WORKING PAPER

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by

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University of Lüneburg
Working Paper Series in Economics

No. 311

October 2014

www.leuphana.de/institute/ivwl/publikationen/working-papers.html

ISSN 1860 - 5508

Value pluralism, trade-offs and efficiencies

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October 1, 2014

Abstract: Political decision-makers face increasing demands to justify their actions with respect to multiple normative objectives or values. Here, we provide a general philosophical-economic clarification of the discussion of value pluralism, value-efficiency (i.e. efficiency with respect to values) and feasible relationships between values. We derive what relationships between values can exist in states of affairs that are value-efficient. In particular, we show that in a value-efficient state of affairs there is a trade-off between at least two values, and that a win-win relationship between values is no indication of value-inefficiency when there are three or more values. Further, we connect these relationships to the opportunity costs of attaining a value to a higher degree. Lastly, we contrast Pareto-efficiency with value-efficiency and show that there can be a win-win relationship between values in a Pareto-efficient state of affairs. Our analysis provides insights that help decision-making in situations where there are multiple values at stake.

JEL-Classification: D63, H43, H00

Keywords: efficiency, value pluralism, value trade-offs, welfarism

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1 Introduction

Political decision-makers face increasing demands to justify their actions with respect to multiple normative objectives or values. Potential candidates for fundamental values are, for example, equality, efficiency, freedom, security, or justice. Whatever the values, there are two central questions (e.g. Barry 1965): first, about the *feasibility* of combinations of degrees of attainment of values; second, about the *desirability* of combinations of degrees of attainment of values. For example, LeGrand (1990) asks these questions with regard to the trade-off between equality and efficiency: Does an increase in income equality reduce economic growth? How should society balance the objectives relating to income equality and economic growth? Here, some (e.g. Dasgupta 2005, Cowen 2007) argue that answering the first question is more pressing because merely clarifying the feasibility of actions can help decision-making and reduce conflict between different ethical perspectives. For clarifying feasibility, it is important to know the (factual) relationship between values, e.g. whether there is a trade-off or a win-win relationship between income equality and economic growth.

Apart from the large literature on the equality-efficiency trade-off (Okun 1975, Putterman et al. 1998, Blank 2002), there are many more results on relationships between other values in the economics literature, such as between income inequality and intergenerational income mobility (Björklund and Jäntti 1997, Corak 2013), between income inequality and subjective happiness (Alesina et al. 2004), between economic freedom and economic growth (DeHaan et al. 2006), between poverty reduction and environmental degradation (Baland et al. 2010), or between Pareto-efficiency and poverty reduction in payments for environmental services (Engel et al. 2008). The relationships between values also feature in political debates, for example, in the one on the social effects of economic growth such as the World Bank's report on green growth (World Bank 2012).

Our aims here are (i) to provide a general philosophical-economic clarification of the discussion of value pluralism and relationships between values; (ii) to contribute to the discussion by deriving a number of original statements; (iii) and, thus, to provide insights that help decision-making in situations where there are multiple values at stake.

We proceed in two steps: Firstly, to conceptualize relationships between values carefully, we build on the philosophical literature for a definition of *value* in ethical theories and the debate on value pluralism. For example, it must be clear why equality and efficiency are values and why the relationship between the two is normatively meaningful. In this context it must also be clear whether equality and efficiency are instrumental to some other value such as social welfare or whether they are both intrinsic values. Secondly, we centrally employ the criterion of *value-efficiency*, i.e. efficiency with respect to values. This efficiency criterion is uncontroversial because it does not require weighing the degree of attainment of different values. Rather, it defines a state of affairs as value-efficient, if it is impossible to increase the degree of attainment of one value without necessarily reducing the degree of attainment of any other value.[1] This notion of efficiency has been more or less explicitly discussed in the philosophical and economic literature (e.g. Sen 1979a, LeGrand 1990, Raz 1997, Dasgupta 2005, Pattanaik and Xu 2012), but this literature has not directly discussed the question of how value-efficiency connects to relationships between values such as trade-offs and win-win relationships.

As a result, we derive what relationships between values can exist in states of affairs that are value-efficient. In particular, we show that in a value-efficient state of affairs there is a trade-off between at least two values, and that a win-win relationship between values is no indication of value-inefficiency when there are three or more values. Further, we connect these relationships to the opportunity costs of attaining a value to a higher degree. Lastly, we contrast Pareto-efficiency with value-efficiency and show that there can be a win-win relationship between values in a Pareto-efficient state of affairs.

This provides a unifying perspective for the interpretation of the many specific results on relationships between particular values such as the examples given above on relationships between economic growth, income equality and economic freedom. Also, these results on relationships between values and value-efficiency provide insights that help decision-making in situations where there are multiple values at stake.

The paper is structured as follows. Section 2 reviews the philosophical literature

[1]It is undisputed that inefficient policy-making is considered bad. For good policy-making to be good it is necessary to be efficient.

and gives a definition of value. Section 3 introduces a microeconomic model, gives a definition of value-efficiency and a definition of different relationships between values. Section 4 discusses the connection between Pareto-efficiency and value-efficiency. Finally, Section 5 concludes.

2 Philosophical background

2.1 Definition of value

For the analysis of relationships between values one must be clear on what a *value* is and what it is not. Many definitions[2] of value focus on 'good' states of affairs. The examples from the introduction on values such as equality or efficiency also imply statements on good states of affairs, i.e. a state of affairs is better if it is more equal or more efficient. In light of this, we define a value in the spirit of Hurka (2006) and Chang (1997b) as follows:

Definition 1 (Value)
A *value* is a consideration which allows a comparison of states of affairs in terms of their goodness.

This definition refers to *states of affairs* which excludes rules and procedures from the definition of value.[3,4] A *comparison* examines the differences between different states

[2]For Chang (1997b: 5) a value "is any consideration with respect to which a meaningful evaluative comparison can be made". Hurka (2006: 357) says that a theory of value determines "which states of affairs are intrinsically good and which intrinsically evil". Zimmerman (2010) refers to Scanlon (1998: 97) who has called the relationship between valueableness, goodness and intrinsic properties "a buck-passing account, since it "passes the buck" of explaining why something is worthy of being valued from its goodness to some property that underlies it" (Zimmerman 2010: Sec. 2).

[3] A "state of affairs" corresponds to what Chang (1997b), more generally, calls a "bearer of value" or "items".

[4] Sen (2000) suggests a broad conception of states of affairs and refers to "comprehensive outcomes" that include the processes of choice such as actions performed and underlying motivations as well as final outcomes. We define states of affairs more narrowly in order to relate to the established literature.

of affairs in terms of a *consideration*. What constitutes the *goodness* of a state of affairs is determined in an ethical theory. For example, the conception of goodness in 'outcome utilitarianism' says that a state of affairs is better than another one if its sum of individual utilities is larger (Sen 1979b). Of course, there can be different conceptions of goodness, for example, there can be different equity criteria over individual utilities (Sen 1979a: 548) or non-preference metrics for individual advantage such as the capability approach (see e.g. Sinnott-Armstrong 2012).

The definition of value only allows to compare states of affairs in terms of their goodness. It does in itself not answer the fundamental question in ethics on how to act. One answer to this question is provided in 'act consequentialism' which says that an action is right if it brings about a state of affairs which is at least as good as each alternative state that results from any other feasible action (Sen 1979b: 464). That is, an action is right if it brings about the best consequences (Hurka 2006: 357). For example, 'act utilitarianism' says that an action is right if it leads to a state of affairs with a larger sum of individual utilities than any other feasible action. That is, act utilitarianism is based on act consequentialism and outcome utilitarianism (Sen 1979b).

Consequentialist ethical theories exclude other ethical theories such as deontological ethics which determines the right action without reference to good consequences or virtue ethics which relies on questions of moral character (Copp 2006: 20). This also means that relationships between values are most relevant for consequentialist ethical theories. For example, if there is a trade-off between values then determining the right action under consequentialism may require balancing of the different degrees of attainment of values with respect to a fundamental value. This raises the further question whether there is a 'fundamental' or intrinsic value. We follow Zimmerman (2010: Sec. 2) to define an intrinsic value as follows:

Definition 2 (Intrinsic value)
An *intrinsic value* is a value which allows a comparison of states of affairs in terms of their intrinsic goodness, i.e. goodness that is not derived from some other goodness.

For example, the intrinsic value in Bentham's utilitarianism (1907 [1789], 1988 [1776])

is aggregate happiness as it is not derived from some other value. A counterexample is an instrumental value that contributes to an intrinsic value.[5,6] For example, Pareto-efficiency is an instrumental value to social welfare as a Pareto-inefficient state can never maximize any function defined over individual utilities. Likewise, political liberties are sometimes seen as instrumental values to ensure other liberties such as civil liberties and liberty of conscience (e.g. in Rawls 1987: 13).

With this philosophical framework one can distinguish between an intrinsic value such as equality in egalitarianism and an instrumental value such as Pareto-efficiency for social welfare. This distinction is important because formulating relationships between instrumental and intrinsic values can be problematic, for instance, if not all intrinsic values are clearly defined. For example, some have questioned whether the trade-off between efficiency and equity is a normatively meaningful relationship because efficiency is an instrumental value and equity is an intrinsic value (LeGrand 1990). In this sense, a trade-off between equity and efficiency begs the question what the intrinsic value behind efficiency is. If the trade-off is assumed to be between intrinsic values, then this requires justification why Pareto-efficiency is an intrinsic value in the same way as equity (LeGrand 1990: 566).

2.2 Value pluralism

With regard to intrinsic values, there is the question if there is one single intrinsic value to which all values can be reduced to. The idea that all values can be reduced to one single intrinsic value is called *value monism* (Mason 2011). An example of value monism is Bentham's utilitarianism (1907 [1789], 1988 [1776]) where only aggregate happiness

[5] On the question whether every value that is not intrinsic is an instrumental value see Zimmerman (2010: Sec. 2)

[6] Chang (1997b: 9) uses a similar framework when she talks about values. For her bearers of value (here state of affairs) are compared in terms of their merits (here attributes) with respect to a covering value (here intrinsic value). And a covering value (here intrinsic value) can rely on different contributory values (here instrumental values). She then defines comparativism as the view that justified choice requires the comparison of bearers of values.

is intrinsically good and all other values are instrumental to this one intrinsic value. Under value monism one can formulate relationships between instrumental values. For example, if social welfare is the intrinsic value this allows trade-offs between different constituents of well-being, such as consumption, leisure or health and education (e.g. in Dasgupta 2005: 241).

If it is impossible to reduce all values to one intrinsic value, this is value pluralism:

Definition 3 (Value Pluralism)
An ethical theory is characterized by *value pluralism* if it is based on multiple intrinsic values.[7]

Value pluralism is found in the work of philosophers such as Isaiah Berlin (Berlin 1969) who speaks of different concepts of liberty and other values such as equality or justice. Also, Brian Barry speaks of a "plurality of 'ultimate' values" (Barry 1965: 5) such as equality and freedom when he discusses political arguments on normative objectives. Ethical theories under value pluralism allow the formulation of relationships between intrinsic values. For example, under value pluralism there can be a trade-off between the intrinsic value of social welfare and the intrinsic value of nature. Similarly, one could think of the relationship between intra- and intergenerational justice in sustainability problems as a relationship between intrinsic values (e.g. Baumgärtner et al. 2012).

With regard to desirability, value pluralism can create problems for decision-making such as incomparability which results from incomplete orderings of a set of states of affairs (see Sen 1985: 179, Chang 1997b).[8] For example, it can be that there are two acts that lead to two states of affairs where one has a higher degree of attainment of

[7] Sen (1985: 178) argues that value pluralism is different from informational pluralism: That is, there can be one intrinsic value (value monism) which subsumes many different kinds of information such as one conception of social welfare that relies on utility and non-preference information. Or there can be multiple intrinsic values (value pluralism) that are all based on the same kind of information such as different social welfare functions that are all based on utility-information.

[8] Hsieh takes 'incommensurability' to refer to the relation between values in the abstract sense and 'incomparability' to refer to the relation between concrete bearers of value which are states of affairs in this analysis (Hsieh 2008: Sec. 1.2).

one intrinsic value such as intergenerational equity, and the other has a higher degree of attainment of another intrinsic value such as intragenerational justice. In order to determine one right action in this context, one cannot use another more 'fundamental' value to balance the degree of attainment of the two values as both are intrinsic values. Nevertheless, there exist several approaches to decision-making under value pluralism (e.g. Mason 2011: Sec. 4).[9]

Value pluralism and value monism comprise different ethical theories which has consequences on how the set of feasible states of affairs in terms of values is defined. Ethical theories under value monism view the set of feasible states of affairs in terms of one intrinsic value and multiple instrumental values. This means there can be trade-offs between instrumental values such as equality and economic growth with regard to an intrinsic value such as utilitarian social welfare. Ethical theories under value pluralism view the set of feasible states of affairs in terms of multiple intrinsic value and multiple instrumental values. This means there can be trade-offs between intrinsic values such as social welfare and the intrinsic value of nature. Also, there can be normatively meaningful trade-offs between instrumental and intrinsic values under value pluralism. Yet, these require that all intrinsic values are explicated to allow a clear interpretation of this relationship.

The concrete form of the set of states of affairs plays a big role in the difficulty of decision-making, irrespective of the distinction between value pluralism and value monism. For example, if the feasible set does not force one into making trade-offs be-

[9] Mason (2011: Sec. 4) lists the following approaches: The first approach is practical wisdom (e.g. Anderson 1993, Nagel 1979). Practical wisdom solves problems of incomparability due to multiple intrinsic values without reasoning from general principles, but rather with a faculty of judgement. The second approach uses covering values to determine the weight of each intrinsic value for each circumstance of decision-making (e.g. Chang 1997b). These covering values are said not to be a case of value monism as they always depend on the concrete choice situation. The third approach (suggested by Joseph Raz 1999) who says that one is free to choose among "rationally eligible" options, i.e. states of affairs that are not dominated by others. The fourth approach, says that rather than trying to achieve a rational choice under value pluralism one should accept irresolvable conflicts between values (Williams 1981).

tween values, decision-making is easy – the higher attainment of one value necessarily increases the attainment of any other value and one can attain a value without compromising any other value. For example, if the feasible set showed that equality and economic growth are always in a win-win relationship, this would also ease political debates on this issue considerably. On the other hand, if the feasible set forces one constantly into making trade-offs between values, then decision-making is rather more difficult. In the following, we therefore want to focus our analysis on the feasible set and the relationships between values.

3 Formal model and analysis

3.1 Actions and states of affairs

In order to relate the model to the discussion on ethics and act consequentialism in particular, we consider states of affairs, which can be thought of as the outcome of a particular action. A *state of affairs* $y \in Y \subseteq \mathbb{R}^m$ is a complete description of the world in terms of m different attributes, so that $y = (y_1, ..., y_j, ..., y_m)$. Thus, the set Y can be thought of as the set of feasible states of affairs in terms of attributes. These attributes y_j contain continuously measurable information on, for example, stocks such as physical, social, human and natural capital; on flows such as payoffs, income, and environmental (dis-)services; and on individuals such as their number, the distribution of income, capabilities, and resources over individuals. We assume that the set of states of affairs Y is non-empty, closed and bounded and, thus, a compact set. Further, superscripts denote different states of affairs, such as y^a and y^b. Here, the assumption is that all these attributes are continuously measurable or at least representable, prima facie, via indicators, which allow to measure distance in Y-space.[10] For example, a state of affairs could contain attributes on the income distribution or the level of gross domestic product (GDP).

[10] This excludes the use of discrete attributes as in e.g. Pattanaik and Xu (2012).

3.2 Value relation and single-value index function

As discussed in Section 2 different ethical theories determine values differently. Therefore, the *value set* V contains $l = \#V$ values where $v \in V$ denotes a value in the set V. The concrete nature of these values and the number l of values are determined within a given ethical theory. In this way, the value set should only contain values which allow meaningful relationships (see Section 2). For example, under value monism a value set V with $l = 1$ contains one intrinsic value such as utilitarian social welfare. In the same way, V could contain multiple values $l > 1$ under value monism if there are different instrumental values to the single intrinsic value. Alternatively, under value pluralism, V with $l > 1$ could contain different intrinsic values. As we are interested in relationships between values, formulations of value sets with more than one value are most relevant to our analysis.

For the comparison of states of affairs there exists a value relation for each value.

Definition 4 (Value relation)
A *value relation* $\succeq_v$ is a binary relation on the set of states of affairs Y with respect to a value $v \in V$, where $y^a \succeq_v y^b$ means that y^a is as at least as good as y^b in terms of value v.

For example, under egalitarianism income inequality could provide a value relation for the value of equality. In economics the properties of value relations are discussed in the social choice and fair social orderings literature (e.g. Fleurbaey et al. 2005). Also, in philosophy there has been some discussion on the properties of value relations in recent years (e.g. Rabinowicz 2008). The traditional framework includes three value relations: *better than*, *worse than* and *equally good as* ("trichotomy thesis") (Chang 1997b: 4).[11]

[11]These value relations can be derived from the relation $\succeq_v$ as follows: *better than*: $y^a \succ_v y^b$ if and only if $y^a \succeq_v y^b$ and not $y^b \succeq_v y^a$; *worse than*: $y^a \prec_v y^b$ if and only if $y^b \succeq_v y^a$ and not $y^a \succeq_v y^b$; *equal to*: $y^a \sim_v y^b$ if and only if $y^a \succeq_v y^b$ and $y^b \succeq_v y^a$. Chang (1997a, 2002a, 2005) has suggested a fourth value relation that she called "on a par" where two states of affairs are comparable, yet not better than, worse than or equal to another. Boot (2009) comments that this debate is not directly relevant to justified choice as it creates the same problems as incomparability between bearers of value

The properties of value relations are directly relevant for decision-making under act consequentialism as these determine the ordering of states of affairs with respect to a value (see e.g. Sen 1970b: 9). Common assumptions on the properties of value relations are the following:

Definition 5

A value relation $\succeq_v$ is

- *reflexive*, if and only if for all $y^a \in Y$ one has: $y^a \succeq_v y^a$
- *transitive*, if and only if for all $y^a, y^b, y^c \in Y$ one has: $y^a \succeq_v y^b$ and $y^b \succeq_v y^c$ implies $y^a \succeq_v y^c$
- *complete*, if and only if for all $y^a, y^b \in Y$ one has: $y^a \succeq_v y^b$ or $y^b \succeq_v y^a$ (or both)
- *anti-symmetric*: if and only if for all $y^a, y^b \in Y$ one has: $y^a \succeq_v y^b$ and $y^b \succeq_v y^a$ implies $y^a = y^b$
- *continuous*, if and only if for any sequence of pairs $\{(y_n^a, y_n^b)\}_{n=1}^{\infty}$ with $y_n^a \succeq_v y_n^b$ for all n, $y^a = \lim_{n\to\infty} y_n^a$, and $y^b = \lim_{n\to\infty} y_n^b$, one has $y^a \succeq y^b$
- *lexicographic* for two attributes[12], if and only if there exist two attributes $y_i, y_j \in \{y_1, ..., y_m\}$ for which one has: $y^a \succeq_v y^b$ if and only if $y_i^a > y_i^b$ or $y_i^a = y_i^b$ and $y_j^a \geq y_j^b$.

Each of these assumptions on value relations can be, and has been, criticized in philosophy. For example, Broome (1991: 18) considers reflexivity and transitivity as the prime characteristics of rationality. Hausman (1993) criticizes just these characteristics with respect to value relations due to the vagueness of some normative predicates. The assumption of completeness excludes cases where no value relation holds between states

where no value relation holds. Thus, for the course of this analysis we will not consider parity as a fourth value relation.

[12]This is a very special lexicographic ordering of attributes but which still captures the intuition on priority of an increase in one attribute over any increase in other attributes. A more general treatment of lexicographic relations can be found in e.g. Hougaard and Tvede (2001).

of affairs and, therefore, excludes problems of incomparability and incommensurability which are sometimes highlighted in philosophical reasoning (e.g. Chang 1997a, Hsieh 2008). Still, completeness of each respective value relation allows us to model incomparability. That is, two states of affairs $y^a, y^b \in Y$ can be incomparable in terms of values, if two intrinsic values $v, w \in V$ individually can provide a complete ordering of states of affairs, but differ in their ordering regarding of the two states, e.g. $y^a \succ_v y^b$ and $y^a \prec_w y^b$. Then, both states of affairs are ordered completely with respect to $v, w \in V$, but y^a is better than y^b in terms of v and worse in terms of w, so that the two states of affairs are incomparable in the sense that it is impossible to rank one over the other.

A prominent discussion on a complete and transitive value relation is the social ordering in Arrow's impossibility theorem (Arrow 1951). It shows the impossibility of establishing a complete and transitive social choice function from ordinal non-comparable utility information and further axioms (see e.g. Roemer 1996). Still, there are different interpretations of Arrow's impossibility theorem. A rather optimistic one is provided by Sen (1999) who highlights the different possibilities of making interpersonal comparisons in terms of incomes, primary goods, or basic needs. The difficulty in finding and constructing such complete and transitive social orderings for the social evaluation of states of affairs has long been debated for example in the related discussion on indices for distributive justice (e.g. Fleurbaey 2007). A salient example is Rawls's (1971) theory of justice which uses primary goods as its metric of individual advantage to identify the worst-off individuals which creates the need to construct a suitable ordering for the comparison of individuals.

The more technical assumption of continuity excludes some value relations that might be relevant in ethical theories. For example, lexicographic value relations are not continuous as they give priority to an increase in one attribute irrespective of any increases in some another attribute. An example for this is John Ralws lexicographic ordering of basic liberties before prosperity in his difference principle (Rawls 1971: Sec. 8) or James Griffin's (1986: 83) discussion of cases where one attribute trumps another.

Different combinations of these assumptions establish different orderings over the set of states of affairs (as in Sen 1970b: 9). In this way, these assumptions are linked to

a maximizing account of consequentialism which says an action is right if it leads to a state of affairs with the highest possible degree of attainment of a value (e.g. Broome 1991, Sinnott-Armstrong 2012).

Under certain assumptions on value relations there exists an index function that represents the ordering of a value relation.

Definition 6 (Index function)
A function $I_v : Y \to \mathbb{R}$ is an *index function* representing value relation $\succeq_v$ if and only if, for any $y^a, y^b \in Y$,

$$y^a \succeq_v y^b \Leftrightarrow I_v(y^a) \geq I_v(y^b)$$

The index function I_v is an index of value v and shows the degree of attainment of this value.

Lemma 1 (Existence of index function)
If the value relation $\succeq_v$ is complete, transitive and continuous on Y, then there exists a continuous index function I_v: $Y \to R$ which represents the value relation $\succeq_v$

Proof. By analogy the standard proof for the existence of a utility function applies, see e.g. MasColell et al. (1995: 47). □

An example of such an index function is a utility function which show the degree of attainment of the value of an individual preference. Another example are Bergson-Samuelson social welfare functions $W(\cdot)$ which show the degree of attainment of social welfare as a function of individual utilities U_i (e.g. Suzumura 1987). Despite Arrow's impossibility theorem and the associated debate on its axiomatic foundation, social welfare functions that are based on interpersonally comparable utility information are used in areas of applied economics such as the economics of climate change (e.g. Stern 2007).

3.3 Value pluralism and value-efficiency

As discussed in Sections 2 and 3.1, the value set V can contain one single or multiple values depending on the respective ethical theory. For example, it can contain one

intrinsic value under value monism or multiple intrinsic values under value pluralism. Given such a value set V one can define value-efficiency as follows:

Definition 7 (Value-efficiency)
A state of affairs $y \in Y$ is *value-efficient* if and only if there exists no other state of affairs $y' \in Y$ for which $y' \succeq_v y$ for all $v \in V$ and $y' \succ_v y$ for at least one $v \in V$.

This criterion is in line with the maximizing account of consequentialism, as discussed above, where a state of affairs with a higher attainment of one value is always better than one with a lower degree of attainment. Indeed, value-efficiency provides some guidance for actions as it characterizes those actions as bad that lead to value-inefficient states of affairs. As value-efficiency itself is not a very demanding concept it provides room for many consequentialist ethical theories that are based on different definitions of value. Some authors have gone further and suggested value-efficiency as a criterion for choosing states of affairs under value pluralism. For example, Raz (1997) says that under intrinsic value pluralism any value-efficient state of affairs can be chosen with free will (what he calls 'rationally eligibile' states of affairs). Similarly, Brun and Hirsch-Hadorn (2008) determine value-efficient states of affairs concerning the multiple values within the sustainability concept.

In economics this notion of value-efficiency has also been mentioned and discussed. For example, Sen (1979a: 553) refers to 'dominance' with respect to normative considerations and discusses its difference to Pareto-efficiency under value pluralism. LeGrand (1990: 559) specifically uses the notion of value-efficiency in his discussion of the equity-efficiency trade-off. Pattanaik and Xu (2012) discuss dominance with respect to evaluative attributes and the use of context-specific information in decision-making. Others have noted the limited usefulness of value-efficiency for decision-making as it provides only incomplete orderings of states of affairs (Sen 1985: 178). Finally, Dasgupta (2005) shows the range of values that can be incorporated in economic analysis by distinguishing Pareto-efficiency which is based solely on utility information from broader 'efficiency' which is based on utility and non-preference information. Based on these specific contributions, we will further discuss the relationship between Pareto-efficiency

and value-efficiency in Section 4.

With Definition 7 of value-efficiency, one may ask under what conditions there exist value-efficient states of affairs for different values. If the set of states of affairs Y is a finite set and $\succeq_v$ satisfies reflexivity, completeness and transitivity for all $v \in V$, then there exists at least one value-efficient element (Sen 1970b: 30). If Y is an infinite set and $\succeq_v$ additionally satisfies continuity, then there exists at least one value-efficient element due to the Bolzano-Weierstrass theorem. There exists a broad literature on the existence of maximal elements with weaker continuity and transitivity axioms following Bergstrom (1975) and Walker (1977). For the case of lexicographic value relations there are several results on the existence of value-efficient states (e.g. Houy and Tadenuma 2009). Altogether, the discussion shows that there exist value-efficient state of affairs for values that satisfy many different properties and for different sets of states of affairs. For example, there exists a value-efficient state if some values are lexicographic, such as priority of the worst-off, and others are continuous, such as indices for income inequality.

3.4 Relationships between values

As argued in Section 2 the form of the set of feasible states of affairs and relationships between values impact on the difficulty of decision-making. This leads us to distinguish the following relationships[13] between two values. Also, for value sets with more than two values $l > 2$, we will continue with pairwise relationships between two values.

Definition 8 (Relationships between values)
In a feasible state of affairs y a *relationship* R between two values $v, w \in V$ is a binary relation on $V \times V$, denoted as vRw, with the following special cases:[14]

(i) R is a *trade-off* relationship if and only if $y' \succ_v y$ implies $y' \prec_w y$ for all $y' \in Y$

[13] These relationships are common in many discussions, e.g. LeGrand (1990), Engel et al. (2008), Glotzbach and Baumgärtner (2012), and Baumgärtner et al. (2012).

[14] More generally, relationships may be defined for a local environment around the state of affairs $y \in Y$ in which the condition(s) must hold. This leads to the additional condition on y' that $\|y' - y\| \leq \varepsilon$ for $\varepsilon > 0$.

(ii) R is a *win-win* relationship if and only if $y' \succ_v y$ implies $y' \succ_w y$ for all $y' \in Y$

(iii) R is an *independence* relationship if and only if there exists $y', y'' \in Y$ such that $y' \succ_v y$ implies $y' \succ_w y$ and $y'' \succ_v y$ implies $y'' \sim_w y$

The relationships R are defined as directed relationships from one value v on another value w. The converse relationship only holds if R is symmetric.[15,16]

The most familiar relationship (i) is the one of a *trade-off* between values. A trade-off is the case when attaining one value to a higher degree necessarily reduces the degree to which one attains the other one. This is a symmetric relationship which holds both ways. An example from the introduction is the trade-off between efficiency and equality.

The next relationship (ii) is the one of a *win-win relationship* between values. A win-win relationship is the case where achieving one value facilitates achieving the other one, that is, attaining one value to a higher degree induces a higher degree of attainment of the other one. This is an asymmetric relationship which does not necessarily hold both ways. An example from the introduction is the win-win relationship between income equality and intergenerational income mobility.

The last relationship (iii) is one of *independence* between values. Independence is the case when values can be achieved independently, that is, attaining one value to a higher degree does not necessitate any change in the degree to which one attains the other one. An example is the case where the intragenerational distribution of CO_2 emission permits is independent from the intergenerational distribution of CO_2 emission permits, so that the attainment of intragenerational distributive justice is independent of the attainment of intergenerational distributive justice.

These relationships are illustrated in Figure 1 for the case of a feasible set of states

[15]A trade-off relationship is always symmetric in that one value trades-off with another. Win-win relationships and independence relationships are not symmetric. For example, it can be that relationships are only onesided as illustrated below in Figure 1.

[16]If some value relation does not satisfy completeness, then there could be incomparability as a relationship where one value is attained to a higher degree $y' \succ_v y$, the two states are incomparable with regard to another value w.

of affairs (depicted in value-space) with two values $v, w \in V$.[17] The axes in this figure show the degree of attainment of values v and w via the respective index functions I_v and I_w. A point in this figure represents a state of affairs such as y^b which results from an action. The black boundary line is the frontier which delimits states of affairs that are feasible, those inside the grey area, from states of affairs that are not feasible, those inside the white area. The north-eastern part of the frontier, between y^c and y^d shows all value-efficient states of affairs. In y^a there is an independence relationship between

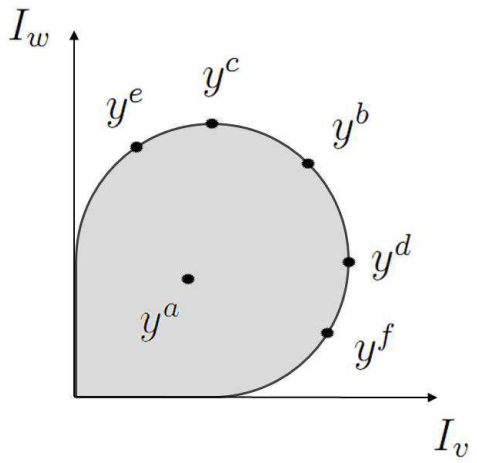

Figure 1: Convex set of feasible states of affairs in value-space for two values $v, w \in V$. The axes show the degree of attainment of values v and w via the respective index functions I_v and I_w. Each point in the figure corresponds to a state of affairs that results from a specific action. The black frontier delimits feasible states of affairs in the grey area from not feasible ones in the white area. Value-efficient states of affairs are on the frontier between y^c and y^d. There are different relationships in different states of affairs: Trade-off relationship in y^c,y^b,y^d; Win-win relationship in y^e,y^f; Independence relationship in y^a. Adapted from Baumgärtner et al. (2012).

[17] The shape of the set of feasible states of affairs Y in value-space as in Figures 1 and 2 relies on further assumptions regarding the feasible set Y in attribute-space that go beyond the ones made in Section 3.

values v and w as the attainment of either value can be increased *without necessarily changing* the attainment of the other. In y^e there is a win-win relationship between values v and w as an increased attainment of w *necessarily increases* the attainment of v. Yet, this win-win relationship is only onesided as the attainment of v can be increased without necessarily increasing the attainment of w. In y^f the opposite case of win-win relationship is depicted. In any state of affairs along the frontier between y^c and y^d there is a trade-off relationship between the attainment of values v and w as attaining either one to a higher degree *necessarily reduces* the degree of attainment of the other one.

Figure 2 illustrates the relationships between values for the case of a feasible set of states of affairs (again depicted in value-space) with three values $u, v, w \in V$. Correspondingly, there are three axes in this figure which show the degree of attainment of values u, v and w via the respective index functions I_u, I_v and I_w. The surface of the set in value-space, which is indicated by the thin black lines, delimits states of affairs that are feasible, those inside the grey volume, from states of affairs that are not feasible, those inside the white volume. Also, the surface shows all value-efficient states of affairs. In y^a there is a trade-off relationship between v and w as increasing either one *necessarily reduces* the attainment of the other value. Also, there is an independence relationship between v and u as increasing the degree of attainment of v can either lead to an increased attainment of u (by going from y^a to y^c) or remain on the same level of attainment (by going from y^a to y^b). There are no win-win relationships in Figure 2 as in no state of affairs the increased attainment of one value *necessarily increases* the attainment of any other.

From Figures 1 and 2 the connection between a trade-off between values and efficiency becomes apparent:

Proposition 1 (Value-efficiency and relationships between values)

(i) If there exist at least two value-efficient state of affairs, then in every value-efficient state of affairs there exists at least one trade-off relationship between two values $v, w \in V$.

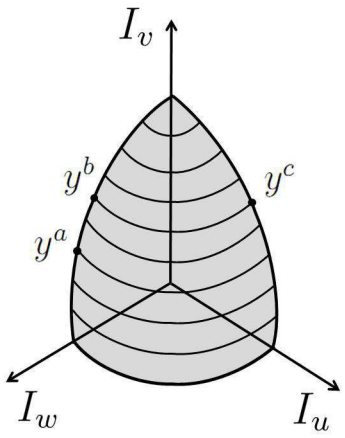

Figure 2: Convex feasible set in value-space for three values $u, v, w \in V$. The three axes show the degree of attainment of values u, v and w via the respective index functions I_u, I_v and I_w. Each point in the figure corresponds to a state of affairs that results from a specific action. The surface of the set in value-space, indicated by the thin black lines, delimits states of affairs that are feasible in the grey volume from states of affairs that are not feasible in the white volume. The surface also contains all value-efficient states of affairs. There are different relationships in between different values in a state of affairs: In y^a there is a trade-off relationship between v and w and independence relationship between u and v.

(ii) If in a state of affairs $y \in Y$ there is a trade-off between at least two values $v, w \in V$, then y is value-efficient.[18]

(iii) If there exist at least three values in the value set, $\#V = l \geq 3$, there can be win-win relationships or independence relationships between values in a value-efficient state of affairs.

Proof. See Appendix A.1 □

[18]If one considers locally defined relationships this may not hold as it may be that in a value-inefficient state there are trade-offs in a local environment.

This means that win-win relationships between two values do not necessarily indicate value-inefficient states of affairs. Rather, the absence of value trade-offs is a clear indication of a value-inefficient state of affairs. For example, suppose there are three values such as income equality, intergenerational income mobility and overall economic well-being as indexed by GDP. There can be a win-win relationship between income equality and intergenerational income mobility in a value-efficient state of affairs. Yet, it must be that there is a trade-off with GDP and economic well-being as this state of affairs would otherwise not be value-efficient. If the value set contains only two values $\#V = l = 2$ then there is always a trade-off between these values in any value-efficient state of affairs. This can be illustrated in Figure 1 where the increased attainment of one value reduces the attainment of the other in all value-efficient states on the frontier between y^c and y^d.[19]

3.5 Opportunity costs

The concept of opportunity costs is closely related to different relationships between values. We define opportunity costs between values as follows:

Definition 9 (Opportunity costs)
The opportunity cost of value $v \in V$, in units of value $w \in V$, is the minimal amount, given the set of feasible states of affairs Y, of value w that one has to forego to attain an additional unit of value $v \in V$. In particular, if an index function exists for values $v, w \in V$, the marginal opportunity costs of achieving a value v to a higher degree, in units of value w foregone, in a value-efficient state $y \in Y$ are:

$$C_{v,w}(y) = dI_w(y)/dI_v(y) \ . \tag{1}$$

[19]More generally, the analysis of pairwise relationships between two values proved limited for cases where more than two values are involved. For example, in this case the information on win-win or trade-off relationships between two values must be interpreted much more carefully in light of the effects on other potentially involved values. A possibility would be to define binary relationships between values with the *ceteris paribus*-provision that *the degree of attainment of all other values remains constant.* This would ensure that there are only trade-offs between values in a value-efficient state of affairs.

Proposition 2 (Opportunity costs and relationships)
The sign of opportunity costs, if they are defined, corresponds to the relationship vRw between values $v, w \in V$ in a state of affairs $y \in Y$:

(i) if R is a trade-off, then opportunity costs of v in units of w are positive.

(ii) if R is a win-win relationship, then opportunity costs of v in units of w are negative.

(iii) if R is an independence relationship, then opportunity costs of v in units of w are zero or negative.

Proof. See Appendix A.2. □

This can be illustrated in Figure 1 for the case of two values $v, w \in V$. In any state of affairs along the frontier between y^c and y^d there are positive opportunity costs of attaining either v or w to a higher degree as there is a trade-off relationship in these states. In y^a there are negative or zero opportunity costs to increasing either v or w to a higher degree as there is an independence relationship in y^a. In y^e there are negative opportunity costs to increasing w in units of v as there is a one-sided win-win relationship in y^e. The opposite case is in y^f where there are negative opportunity costs to increasing v in units of w as there is the reverse one-sided win-win relationship in y^f.

In Figure 2 opportunity costs can be illustrated for the case of three values $u, v, w \in V$. In y^a there are positive opportunity costs between v and w as there is a trade-off relationship between the two values in y^a. Also, there are negative or zero opportunity costs between v and u as there is an independence relationship between these two values in y^a, depending if one moves from y^a to y^c or from y^a to y^b. There is no state in Figure 2 where there are only negative opportunity costs as there exists no state of affairs where there is a win-win relationship between any two values.

Corollary 1 (Opportunity costs and value-efficiency)
In a value-efficient state of affairs $y \in Y$ opportunity costs are as follows:

(i) If there exist at least two value-efficient state of affairs, then in every value-efficient state of affairs there exist positive opportunity costs between two values $v, w \in V$.

(ii) If in a state of affairs $y \in Y$ there exist positive opportunity costs between at least two values $v, w \in V$, then y is value-efficient.[20]

(iii) If there exist at least three values in the value set, $\#V = l \geq 3$, there can be positive or zero or negative opportunity costs between values in a value-efficient state of affairs.

Proof. See Appendix A.3. □

As illustrated in Figure 1 and 2 there exist positive opportunity costs in value-efficient states for both the case of two values or three values in the value set. For the case of three values, it becomes clear that negative opportunity costs are not an indication of an value-inefficient state of affairs.

4 Value-efficiency and Pareto-efficiency

4.1 Individualistic framework

As the definition of value-efficiency and relationships between values is based on a very broad consequentialist definition of value, it is interesting to look at its connection to the familiar definition of Pareto-efficiency. This requires to introduce the familiar individualistic framework from welfare economics. In a first step, define a preference relation as special case of a value relation with respect to the value of an individual preference. Suppose there are z individuals whose self-regarding preferences p_k (with $k \in \{1, ..., z\}$) are contained in a set P with $\{p_1, ..., p_k, ..., p_z\} = P$.

Definition 10 (Preference relation)
For all individuals $k = 1, ..., z$, a *preference relation* $\succeq_{p_k}$ of individual k is a binary relation on the set of states of affairs Y, where $y^a \succeq_{p_k} y^b$ means that y^a is as at least as good as y^b in terms of individual preference p_k.[21]

[20] If one considers locally defined relationships this may not hold as it may be that in a value-inefficient state there are trade-offs in a local environment.

[21] The assumption that individuals have complete preferences over the whole set of state of affairs

In this setting, Pareto-efficiency can be defined as follows:

Definition 11 (Pareto-efficiency)
A state of affairs $y \in Y$ is *Pareto-efficient* if and only if there exists no other state of affairs $y' \in Y$ for which $y' \succeq_{p_k} y$ for all individual preferences $p_k \in P$ and $y' \succ_{p_k} y$ for at least one individual preference $p_k \in P$.

This definition of efficiency shows the liberal heritage of Pareto-efficiency which is based on the set P of individual preferences and the idea that all individuals should be free to pursue the satisfaction of their individual preferences.

4.2 Value sets and individual preferences

In the next step, we consider four different cases for the role of preferences in value sets to discuss the connection between value-efficiency and Pareto-efficiency.

The first case is the one where the value set contains all individual preferences and only individual preferences $P = V$ in which case value-efficiency in Definition 7 reduces to Pareto-efficiency in Definition 11.

Proposition 3 (Equivalence of value-efficiency and Pareto-efficiency)
Value-efficiency is equivalent to Pareto-efficiency if and only if $P = V$.

Proof. See Appendix A.4 □

The equivalence of value-efficiency and Pareto-efficiency is briefly discussed, for example, in Dasgupta (2005: 240) who discusses the case when all non-preference values are incorporated into a notion of individual utility. This case is well studied in welfare economics where Pareto-efficiency serves as a central normative criterion, especially following Arrow's impossibility theorem (Sen 1999: 352). Several authors have defended

Y where each state of affairs $y \in Y$ has m different attributes is stronger than the usual assumption that individuals only have preferences over their individual consumption sets. While it is possible to define preference relations over only particular attributes of a state of affairs that concern an individuals self-regarding preference, we do not do so here in order to keep formal requirements to a reasonable level that sill allows us to support our results.

this prominent use of Pareto-efficiency. For example, Buchanan says that "[s]ince 'social' values do not exist apart from individual values in a free society, consensus or unanimity (mutuality of gain) is the only test which can insure that a change is beneficial" (Buchanan 1959: 137). This exclusive reliance on individual preferences in the assessment of states of affairs leads to the debate on the ethical appeal of welfarism (e.g. Sen 1979b, Sen 1980, Roemer 1996, Kaplow and Shavell 2001, Fleurbaey et al. 2003). For example, this concerns the question if all values can be reduced to individual preferences and how values that deviate from individual preferences can be justified. Further, if the value set contains only individual preferences, the earlier results in Section 3.4 can be interpreted accordingly. For example, Proposition 1 says that there can be a win-win relationships between two individual preferences in Pareto-efficient states of affairs when there are trade-offs between other individual preferences.

The second case where only some individual preferences are included in the value set, $V \subset P$, is discriminatory. This would require an ethical theory where preferences of some people do not matter in the assessment of states of affairs. This of course includes cases where the value set does not contain all individual preferences and further non-preference values.

There may be values that are not derived from individual preferences, sometimes called non-preference (or non-utility) values.

Definition 12 (Non-preference value)
A value v is a non-preference value if $v \in V \backslash P$.

For example, Dasgupta (2005: 240) mentions democracy and civil liberties as examples of such additional non-preference values. Another salient example, he mentions, is the liberal paradox from microeconomic theory where under certain conditions liberalism (as an inviolable personal domain) is in conflict with Pareto-efficiency (Sen 1970a).

Non-preference values allow the third case of value sets which are based ethical theories, especially the ones labeled 'non-welfarist', which do not base their value set V on the satisfaction of individual preferences, $P \cap V = \varnothing$. For example, Kaplow (2007) discusses the capability approach by Sen (1980) and primary goods in Rawls (1971) as

theories do not include individual preferences but rather the means to the fulfillment of individual preferences in their assessment of states of affairs. He goes on to discuss the conflict of these alternative ethical theories with Pareto-efficiency. Similarly, there is a discussion on the conflict of efficiency criteria for value sets derived from different ethical theories (e.g. Brun and Tungodden 2004, Fleurbaey 2007). This concerns the conflict between an efficiency criterion for one value set V (value-efficiency) which contains only non-preference values such as primary goods and another efficiency criterion on a set P (Pareto-efficiency) which contains only individual preferences.

A related case is the fourth case where the value set contains individual preferences and additionally non-preference values, $P \subset V$. In this case Pareto-efficiency and value-efficiency are not equivalent. Still, the inclusion of non-preference values into an economic framework can lead to a conflict with Pareto-efficiency in some sets of feasible states of affairs (e.g. Kaplow and Shavell 2001, Fleurbaey et al. 2003).

This last case can be illustrated in Figure 3. It shows a convex set of feasible states of affairs in value-space with three values: two individual preferences $p_1, p_2 \in P \subset V$ and one non-preference value $v \in V$. The axes in this figure show the degree of attainment of the three values via their respective index functions: two utility functions U_1, U_2 and an index function for a non-preference value I_v. The surface of the set in value-space, which is indicated by the thin black lines, delimits states of affairs that are feasible, those inside the grey volume, from states of affairs that are not feasible, those inside the white volume. Also, the surface shows all value-efficient states of affairs. All Pareto-efficient states of affairs are those on the dashed line on the surface where the non-preference value is attained to the lowest degree. Thus, surface of the set in value-space encompasses all value-efficient and all Pareto-efficient states of affairs.

Here, one can distinguish a Pareto-efficient and value-efficient state of affairs such as y^a from a value-efficient state such as y^b. States of affairs that are not on the surface are value-inefficient and Pareto-inefficient. In the following we focus on this case of preferences and non-preference values $P \subset V$ as this has attracted the most interest in economics.

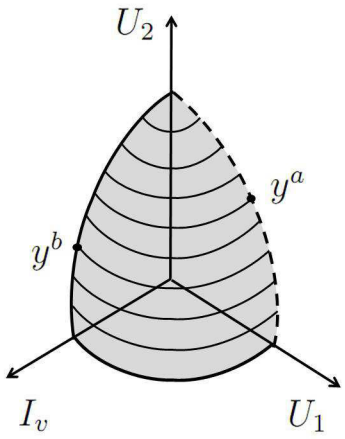

Figure 3: Convex set of feasible states of affairs in value-space with three values. The axes in this figure show the degree of attainment of the three values via their respective index functions: two utility functions U_1, U_2 and an index function for a non-preference value I_v. The surface of the set in value-space, which is indicated by the thin black lines, delimits states of affairs that are feasible, those inside the grey volume, from states of affairs that are not feasible, those inside the white volume. All value-efficient states of affairs are on the surface of the set in value-space. All Pareto-efficient states of affairs are those on the dashed line on the surface where the non-preference value is attained to the lowest degree. State of affairs y^a is Pareto-efficient and value-efficient, state of affairs y^b is value-efficient and not Pareto-efficient.

Corollary 2 (to Proposition 1 (iii))
If there are at least two non-preference values $v, w \in V \backslash P$ and at least two individual preferences $p_1, p_2 \in P \subset V$, then there can be any relationship between the two values v, w in a Pareto-efficient state of affairs $y \in Y$.

Proof. See Appendix A.5 □

This result is relevant to the interpretation of Proposition 1 as this means that there can be a win-win relationship between non-preference values in a given Pareto-efficient state of affairs. For example, if individuals do not care about the values of equality and

liberty as a minimal inviolable personal domain (as in Sen 1970a), then there can be a Pareto-efficient state which exhibits a win-win relationship between these non-preference values.

Proposition 4 (Conflict of value-efficiency and Pareto-efficiency)
If $P \subset V$, then there may exist a value-efficient state of affairs that is not Pareto-efficient, and vice versa, a Pareto-efficient state that is not value-efficient.[22]

Proof. See Appendix A.6 □

Generally, a Pareto-efficient state of affairs is not value-efficient if there exists another state of affairs where people are equally well off and some non-preference value is attained to a higher degree. For example, Dasgupta (Dasgupta 2005: 240) considers the case of the liberal paradox, where a state that respects liberty can be Pareto-inefficient, but is value-efficient as illustrated in Figure 3 through state of affairs y^b.

5 Conclusion

We have studied relationships between values on the set of feasible states of affairs by following a consequentialist definition of value that focuses on the assessment of states of affairs. We have shown that for value sets with three or more values, there can be independence, win-win relationships or trade-offs between values in value-efficient states of affairs. That is, neither win-win nor independence relationships between values indicate value-inefficient states of affairs, if there are more than two values. We have demonstrated that in any case the absence of trade-offs between values indicates a value-inefficient state of affairs. With regard to opportunity costs, it has become clear that trade-offs are associated with positive opportunity costs, win-win relationships

[22] This is a comparatively weak statement. Kaplow and Shavell (2001) make a stronger statement yet they refer to the set of all conceivable states, and not explicitly to the set of feasible states. It is clear that a general statement regarding the conflict between value and Pareto-efficiency in the feasible set requires much more detailed assumptions regarding values and the feasible set as the broad literature on social choice theory shows.

with negative opportunity costs and independence relationships with negative or zero opportunity costs.

The practical relevance of these results to decision-makers is the following. First, and foremost, the value set must be complete and clear for decision-making, as value-efficiency and the indication of (in)efficiency, crucially hinges upon the values and the number of values in the value set. Second, a trade-off between *two* values indicates a state of affairs that is efficient with respect to *all* values. Such a trade-off can be recognized from positive opportunity costs of some value. Third, a win-win relationship between two values does not imply a need to change the state of affairs. For, giving in to a win-win relationship between two values may incur a trade-off between one of those values and a third value.

Regarding the connection between Pareto-efficiency and value-efficiency, we have shown that the former is a special case of the latter when individual preferences are taken to be the only values. If there are values that are not reducible to individual preferences, as in some ethical theories, we have seen that there can be win-win relationship between non-preference values in a Pareto-efficient state of affairs.

The practical relevance of these results to decision-makers is the following. If there is at least one non-preference value, Pareto-efficiency cannot taken to be an indication of value-efficiency. This matters in all practical contexts where Pareto-efficiency is taken as the criterion of a "good" state of affairs, for example when justifying institutions like competitive markets, free trade or anti-trust regulation. This underscores how important the conception of well-being is for the analysis of conflicts of non-preference values with Pareto-efficiency as this conception determines what constitutes individual preferences and, consequently, which values are preference-based and which are not (e.g. Sen 1980, Anderson 1993).

While these results are quite general, they are not derived for a concrete ethical problem that generates a specific set of feasible states of affairs. That is, in a detailed economic model results on relationships between particular values could be derived from more specific assumptions on individual preferences, instruments and resources. In this vein, the general insights into value-efficiency and relationships between values in this

paper could be applied for concrete ethical theories such as Sen's capability approach (e.g. Pattanaik and Xu 2012) or the relationship between intra- and intergenerational justice (e.g. Baumgärtner et al. 2012).

Acknowledgements

We are grateful to Dave Abson, Urs Allenspacher, Georg Brun, John-Oliver Engler, Gertrude Hirsch-Hadorn, Ivo Wallimann-Helmer, Michael Liebendörfer, Dominic Roser, Michael Schefczyk, Fabian Schuppert, Martin Quaas, the team of the Chair of Economics / Resource Economics at ETH Zürich, for critical and constructive discussion, and to the German Federal Ministry of Education and Research for financial support under grant 01UN1011A.

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Appendix

A.1 Proof of Proposition 1

(i): Consider two value-efficient states of affairs $y, y' \in Y$ and a value set with $\#V = l$ values. For two values $\#V = l = 2$ and $v, w \in V$, value-efficiency of y, y' requires a trade-off between v and w, i.e. $y \prec_v y'$, $y \succ_w y'$. For more than two values $\#V = l > 2$, value-efficiency of y, y' requires a trade-off between at least two values. To show this assume there exists no trade-off between any two values in y, i.e. $y \prec_v y'$ or $y \sim_v y'$ for all $v \in V$, then y' is not value-efficient as Definition 7 that there must exists no other state of affairs $y' \in Y$ for which $y' \succeq_v y$ for all $v \in V$ and $y' \succ_v y$ for at least one $v \in V$.

(ii): Take two values v, w from a value set V with $\#V = l$ values and any two states of affairs $y, y' \in Y$. If $y \prec_v y'$ does necessarily lead to $y \succ_w y'$ for some $w \in V$, then y is a value-efficient state of affairs as Definition 7 says there must exist no $y' \in Y$ for which $y \prec_v y'$ for some $v \in V$ and $y \preceq_w y'$ for all $w \in V$.

(iii): Assume there are 3 values in the value set $u, v, w \in V$ and two states of affairs $y, y' \in Y$. Assume the orderings necessary for a win-win relationship between u and v: $y \prec_u y'$, $y \prec_v y'$; and show that $y, y' \in Y$ can still be value-efficient. Assume $y \succ_w y'$ so

that y' does not dominate y. This yields two value-efficient states of affairs y, y' where y exhibits a win-win relationship between $u, v \in V$.

To show an an independence relationship in a value-efficient state of affairs assume one further state of affairs y''. Assume additionally the orderings necessary for an independence relationship between u and v: $y \prec_u y''$, $y \sim_v y''$; and show that $y, y', y'' \in Y$ can still all be value-efficient. Assume $y \succ_w y'$, $y \succ_w y''$ so that y' and y'' do not dominate y. Assume $y' \sim_w y''$ and $y' \prec_u y''$, $y' \succ_v y''$ so that y' does not dominate y''. This yields three value-efficient states of affairs y, y', y'' where y exhibits an independence relationship between $u, v \in V$.

A.2 Proof of Proposition 2

Follows immediately from Definitions 8 and 9.

A.3 Proof of Corollary 1

Follows immediately from Propositions 1 and 2.

A.4 Proof of Proposition 3

If all $v \in V$ are individual preferences, then all value relations are identical to preference relations. This makes value-efficiency equivalent to Pareto-efficiency.

A.5 Proof of Corollary 2

Trade-off relationship

Assume there are 4 values in the value set: two individual preferences $p_1, p_2 \in P \subset V$ and two non-preference values $v, w \in V$ and two states of affairs y, y'. Assume the orderings necessary for both states to be Pareto-efficient: for the first individual $y \prec_{p_1} y'$, and for the second individual $y \succ_{p_2} y'$. Further, assume orderings for a trade-off between v and w: $y \prec_v y'$ and $y \succ_w y'$. This yields two Pareto-efficient and value-efficient states of affairs y, y' where y exhibits a trade-off relationship between $v, w \in V$.

Win-win relationship

Assume there are 4 values in the value set: two individual preferences $1, 2 \in P \subset V$ and two non-preference values $v, w \in V$ and two states of affairs y, y'. Assume the orderings necessary for both states to be Pareto-efficient: for the first individual $y \prec_{p_1} y'$, and for the second individual $y \succ_{p_2} y'$. Further, assume orderings for a win-win relationship between v and w: $y \prec_v y'$ and $y \prec_w y'$. This yields two Pareto-efficient and value-efficient states of affairs y, y' where y exhibits a trade-off relationship between $v, w \in V$.

Independence relationship

Assume there are 4 values in the value set: two individual preferences $1, 2 \in P \subset V$ and two non-preference values $v, w \in V$ and three states of affairs y, y', y''. Assume the orderings necessary for all three states to be Pareto-efficient: for the first individual $y \prec_{p_1} y'$, $y \prec_{p_1} y''$, $y' \prec_{p_1} y''$, and for the second individual $y \succ_{p_2} y'$, $y \succ_{p_2} y''$, $y' \succ_{p_2} y''$. Further, assume orderings for an independence relationship between v and w: $y \prec_v y'$, $y \prec_v y''$ and $y \prec_w y'$, $y \sim_w y''$. Assume $y' \sim_v y''$ and $y' \prec_w y''$, so that y' does not dominate y''. This yields three Pareto-efficient and value-efficient states of affairs y, y', y'' where y exhibits an independence relationship between $v, w \in V$.

A.6 Proof of Proposition 4

Assume a value set with three values: two individual preferences $p_1, p_2 \in P \subset V$ and a non-preference value $v \in V$ and two states of affairs y, y'. Then it can be that $y \prec_{p_1} y'$ and $y \prec_{p_2} y'$, but $y \succ_v y'$. This yields two value-efficient states of affairs y, y', where state y is not Pareto-efficient.

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