increasing UVAT), but to continue to incentivize environmental innovation—up to a certain point, depending on the environmental objectives of each State. The damage will also be increasingly accurately evaluated. For many economic actors, this foreseeability, combined with the principle of the consistency of the tax, should mean an important signal for improving the environmental performance of the goods and services in question.

4.4 Respect for national sovereignty

As stated above, the introduction of a tax is a decision that should always be taken collectively in a democratic framework. Each State or entity which rallies to the idea of DaVAT should remain independent in fixing its effective rates (*UVAT* and *Fp*) and in establishing specific damage taxes (SDT).

There is no simple method of setting the "right" value of *Fp*, just as there are no simple ways to set the "right" levels of VAT rate, fuel excises, or taxes on sugary beverages. This remains a political decision. However, the characterization and weighting factors of the *LCA for DaVAT* being fixed first, it is possible to see how the value of *Fp* compares with that of existing indicators such as the releases price of a reference substance (e.g., the price of one ton of carbon dioxide equivalent [tCO_2eq]), or the cost associated with an endpoint indicator (e.g., cost of a disability-adjusted life year [DALY]). Section 6 (*prices changes*) gives an example of these ways of assessing *Fp* with regard to existing indicators. The macroeconomic effects of *Fp*, for their part, can be modeled according to techniques similar to those calculating the effects of a carbon tax (Di Cosmo and Hyland 2013). That is, by using the estimated price and income elasticities and, in this case, an LCA standardized database giving the default scores for each category of goods and services as well as for the technology and production practices associated.

In any event, the reform can serve various economic policies. A State can decide to "shift the tax burden from employment, income and investment, to pollution, resource depletion and waste" as proposed by UNEP (UNEP 2015, 183) or to keep the consumption tax revenue unchanged, or even to reduce it. The State can also decide to introduce the shift "slowly, over a couple of decades" (UNEP 2015, 183) or to implement it more quickly as it has been the case with carbon tax in British Columbia, where the initial rate 10 CAN $/$tCO_2eq$ fixed in 2008 has been increased annually by 5 CAN $/$tCO_2eq$ per year during 4 years to reach 30 CAN $/$tCO_2eq$ in 2012 (Beck et al. 2015).

A single country can in principle adopt the DaVAT system. What will happen for this country depends on many factors, such as its productive capacity, its level of energy dependency, the initial level of consumption tax, etc. It may, however, be expected that the production and consumption of local products and the energy autonomy of the country will be encouraged, as far as they are low polluting. The imports of the country will be discouraged, as far as they are polluting. Its exports will not be hampered, since DaVAT is deductible from export prices. They can even be encouraged, if they specialize in very low-polluting products and if other countries prefer these types of products. The result should be an increasing competitiveness of the country while its environmental, human health, and resource depletion damage decrease. This should incite other countries to adopt the same system. The polluting exports of a State that does not follow the DaVAT system will not be favored, as they will be more heavily taxed in countries applying DaVAT. The delocalization or spread of pollution will also be discouraged for the same reason: LCA being not confined to the borders of a country, a good produced in more harmful conditions remains more expensive in the countries applying DaVAT. Note that DaVAT is not a custom tax and does not constitute, as such, a barrier to trade. DaVAT applies to all domestic products as well as to the imported products and uses the same metric or environmental criteria for all products, wherever they come from. One parameter that should nevertheless be considered is that some countries have lower experience or capabilities to assess the environmental impacts of their exports (e.g., in the developing world). When implementing DaVAT, this could be disadvantageous for these countries. Support measures to those countries could be envisaged.

The sovereignty principle also involves the right to introduce DaVAT exemption schemes for some categories of products. For example, if, in specific regions where pesticides are extensively used, the application of DaVAT might lead to a sudden increase of prices and hinder poorest people's access to food, exemptions could be granted. Such decision,

however, is political and should be discussed in full transparency while taking account of the alternative options and compensation measures. Any exemptions to the DaVAT regime will be made to the detriment of the tax consistency and could increase the cross-border trading risk, but do not prevent the DaVAT as such from functioning. This is an example of a possible competition between the sovereignty and the consistency principles.

5 DaVAT feasibility

5.1 Practical implementation

The problem that immediately comes to mind with the implementation of an LCA-based tax is well summarized by Albrecht: "From a scientific perspective, it would be best to base the product classification [i.e., here, the environmental performance of the product] on a very detailed assessment like an LCA. It will, however, take a long time before an LCA is concluded for every consumption good. Furthermore, every change in the production process or product design will require a new assessment" (Albrecht 2006, 96). However, it is quite possible, as Albrecht himself suggests in his article, to build up in a relatively short time a database indicating for each *product category* a *default* or *assumed* environmental score. Even though, from a strict LCA perspective, "extensive data gaps exist and much work is needed to fill them" (Wiedmann et al. 2009, 55), associating existing categories of traded goods and services with their environmental impacts does not raise major problems (Wiedmann et al. 2009; Jungbluth et al. 2011). For instance, the Central Product Classification (CPC) developed and maintained by United Nations Statistics Division is compatible with many other national or multinational product classification systems and also with the Ecoinvent3 database (Ingwersen and Subramanian 2013). The default score will not reflect the exact assessment of the environmental impacts of each product, but it will give an indication close enough to make the system work by incentivizing the firms with less-polluting products to commission a specific LCA. The *LCA for DaVAT* database containing the specific and default LCAs of the products and product categories sold worldwide will be established and managed by the international regulatory agency as referred to above. This agency will be first and foremost financed by the countries and organizations supporting the project, and then also by the countries adopting the DaVAT system.

Practical implementation must also take into consideration how the database associated with the DaVAT system will be used by firms and consumers. In practice, there are three possible cases. First, a specific LCA is automatically imposed in case of potentially high-polluting products or industries. Second, some producers and intermediaries outside of this category of high-polluting products can accept the assumptions of the database, i.e., the default environmental score assigned to their products. Third, producers and intermediaries who so wish can commission a specific LCA for their products. Regarding the potentially high-polluting products or industries, the industries concerned will thus transmit to the database the LCA data related to their own production. However, a country opting for DaVAT does not have the power to automatically impose specific LCAs outside its borders. If the company concerned declines the proposal to make a specific LCA, the country can increase the default scores of the company's products. Such indexing system intended to uncooperative potentially high-polluting industries should be the subject of international agreements. Similarly, the choice of the products or activities for which an LCA will be mandatory in the DaVAT system shall be the object of an international consensus, in order to ensure the consistency of the valuation system. This choice can stem from existing legislations. Many countries already impose environmental impact assessments of specific processes or activities considered as having significant effects on the environment. In Europe for instance, such activities include notably crude oil refineries, integrated works for the initial melting of cast-iron and steel, and integrated chemical installations (European Directive 2009). Examples of *product* categories for which a specific LCA can be required if a consensus was reached on this matter are heating systems and motor vehicles (with a power greater than, e.g., 50 kW). Other criteria can be considered, such as having an environmental score I_x exceeding a certain threshold. As for the specific LCAs commissioned by producers and intermediaries (whether mandatorily or voluntarily), they will be carried out at their expenses and will cover all products sold by them. The results of the LCAs will be submitted to the regulatory agency, which adds them to the database. In case of change in the production or supply process, the producers or intermediaries (outside of the category of potentially high-polluting products or industries) will always have the choice: either to be satisfied with the value assigned by default to their products, or to provide the proof that the change does not increase their environmental impacts, or to commission a new specific assessment. It is in the best interest of producers and intermediaries who pay particular attention to the green or healthy nature of their products to commission an LCA in order to reduce the tax burden on them and make them more transparent.

In terms of information, it is important that each seller or buyer of a product can easily identify the environmental score I_x assigned to this product and get all the data sufficiently specific to establish this score (see above Sect. 4.2). Each good or service sold will be associated with a bar code produced by the database and indicating the environmental score of the product. This score (and the data prior to aggregation) will be delivered freely by the regulatory agency managing the

database. Access to the data will be free, though limited (i.e., not allowing data to be downloaded in large quantities). As with excise rules, the destination principle will be applied: the tax is paid by the recipient at the rate of the country of destination, which discourages dumping. The place of the purchase therefore determines *UVAT* (uniform value-added tax), *Fp* (pricing factor fixing the actual amount of the tax) and, if relevant, *Fca* (currency area adjustment factor). Each good or service is taxed at the same uniform rates (*UVAT* and *Fp*) while a single gesture (scanning the bar code) is sufficient for linking the product to its (presumed) harmfulness and assigning to it its own total tax (DaVAT). After final payment by the end-user, the environmental score I_x of the product x is reset to zero. Resetting I_x to zero makes the purchase of used products (for recycling or reuse) more attractive, at least within the boundaries of the same country. This resetting, however, does not delete the identity of the product nor its history from the database, so that in case of export of a used product still identifiable (such as a car) to an area where *Fp* is higher than that of the country of the previous sale, the difference will be payable on the sale.

5.2 Associated costs

The costs of implementation, maintenance, administration, and compliance associated with the DaVAT system are expected to be important during the launching phase, due notably to the establishment of default LCA scores for each product category, the establishment of the international agency managing the LCA data, the setting up of procedures for verifying DaVAT declarations (see next section: *Risks of fraud*), the broadening of the taxation base to all goods and services, and the business compliance with DaVAT requirements.

Regarding the *establishment of a default LCA scores database*, McAusland and Najjar (2015) recently analyzed whether a model close to DaVAT though restricted to the greenhouse gas emissions is logistically feasible in general, i.e., without focusing on a specific country. They consider a carbon-added tax similar in design to a value-added tax. They show that a hybrid system, i.e., giving firms the option to either calculate their own carbon emissions or use product-class *default* carbon scores as the tax basis, should protect competitiveness and reduce leakage. Taking into account 3299 product classes from the North American Industry Classification System (NAICS), they find that the costs of calculating the carbon footprints for each product class would likely be between 0.1 and 1% of the carbon consumption tax revenues in a country such as, e.g., Canada. One of the assumptions[17] made is that each State would commission analyses of an actual footprint of one representative firm for each category, the cost of each analysis being estimated by the authors at between 18,000 CAN $ and 46,000 CAN $. McAusland and Najjar observe that a different approach, utilizing existing multi-regional input-output data, "may cost considerably less but offer less precision" (McAusland and Najjar 2015, 62). In the DaVAT framework, the low precision of the default score is not problematic in itself as the product categories can be, at first, large enough to offset the imprecision of the environmental scores. The classification of categories and the specification of their default scores can themselves become more detailed as new LCA data are provided by businesses and companies. The *LCA for DaVAT database* will therefore not start from scratch in commissioning LCAs for each product or process categories. It will rather use existing databases, gathering information in the same metric. According to Wiedmann et al. (2011), the databases AIIOT (IDE-JETRO 2006), Eora (Lenzen et al. 2010), EXIOPOL (Tukker et al. 2009), GTAP 7 (Narayanan and Walmsley 2008), WIOD (University of Groningen 2010), quantifying the environment impacts of goods and services in terms of regions and sectors, have a budget ranging "from 500 000 AU $+ 250 000 AU $ / year for Eora (implementing compilation and updating capability + maintenance) to around 5 million Euros for EXIOPOL" (Wiedmann et al. 2011, 1940). This is much less than the amounts evoked by McAusland and Najjar and leaves room for additional assessments in order to fill the most important data gaps. Clearly, the new DaVAT database will not obtain all data free of charge. Agreements will have to be negotiated, notably with existing international LCA database providers.

As for the operational costs of the international regulatory agency, they are difficult to determine at this stage. As examples, and for information only, the annual budget of the European Chemicals Agency is around US $ 75 million, and that of the World Trade Organization reaches around US $ 200 million, which remains very close to the amount mentioned by McAusland and Najjar, i.e., 1% of a carbon consumption tax revenue in a country such as, e.g., Canada. Note, however, that the budget at issue here is that of an international agency offering its services to any country adopting the DaVAT system.

The *administrative costs* of VAT for national authorities are estimated in Europe at 1% or less of VAT total revenue (Hyman 2014, 598). These costs could increase during the launching phase of the DaVAT, due to the creation of a new taxation scheme and because of the broadening of the taxation base to all goods and services. However, the standardization of the UVAT and the abolition of the VAT special schemes should also reduce some costs of the old VAT. A comparison between four European countries showed that the cost of the compliance burdens on businesses related to VAT can be divided by four in case of least differentiation of VAT rates,

[17] The other assumptions related to this example are: 600Mt CO_2 consumption in 2008 in Canada; 30 CAN $ carbon tax per ton; entailing a 14% reduction of CO_2 eq consumption (McAusland and Najjar 2015, 58).

reduction in the frequency of the VAT returns per year, and digital registration (SCM Network 2005). Such cost reduction is possible in the DaVAT system as it requires only two rates (*UVAT* and *Fp*) for most of the goods and services, and as it can be largely automated because of the need to connect to a common database. Other costs that may be included among the administrative costs are those related to the management of support measures to disadvantaged groups, as these measures can be seen as an integral part of the DaVAT concept (see Sect. 7 *Acceptability of the proposal*).

The *compliance costs* of VAT for taxpayers are estimated in Europe at about 8% of VAT total revenue (€ 79.5 billion per year according to Capgemini et al. 2010, 36). Here again, the broadening of the taxation base to all goods and services should create new costs for the sectors previously exempted. This broadening, however, also provides the opportunity to simplify the procedure. Typically, the quality of the product classification and of the webpage design allowing businesses to easily assign a good or service to its category (and therefore to its default environmental score) is an important factor in reducing compliance costs. Another factor is the quality of the (cost or analytical) accounting software assigning its total cost to each product. It is, indeed, on the basis of this cost (more precisely on the basis of the GDTs associated with this cost) that DaVAT is calculated. As regards the compliance costs for businesses deciding to carry out a specific LCA of their products, they should be compared with the sometimes very large amounts (between 800 € and 280,000 € according to European Commission 2002a) already devoted by some of them to Environmental Product Declarations (EPDs). Let us recall that, in the DaVAT system, LCA is split as many times as there are purchases in the supply chain. Therefore, the cost of the assessment is limited by the fact that the LCA must not go beyond the purchases needed for the process stage handled by the producers or intermediaries (each purchase bearing the weight of its own damage). The cost for SMEs is thus significantly reduced. In 2002, the European Commission already recommended to "add together the EPDs of the various components of a product to inform the 'final' LCA" and, to do this, to set up "an information management system developing EPDs in the same way, using similar information sources [...]. Such a situation would be especially beneficial for SMEs operating in the chain, since they would avoid having to invest heavily in establishing their own information systems to obtain the information needed for an EPD" (European Commission 2002a, 79–80). There are today several tools allowing to estimate quickly and cheaply the potential results of an LCA. These tools (Fast track LCAs, Quickscan LCAs, Simplified LCAs), which use look-up tables, general databases, or simplified parameterized models, are developed within the framework of multiple projects (Vogtländer and Segers 2011; Heijungs 2013; Padey et al. 2013; Lacirignola et al. 2015; LCA 2 Go 2014). They might be useful, such as the DaVAT database itself, to evaluate the interest for an SME to proceed or not to a specific LCA, depending on the level of accuracy of the DaVAT database and the degree of adaptation of the tool in question to this database.

5.3 Risks of fraud

In Europe, VAT fraud accounts for between € 60 and € 100 billion per year, which represent up to 12% of the theoretically collected VAT (International VAT Association 2007). What can we expect from the DaVAT system? On one hand, opportunities for fraud could increase, as it could act both on financial flows and environmental impact of material flows. On the other hand, the DaVAT system requires that the same tax is levied on the purchase of every good or service, whether coming from domestic market or from another country. As there is no exception to this rule, even in a same currency area, this is a first obstacle to missing trader intra-community fraud (including carousel type fraud), which takes advantage of the VAT exemption for intra-community supplies. Further, the DaVAT system offers the possibility (though needs not) to identify the location of the purchase of a product, and some physical characteristics associated with this product (through its environmental impacts). This type of measure is recommended to fight black economy and fraud consisting of asking the State to reimburse a tax payment on something that does not exist. Linking, as DaVAT does, each billing of goods or services to a material flow of polluting releases can facilitate fraud detection by data mining and data reconciliation, as already experienced by some countries (SAS 2014). Fight against cross-border VAT fraud is indeed "easier to administrate for tangible goods" (Mesdom 2011, 203) while "the great difficulty in services-based missing trader fraud is that the commodity evaporates in use" (Ainsworth 2010, 2). The measures recommended to combat fraud include in general automatic exchange information, real-time VAT payment, automatic data checks, and data reconciliation (Ainsworth 2010).

In the specific case of DaVAT, the tracking of false or inexact LCA declarations will be supported notably by comparison between LCA declarations of similar products. The effective implementation of *controls* and possible *sanctions* relates, respectively, to inspection and certification regulations, and to trade and customs laws. Regarding control, international agencies offering accredited testing, inspection, and certification services already exist in various fields (IFIA 2017). These agencies coordinate inspections to verify compliance with standards, guidelines, or recommendations. Inspections are in general carried out by an external competent authority at the request of, e.g., the importing State. Inspections can also be conducted by the local competent authority, if an agreement was concluded in this sense, e.g., a Mutual Recognition Agreement (WTO 2017). The coordination of controls of LCA declarations will be entrusted to an agency of this sort,

i.e., to the international regulatory agency as referred to above. This last mission of the DaVAT agency comes in addition to the three other ones already specified (i.e., coordination of *discussions* about *calculation methods* of I_x, setting and updating of the *default scores*, management of the *LCA for DaVAT database*). As for possible sanctions, laws of international trade authorize custom sanctions if the rules on "classification or valuation of products" and on "rates of duty, taxes or other charges" are not respected (GATT 1986, a. 10.1). The sanction shall be exercised "in a uniform, impartial and reasonable manner" (GATT 1986, a. 10.3) and shall be proportionate to the seriousness of the infringement. A minor sanction can take the form of pecuniary fines. A serious sanction can result in suspension of the marketing authorization or even in loss of the Authorized Economic Operator status (WCO 2016).

6 Price change estimates for six show cases

To what extent will good and service prices change at the time of DaVAT implementation? Giving a precise answer to this question is difficult at this time. On the one hand, because there is currently no standardized DaVAT database applying the same inventory, characterization, normalization, and weighting methods to all product categories. On the other hand, because the evolution of prices depends on many factors such as supply and demand, market expectations, access to basic necessities, price-control mechanisms, etc. We limit ourselves here to a purely indicative simulation performed from six published LCA studies on six products sold in different countries. The simulation calculates the direct effect of the DaVAT implementation on the prices of these products without taking into account other indirect market effects. Our conclusion indicates the way forward for a closer examination of the effects, notably economic, of the DaVAT.

Table 1 is based on the LCAs of six products selected, respectively, by Bimpeh et al. (2006), Fantin et al. (2012), Prudêncio da Silva et al. (2014), BIO Intelligence service-Ademe (2006), Cavalett et al. (2012), and Volkswagen AG (2010). The six studies use the CML method (Guinée et al. 2002). As stated in Sect. 4.1, the DaVAT system will only be consistent if it uses common databases and applies the same inventory, characterization, normalization, and weighting methods, as well as refers to the same impact categories and the same cut-off rules. The factors that are selected here (characterization and normalization factors of the CML method [Guinée et al. 2002], weighting factors equal to 1) by no means prejudge the choice of the standardized *LCA for DaVAT* which, it is recalled, should be made on the widest possible scale.

All the products correspond to the stage $i = f$, i.e., of the final selling to the end-user. Some functional units have been adjusted as compared with the original study[18] so as to better reflect the usual consumer behavior (for example, we usually buy 1 kg of chicken instead of one ton). To avoid double counting, and in accordance with the principles developed in Sect. 4.1.2, the emissions related to car and gasoline use have been halved.[19] For the same reasons, the emissions related to the washing and ironing of the pair of jeans have not been taken into account (these emissions are associated with the purchase of other products subject to DaVAT, and they depend little on the characteristics of the pair of jeans[20]). The system boundary is specified in each study. The *n.a.* in the table does not mean that there is no impact but that the impact category was not assessed in the study. For each product x, the environmental score I_x is simply the sum of the results of the normalized and equally weighted impact categories. In Table 1, we normalized the characterized results of the six studies listed above by relating them to the reference system *average world citizen for year 1995* proposed in Guinée et al. (2002). The normalized result for each category m is given by the formula:

$$Normalized \quad result[Nz_m](yr.cap) = \frac{Characterization \quad result[Cv_m](kg\,ref\,subst\,eq)}{Normalization \quad factor[Nf_m](kg\,ref\,subst\,eq.yr^{-1}.cap^{-1})}$$

As the environmental single score I_x is dimensionless, the normalized results Nz_m are multiplied by a weighting factor ($W_m = 1\ \text{year}^{-1}\ \text{cap}^{-1}$) canceling the dimensions of the normalized results. So, the score I_x (dimensionless) for each product x is calculated as follows:

$$I_x = \sum_{m=1}^{m} Nz_m.W_m$$

GDT is calculated in accordance with the formula given in Sect. 3:

$$GDT_{x_i} = \sum_{s=1}^{i} I_{x_s}.Fp.Fca$$

The factor *Fca* of currency area adjustment is set equal to 1. The summation index s here equals $i = f = 1$, as the results of the six studies cover all the life cycle of each product until the final purchase.

The factor *Fp* fixing the amount of the tax is arbitrarily set at 100 in a single currency (US $), which is equivalent to setting for example the price of the tCO_2eq at 14.64 US $.[21] It is interesting to note, looking at Table 1, that there is no need to raise the carbon price very high to obtain a rise in the price

[18] See more details on functional units, system boundary, normalization factors and price calculation in the Electronic Supplementary Material.
[19] See calculation details in the Electronic Supplementary Material
[20] See calculation details in the Electronic Supplementary Material
[21] See calculation details in the Electronic Supplementary Material

Table 1 Example of changing prices of six products according to their LCA

	1 kg of industrial white bread produced and bought in Sweden (Bimpeh et al. 2006)	1 l of milk produced and bought in Italy (Fantin et al. 2012)	1 kg of cooled and packaged chicken produced and bought in the Center-West of Brazil (Prudêncio da Silva et al. 2014)	1 pair of jeans produced in Tunisia, bought and used in France (BIO Intelligence service - Ademe 2006)	1 l of gasoline produced, bought and used in Brazil (Cavalett et al., 2012)	1 Golf V 1.6 MPI car produced, bought and used in Europe (Volkswagen AG 2010)
Climate change (kg CO_2 eq. $year^{-1}.cap^{-1}$)	−8.20E-05	2.20E-04	4.03E-04	3.88E-06	2.10E-05	1.80E-00
Stratospheric ozone depletion (kg CFC_{11} eq. $year^{-1}.cap^{-1}$)	4.54E-07	7.35E-07	n.a.	3.35E-08	3.60E-06	5.82E-03
Human toxicity (kg 1,4-DCB eq. $year^{-1}.cap^{-1}$)	4.25E-05	n.a.	n.a.	1.40E-06	3.09E-05	n.a.
Acidification (kg SO_2 eq. $year^{-1}.cap^{-1}$)	9.41E-05	1.87E-04	7.90E-04	1.81E-06	1.23E-04	1.20E-00
Eutrophication (kg PO_4^{3-} eq. $year^{-1}.cap^{-1}$)	1.85E-04	3.16E-04	8.73E-04	1.09E-06	5.13E-05	1.74E-01
Photo-oxidant formation (kg C_2H_4 eq. $year^{-1}.cap^{-1}$)	n.a.	3.36E-05	n.a.	1.03E-05	7.43E-05	1.16E-00
Depletion of abiotic resources (kg Sb eq. $year^{-1}.cap^{-1}$)	n.a.	n.a.	n.a.	7.40E-06	5.47E-04	n.a.
Marine aquatic ecotoxicity (kg 1,4-DCB eq. $year^{-1}.cap^{-1}$)	n.a.	n.a.	n.a.	n.a.	2.45E-03	n.a.
Freshwater aquatic ecotoxicity (kg 1,4- DCB eq. $year^{-1}.cap^{-1}$)	n.a.	n.a.	n.a.	1.31E-04	1.93E-04	n.a.
Terrestrial ecotoxicity (kg 1,4-DCB eq. $year^{-1}.cap^{-1}$)	n.a.	n.a.	1.93E-04	4.02E-05	4.02E-05	n.a.
I (Single environmental score)	2.40E-04	7.57E-04	2.26E-03	1.60E-04	3.53E-03	4.34E-00
GDT (Global Damage Tax) (US $)	0.02	0.08	0.23	0.02	0.35	434.06
Current pre-tax price (US $)	4.16	1.20	3.23	72.26	0.88	18,824.23
Current price VAT incl. (US $)	4.66 (VAT 12% incl.)	1.32 (VAT 10% incl.)	3.62 (VAT 12% incl.)	91.51 (VAT 20% incl.)	1.14 (VAT 30% incl.)	22,400.83 (VAT 19% incl.)
Adjusted price (RVAT 3% + GDT incl.) (US $)	4.31	1.31	3.55	78.56	1.26	19,823.01
Ratio Adjusted price/Current price VAT incl.	0.92	0.99	0.98	0.86	1.10	0.88

of fossil energy products. This is because the DaVAT takes into account many other impacts than climate change. Let us recall that the fixing of *Fp* remains a political decision which, as such, does not belong to the LCA (see Sect. 4.4). Fixing *Fp* means putting a generic monetary value on a (universally characterized, normalized and weighted) dimensionless environmental score. To identify the appropriate value of *Fp*, one can, e.g., compare the *Fp* value set by a country with those of other monetization methods (with respect to the prices associated with reference substances, or with respect to the costs associated with endpoint indicators). The Electronic Supplementary Material provides calculation details, and the price of the reference substances mentioned in Table 1 when *Fp* is set at 100 US $. They also include a comparison between these prices and those proposed by the monetization methods *Stepwise 2006* (Weidema 2009) and *Ecotax 2002* (Finnveden et al. 2006). Such comparisons can also be made in the context of the international discussions on the common weighting to be adopted in the DaVAT system. Expressing in monetary terms the weighted results at midpoint categories is also useful for producers and intermediaries, as it helps them identify the processes where savings (through GDT reduction) are possible. The *Fp* value can also be assessed with respect to the cost associated with an endpoint indicator—even if this type of assessment is much more delicate as it involves many uncertainties. For instance, using the endpoint characterization criteria of ReCiPe 2008 (Goedkoop et al. 2009), one finds that setting *Fp* at 100 US $ amounts to assigning to one equivalent year of healthy life lost (Disability-Adjusted Life Year, or DALY) a cost of 69,060 US $.[22]

The global damage tax (GDT) (in US $) is therefore here equal to I_x multiplied by 100 US $. *UVAT* is arbitrarily set at 3%. The adjusted price is calculated by replacing *VAT* with *UVAT* and by adding *GDT* to the result:

$$\textit{Adjusted Price of } x = \text{Pre-tax } \textit{price of } x.3\% + I_x.100 \text{ US}$$

We are aware of the arbitrary, incomplete, and unrepresentative character of Table 1. We nevertheless believe that, pending a more elaborate simulation (see points 3 and 4 of our conclusion), some observations can already be made.

6.1 Price increase of the most polluting products

Gasoline is the only product of Table 1 with increasing price. Should gasoline prices (taxes included) be lower, the risk of stimulating activities causing serious damage to the environment and health is probable. The increase in gasoline prices is here mainly due to two factors. The first factor is the amount of the *ad valorem* tax (VAT or sales tax) initially applied to the liter of gasoline in the country concerned (here: Brazil). The smaller this amount, the larger the potential for an upward price move. In Brazil, as in many other countries, taxes on gasoline are a mix of VAT (*ad valorem* tax) and excises (per-unit taxes). In our simulation, excises were included in the basic price of the liter of gasoline. The second factor is the values of *Fp* (here: 100 US $) and I_x—that is itself determined by the production, distribution, and use scheme of gasoline. I_x does not push up the prices of all fuels in the same proportion: this depends on their life cycle. The same goes for other energies. Admittedly, electricity often results from a mix of different production technologies. It is, however, already possible to associate to each kWh purchased at different stages in the life of electricity (power plant, high voltage, medium voltage, low voltage) a quantified inventory of the different technologies that produced it. These inventories, already practiced on large scales (Schmidt et al. 2011), should become more accurate with the DaVAT system. Each time a generator will sell electricity to another operator or customer, the sale price will include, as with any selling, the environmental impacts associated with the production of the functional unit in question (i.e., here, the kWh of electricity). These impacts will be transmitted throughout the supply chain, according to the mixing ratio of electricity sources, until they reach the end user. The prices of low-environmental-impact energies will therefore be lowered (not raised), if the *UVAT* rate is sufficiently low.[23]

Some increases (e.g., in fuel costs) are more acceptable in some countries than in others. In Table 1, a single coefficient *Fp* in a single currency US $ is applied to different countries, regardless of variations in the cost of living. This stresses the importance of setting *Fp* at the level and in the currency of each State. If a State is not ready to increase significantly the price of the most polluting products, it can still adopt the DaVAT by setting *UVAT* at a relatively high level, say, 10 or 15%. At constant income, this lowers the price *Fp* of environmental damage. This reduces but does not cancel down the economic and environmental effects of the DaVAT, since damages are integrated in one way or another in the price of products. Care should be taken that the DaVAT system is equitable, i.e., does not overly affect poor people. The DaVAT system should be accompanied by support measures to the benefit of low-income people so as to facilitate their access to low fuel consumption technologies, building insulation, and alternative transport modes. For more details on this topic, see Sect. 7 *Acceptability of the proposal*.

[22] See calculation details in the Electronic Supplementary Material

[23] More precisely: if the difference between the original *VAT* and the *RVAT* rates applied to the pre-tax price of the unit of energy is greater than the *GDT* related to this unit.

6.2 Price decrease of the low-polluting products

The prices of the other products in Table 1 are all lower, which has redistributive properties and is in line with the intention of the DaVAT to reduce the price of the products with lower environmental, human health, and resource depletion impacts. We should, however, be careful not to draw hasty conclusions from this. Firstly, the LCAs considered in Table 1 are not always complete. In particular, the LCA of the car does not take into account the marine aquatic ecotoxicity category, which has the heaviest weight in the environmental score of gasoline. Secondly, the amount of the tax depends on the *UVAT*, *Fp*, *Fca*, and weighting factors, which are all fixed arbitrarily here. As these coefficients are fixed by States (or, for the weighting coefficients, by the largest number of countries likely to adopt the DaVAT system), this reminds us that the States enjoy a large degree of freedom in the application of the DaVAT scheme. Fourthly, the amplitude of variation in product prices depends not only on the life cycle of the products, but also on their basic price and on their initial VAT. The higher the basic price and the initial VAT, the higher the potential for a downward price move.

6.3 Effectiveness of the price changes

Many differences in taxes may appear as not sufficiently large to cause a significant change in consumers' or producers' behavior. Several observations can be made in this respect. First, empirical evidence suggests that even a small tax on a product can reduce its consumption. For instance, in Ireland, a 0.15 € tax levied in 2002 on plastic shopping bags reduced their use by 90% (Convery et al. 2007). Even in cases of low elasticity of demand as with motor and heating fuels, carbon taxes seem "an effective instrument for curbing greenhouse gas emissions, yet are seldom implemented" (Baranzini and Carattini 2017, 17). In British Columbia, the levy in 2008 of a carbon tax gradually increased to 30 CAN $/tCO$_2$eq (corresponding to an increase of roughly 0.07 CAN $ per liter of gasoline) was accompanied by a 18.8% reduction of per capita consumption of fuels subject to the tax compared to the rest of Canada (Elgie and McClay 2013). Rivers and Schaufele (2012) showed that this reduction is 4.9 times greater than that expected from an equivalent increase in just the price of fuel (as opposed to a fuel tax). This is likely related to the fact that the provision of environmental information to consumers reduces their willingness to pay for the most polluting products (Michaud et al. 2017; Ji et al. 2017). DaVAT differs in this regard from other excises, in providing a visible and coherent signal to the consumers and markets. In 2014, a survey of 20,000 adults from five countries showed that one third of the consumers prefer buying products they identify as sustainable (Accenture 2014). This trend seems still greater, according to the same study, in emerging economies such as India, Brazil, and Turkey than in UK and in the USA, probably due to greater exposure to the adverse impacts of unsustainable production and trade practices (Accenture 2014).

A second observation is that the range of products presented in Table 1 is not representative. There are other high-polluting products whose prices should be immediately increased. Thirdly, as the factor *Fp* fixing the actual amount of the tax should increase over time, some damage which are cheap today might become expensive. At constant basic price, this increase in damage prices does not adversely affect the low-polluting products but, on the contrary, makes them comparatively more attractive. For instance, *Fp* raised to 300 US $ instead of 100 US $ increases, in Table 1, the price of the liter of gasoline in Brazil to 1.96 US $ (72% above the initial price) while the price of 1 kg of bread in Sweden, a pair of jeans in France, or the car[24] in Europe, remain, respectively, 6, 14, and 8% below their initial level, the prices of the other products of the table (milk and chicken) being increased by 11% (relative to the original price, which also depends on the initial VAT rate). Fourthly, one may wonder why bother to make LCAs for products whose environmental impacts are negligible compared to overall categories? Remember that, if these products do not belong to potentially high-polluting categories, it is not necessary to conduct an LCA for each product: their environmental score can be a *default* one. However, if a majority of citizens considers that the consumption of certain products is not sufficiently taxed *today* (e.g., for the specific environmental, health, social, or ethical reasons mentioned above), it is always possible to add a specific damage tax (SDT) on these products. As highlighted by several studies (Bishop 1993; Baumgärtner and Quaas 2009; Ekins 2011; Hay et al. 2014; Burritt and Schaltegger 2014), keeping the same valuation rules to measure environmental damage while taking into account the specificity of the human and social aspects of the development of each country (which here is done in particular through SDT) is not only cheaper (administrative simplicity). It is also more transparent and more coherent if we want to integrate the concern for environment, human health, resource depletion, and other aspects of sustainable development into the entire economic chain on a long-term basis.

7 Acceptability of the proposal

In Europe, surveys on attitudes of citizens towards the environment showed that the proposal of "making everyone pay more in taxes, prices etc. to cover environmental costs" was only supported by 6% in 2002 (European commission 2002b, 32). In 2011, 68% of the European citizens agreed or tended to agree with the statement that "taxation should be based more on the way we use energy" (European Commission 2011, 30).

[24] Let us recall that the LCA of the car seems particularly incomplete.

In 2014, 40% of them considered that "introducing heavier fines for offenders" is "the most effective approach in terms of tackling environmental problems" (European Commission 2014, 80). According to a recent survey, "perceived environmental effectiveness and expectation of local co-benefits are the main drivers of acceptability" (Baranzini and Carattini 2017, 18). Several studies have also shown that perception frequently changes after the implementation of environmental prices initiatives, as people experience less negative and more positive consequences than they expected in terms of perceived effectiveness, personal outcome expectations, and fairness of the system (Schade and Schlag 2003; Schuitema et al. 2010; Jagers et al. 2017). At the present time, the question has not been asked, in Europe or elsewhere, whether citizens support a measure that will (i) reduce the price of low-polluting products previously subject to VAT; (ii) increase by about 3% the price of the products previously not subject to VAT; (iii) increase the price of the most polluting products in proportion to their degree of pollution. As a result, one cannot know, at this stage, to what extent citizens support a DaVAT system.

Consumption taxes are sometimes considered unfair or inequitable because people with the lowest incomes pay the largest share in proportion to their income. This view is, however, contested as the efficiency of the consumption taxes enables public authorities to implement compensation and redistribution schemes (Bankman and Weisbach 2005; Decoster et al. 2010; Corbacho et al. 2013). Those schemes are in particular needed in the case of the development of environmental consumption taxes (Ekins and Dresner 2004; West and Williams 2004; Büchs et al. 2011; Kosonen 2012; Dissou and Siddiqui 2014; Beck et al. 2015; Yusuf and Resosudarmo 2015). In the DaVAT framework, the important thing to keep in mind is that the increase in most polluting products' prices is associated with a decrease in the price of the (most numerous) low-polluting products previously subject to VAT, which has redistributive properties. DaVAT is not an additional burden in general, but rather a shift of taxation, though negatively affecting some product categories. As with any tax shift, the possible increase in State revenue allows the government to reduce other levies, e.g., on income or on labor (Kosonen and Nicodème 2010). Besides, the price change can be modulated by each State according to its own specificities and should be accompanied by support measures to disadvantaged groups. Those measures should target first low-income households and should be oriented, as much as possible, to behavioral changes. For example, they can take the form of subsidies for purchasing *services* (home energy assessment, access to free or cheap public transport, car sharing, home delivery services…) and *goods* (thermal insulation system, low-energy heating system, low-environmental-impact car…). Public authorities should also provide support for strengthening the infrastructures needed for the good performance of the measures (development of public transport, availability of low-environmental-impact energy).

It should furthermore be noted that, on the one hand, a consumption tax is not the only tool, or even the best tool, for social redistribution. To achieving this goal, taxes on natural and legal persons and social expenditures programs are better suited (Atkinson and Stiglitz 1976; Decoster et al. 2010). On the other hand, the issue of equity cannot be reduced, in the DaVAT framework, to that of social redistribution. Consumption, whether by people on low or on high incomes, is not neutral. It can create (environmental, human health, and resource depletion) damages—of which the poorest populations are very often the first victims—or strengthen positive dynamics—for the existing population, but also for the future generations. From this point of view, a consumption tax is fairer if it strengthens consumer's access to the productions less harmful to the environment, resources and human health, and if it discourages the purchase of the more harmful ones.

8 Conclusions

A damage and value-added tax (DaVAT) partially based on the LCA of goods and services is conceived and expected to contribute to reduce human health, resources and environmental damages, displacements of pollution in time, space, and to other impact categories. The DaVAT is not a system of differential rates, as it only includes *two rates.* The first one (*UVAT*) applies to the *price* of all goods and services. The second one (*Fp*) applies to their *LCA score*. DaVAT also provides for the possibility to introduce additional specific damage taxes (SDT). As mentioned above, the main interest of the DaVAT is to contribute to reduce the overall environmental burden and the leakage and shifting effects of environmental impacts. In the coming years, those displacements of polluting releases will tend to be increasingly important. To take just the example of the development of alternative energy sources, many possible shifts can be evoked. They include, for instance, the heavy metal releases associated with the production of some photovoltaics (Fthenakis et al. 2009), the impacts of biogas systems on acidification (Varun et al. 2009), the effects of some bioethanol cultures on acidification, eutrophication and photochemical smog (Morales et al. 2015), or the carcinogenic risks associated with the construction of certain mini hydro power plants (Hanafi and Riman 2015). The manufacturing and recycling processes of wind turbines can also be improved from a human toxicity and terrestrial ecotoxicity point of view (Martínez et al. 2009). DaVAT is thus not only a tool to reduce the environmental impacts of our production and consumption activities, it also provides a new information and guidance tool for both businesses and consumers that should help them make good investment and purchase decisions and, notably, not to miss the turn of energy transition. Even when the overall aggregated environmental score I_x is not significantly modified (weak points being compensated by strong points), it is in

the interest of all intermediaries to minimize what can be minimized, in order to reduce the final price of the product and/or to increase their profit margin. Such a tool opens up another way of seeing the tax. DaVAT should be conceived not only as a burden reducing purchasing power, but as a means to guide economic activities in the right direction.

In the DaVAT system, an international agency specially created for the purpose will manage and deliver freely the LCA score of products and product categories. LCA will be mandatory for potentially high-polluting products or industries. Other businesses will have the choice, either of accepting the default LCA score provided by the agency, or commissioning a specific LCA at their own expenses. The LCA used to determine DaVAT is split as many times as there are purchases in the supply chain. In other terms, an LCA commissioned by an intermediary or an SME is limited to their own activities. The *LCA for DaVAT* seems to comply with the existing international standards in that matter but requires a specific standardization for this specific application (not for LCA in general). It will be *consistent* only if it applies everywhere the same inventory, characterization, normalization, and weighting methods, as well as the same impact categories and the same cut-off rules. To be effective and credible, the DaVAT should also be *transparent*, be *capable of evolving*, and *respect the sovereignty* of each State in matters of tax levying.

Some arguments in favor of the efficiency, feasibility, and acceptability of the DaVAT have been provided. Let us summarize them in the light of the concrete case mentioned in the introduction, i.e., the call upon the European Commission to explore the possibility of establishing differential VAT rates to promote "green" economy. Such differential VAT rates were not adopted for the following reasons: no *consistency* in the definition of the "green" criterion and of the limits of the system; risk of *rebound effect*; risk of *public loss of revenue*; products *evolution*; risk of *distortions between States*; risk of *non-integration of the tax in the prices*; *insufficiency to change behaviors* (elasticity) (Naess-Schmidt et al. 2008; Oosterhuis et al. 2008; Oosterhuis and Schaafsma 2010). Even though the DaVAT system focuses not specifically on the European Union and is not a system of differential rates, it appears capable of meeting, at least for certain points, the objections raised by the European Commission. Indeed, replacing most of the VAT or sales tax with a *unitary* global damage tax (GDT) based on the LCA of the goods and services gives a *coherent criterion* both for the identification of the taxed unit and for the method to calculate the amount of the tax. The limits of the system are set consistently since, according to the principles of LCA, it covers the *major impact categories* and *all stages of the product life* while aligning its subdivision, as the current VAT system, on the operations of selling and buying products. The risk of rebound effects is reduced, but not completely avoided, by two facts. First, the *price of the products having the greatest impact* on the environment, human health, and resource depletion will be *increased.* Second, the price of damage should *rise over time* if the socio-economic circumstances permit, and if scientific knowledge on the state of the environment warrants it. The risk of revenue loss for States is limited by the *extension of the tax to all goods and services*, the diversification and spreading of the taxable materials, and the *flexibility of the levers available to the States* (*Fp*, *Fca*, *UVAT*, SDT). The problems associated with the evolution of the products are limited by the fact that DaVAT is itself *evolving*, adapting to the increase of the environmental performance of the products (the factor *Fp* fixing the actual amount of the GDT being regularly indexed), to the evolution of our knowledge about it, and to the socioeconomic context. DaVAT respects the sovereignty of States (free to determine their own tax coefficients) while promoting convergence of policies, which *limits risks of distortion*. As GDT is a transparent and unitary tax (not an *ad valorem* tax), it *cannot be smoothed and hidden* by the decrease in the basic price of the product. Finally, DaVAT should encourage consumers, designers, producers, and intermediaries to *change* their *behaviors* because of its foreseeable evolution, the incentivizing of environmental benchmarking, and the possibility to introduce additional specific damage taxes (SDT). Let us add that the *price decrease of the low-polluting products* and the *support measures to the disadvantaged groups*, which can be seen as necessary companions of the DaVAT, make this tax an instrument for ensuring equity and social fairness.

DaVAT is not the only and final solution to all environmental problems, notably due to the inherent limitations of the LCA. LCA includes little or no potential *misuses* of a product. LCA does not provide a consensual criterion to integrate environmental impacts over *very long periods* (as for example with nuclear waste). LCA does not take into account the degree of *risk* associated with technologies, nor the *economic and social situation* of actors which can force some of them to use a particular pollutant (e.g., charcoal for heating or cooking). Therefore, it will always be necessary to set up more specific taxes, regulations, awareness campaigns, support, and compensation measures to disadvantaged branches of activity or persons.

The main interest of the DaVAT is to use the same valuation rules to measure environmental, human health, and resource depletion impacts into the entire economic chain, thus reducing the risks of delocalization and displacements of pollution while protecting competitiveness. DaVAT thereby brings more coherence into the current system of environmental taxation and, generally, more attention to the damages associated with products once they will be included in the price.

A closer examination of the DaVAT project and of the modalities of its implementation should be organized around four axes.

1 Modeling and simulation of the project on the basis of already available data, in order to estimate the

implementation costs and to verify that the system would provide the intended incentives.

2 Development, in consultation with all stakeholders, of an LCA method standardized specifically for use in DaVAT. LCA as a whole can stay as it is, but for use in DaVAT specific guidelines should be established. These guidelines should clarify inventory, characterization, normalization, weighting, and review processes, as well as a legal, administrative, and logistical common framework to implement, manage, and regularly update the DaVAT system.

3 Establishment, on the widest possible scale, of an LCA database giving the default scores for each category of goods and services and of the intermediates.

4 Modeling and simulation, from this database, of the economic, environmental, health, and social impact of the DaVAT, in order to provide the countries wishing to adopt the system with a reliable projection and analysis tool.

After its invention in France in 1954, VAT has been adopted by 161 countries worldwide and has become the tax accepted by the largest number of countries. Perhaps the DaVAT has the potential to spread so quickly to so many countries. The reason for the VAT's success is the economic neutrality of the tax, i.e., the fact that there is no cascade effect: the amount of the tax remains the same whatever the number of intermediaries involved in the supply chain. The reason for the success of the DaVAT could be the *refinement* of this economic neutrality: the amount of the tax remains independent of the *length* of the buying chain (i.e., the number of intermediaries), though not of the *patterns* of production and consumption, in other words of their environmental impact. One of the distinctive features of the VAT is to establish a *responsibility scheme* where each market participant is held accountable for collecting the tax. The DaVAT will extend this responsibility by making all producers, intermediaries, and consumers more attentive to the damage associated with their activities. At a time when environmental problems are increasingly widespread and many-sided, this additional attention seems not only acceptable, but also desirable.

Acknowledgments The authors would like to warmly thank the four JLCA's anonymous reviewers for their constructive and insightful comments, criticisms, and suggestions, which have greatly contributed to enrich the article. The views expressed here are those of the authors.

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