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Analysis

# The economic, environmental and social performance of European certified food

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ABSTRACT

To identify whether EU certified food – here organic and geographical indications – is more sustainable than a conventional reference, we developed 25 indicators covering the three sustainability pillars. Original data was collected on 52 products at farm, processing and retail levels, allowing the estimation of circa 2000 indicator values. Most strikingly, we show that, in our sample, certified food outperforms its non-certified reference on most economic and social indicators. On major environmental indicators – carbon and water footprint – their performance is similar. Although certified food is 61% more expensive, the extra-performance per euro is similar to classical policy interventions to improve diet sustainability such as subsidies or taxes. Cumulatively, our findings legitimate the recent initiatives by standards to cover broader sustainability aspects.

## 1. Introduction

Consumer-oriented policy is increasingly seen as a key lever (Moran et al., 2018) – if not the cornerstone (Springmann et al., 2018) – of a sustainable food system, with diet change and food waste reduction at the forefront (Bonnet et al., 2020; Rogissart et al., 2019). However, environmentally friendly production practices could provide an equally promising way forward, provided that they can be communicated clearly to consumers and thereby inform their choice (Poore and Nemecek, 2018; Smith et al., 2019b). This is precisely the role of certified food (eg. Hindsley et al., 2020; Vlaeminck et al., 2014). In 2012, the Quality Package (Regulation (EU) No. 1151/2012) was passed in the EU to improve the operation of Geographical Indications (GIs) certification schemes, initially based on product typicality. The Regulation details the rationale for promoting GIs as a means to generate a fair return for farmers and processors and to enable consumers to make better-

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informed purchasing decisions through effective labelling. Similarly, the organic standard guarantees that neither farmers nor processors used synthetic chemicals. But beyond their initial promise – typicality for GIs and absence of chemicals for organic products – is certified food more sustainable than other food products?

Here we focus on organic and GI certifications, the two largest quality food standards in the EU with 4% and 5.7% respectively of total retail sales in European countries where data is available (Chever et al., 2012; FiBL, 2017). Other certifications were not retained because they are either specific to a country or because their market share is much lower: Fair Trade for example, most likely the next quality food standard sold across the EU, only represents 0.4% of total retail sales of food and beverages (Food Drink Europe, 2020; Statista, 2015). Two certifications are grouped under GI: Protected Geographical Indication (PGI) which guarantees the location and method of food processing and Protected Designation of Origin (PDO) which guarantees the location and practices of both farmers and processors.

Regarding GIs, previous studies have focused on their economic performance (Arfini et al., 2006; London Economics, 2008; Vandecandelaere et al., 2018), showing that GI value chains add substantial value to their raw materials and to the labour employed in their production, to the benefit of producers, local and national economies. The existing analysis of the environmental and social performance of GIs is skim and entirely qualitative.

For organic farming, existing impact analyses are more comprehensive, covering both the economic and environmental pillars of sustainability and even some aspects of social sustainability. Several studies have applied Life-Cycle Assessments (LCA) to quantify differences in environmental impacts between organic and conventional agriculture (Nemecek et al., 2011; Thomassen et al., 2008). These assessments are not universally favourable to organic products (Meier et al., 2015; Seufert and Ramankutty, 2017), in particular when indirect land-use change consequences of lower yield are included in the assessment (Bellora and Bureau, 2016). On the economic side, organic products clearly capture a price premium, which in general allows organic farms to obtain higher net results despite their lower yields (Crowder and Reganold, 2015; European Commission, 2013; Smith et al., 2019a). Social performance assessments are less common, yet organic value chains have been shown to generate more jobs and to attract younger and better educated workers (Finley et al., 2018; Koesling et al., 2008; Mahé and Lerbourg, 2012). However, the environmental performance assessments of organic farming are usually conducted in isolation from socio-economic assessments (Pimentel and Burgess, 2014), with a few exceptions focusing on a single product (Ssebunya et al., 2019). This isolation hinders the assessment of the broad sustainability performance of organic value chains, let alone the synergy or trade-off between different sustainability aspects. Moreover, methodological heterogeneity has been identified as an important pitfall in existing meta-analysis of the environmental performance of organic food (Meier et al., 2015).

Here we assess the sustainability performance of EU certified food, questioning whether it outperforms conventional food and at which cost, and identifying synergies and trade-offs between different sustainability indicators. Compared to the existing literature, this assessment thus innovates along three key aspects:

- ✓ The same methodology is applied to a large – 52 – number of products, providing a uniquely consistent picture of the sustainability of certified and non-certified products. For GI, our sample size is comparable to the largest existing field studies which focus on only a few indicators within the same sustainability pillar. Meta-analyses of a few performances of organic farming have larger sample sizes (SM 7), but our field study complements them as we trade sample size for consistent methodology and wide array of indicators covering the three sustainability pillars.
- ✓ The performance criteria are assessed at the different levels of the value chains, including at least the farm and the processing levels;
- ✓ It provides the first quantitative evaluation of the environmental and social performance of GIs.

## 2. Material and methods

### 2.1. Data

#### 2.1.1. Choice of products and their references

Twenty-six certified products were selected in thirteen countries (SM 5, Table S5). Choices aimed at a diversity of sectors – animal (9 products), vegetal (14 products) and unfed seafood/fish (3 products) – and certifications – organic (7 products), PDO (8 products), PGI (11 products) – while taking into account country-specific constraints (some certifications simply do not exist in some countries for some sectors). Ultimately, the cases are evenly distributed across certifications, while regarding sectors, the unfed seafood/fish sector has much fewer cases than the vegetal and animal sectors.

In order to mitigate the influence of other possible drivers of performance than certification, such as country - or sector-specific features, only the difference between a certified product and its reference product is analysed. This strategy is inspired from the rationale of *controlled trials*. For this reason, detailed guidelines were designed to select only products with a comparable reference (see SM 1). For instance, for a sheep-milk cheese from Serbia initially in the sample, the only possible reference product within Serbia was a cow-milk cheese. For many indicators, the difference in outcome would likely have been more driven by the difference between cow and sheep systems than from the difference between certified and non-certified value chains. This product was therefore removed from the analysis as it was impossible to find a reference product meeting our guidelines.

#### 2.1.2. Data collection

Guidelines were also provided for data collection (eg. relying to the extent possible on secondary data, interviewing key stakeholders in the value chain, drawing a value chain diagram delimiting the system boundaries, …) to improve collection efficiency and data source comparability across products (see SM 1). Note that a reference product can be an actual non-certified product with similar characteristics or the average conventional product in the same country.

The values of these variables were collected by in-country scientists according to the following prioritization protocol: first, review of existing reports and databases on the value chain providing average values based on representative samples (secondary data); second, ad-hoc surveys, in person or online, of a sample of farms and firms (primary data); and last, expert judgment elicitation, following the IPCC guidance (IPCC, 2006).

The detailed list of variables, all the spreadsheets including the raw data, their source, and the resulting estimated indicators can be downloaded at https://data.inrae.fr/dataset.xhtml?persistentId=doi:10.15454/OP51SJ.

#### 2.1.3. Quality control procedure

Finally, a quality check procedure was put in place to mitigate the risk of misreporting data. The three main aspects of this procedure were 1) to write down all data, their date and source in a shared spreadsheet, 2) to distinguish the person who collected data from the person who estimated the indicator, and 3) to write down, for each product and indicator, a common interpretation of the estimated differences in performance that made sense for both the person who collected the data and the person who estimated the indicator. These interpretations are recorded in Arfini and Bellassen (2019). The ability of the procedure to result in homogeneous and unbiased data is confirmed by a cluster analysis of the results which shows no country or partner effect (SM 6) and by a comparison with existing studies for the few indicators and certifications for which they exist (SM 7).

More details on the data collection procedure are provided in SM 1.

### *2.2. Indicator estimation*

#### *2.2.1. Overview of indicators and minimal systematic comparison*

Twenty-five indicators were designed to cover the performance of food value chains over the three sustainability pillars: economy, environment and society. The SAFA guidelines (Sustainability Assessment of Food and Agriculture systems) developed by the FAO (2013) formed the basis of indicator choice and design. However, SAFA falls short of detailing a full method to estimate indicators from collected primary data and to interpret them. A subset of SAFA themes were therefore operationalized into 25 actual indicators (Table 1).

In order to ensure a common basis of comparison between products despite the heterogeneity in data availability, two orders of priority were established for indicators. The collection of variables necessary to estimate 13 "systematic indicators" (four economic; four environmental; five social) was thus prioritized over the variables necessary to estimate 12 "complementary indicators" (five economic; three environmental; four social). Altogether, the twenty-five indicators necessitate the collection of 150 variables (see SM 1 for details on indicator design and estimation). We mostly focus here on the "systematic indicators". This subset was selected to be equally distributed over the three pillars, and to use indicators that were most common in their field and for which we had the least missing values. These thirteen indicators cover six of the sustainable development goals of the UN (SM 2, Table S2.1). Results from the entire set are nevertheless provided (SM 3 and SM 4) and used to discuss the key messages where relevant.

#### *2.2.2. Relative difference and value chain averages*

Indicators are estimated for different levels of the value chain (farm level, processing level and, where relevant, retail level). To control for the influence of country and product type, we analyse relative differences between the certified product and its reference product rather than absolute values (Eq. 1).

$$rel\_diff_{j,k} = \frac{indic_{CERT,j,k} - indic_{REF,j,k}}{indic_{REF,j,k}} \tag{1}$$

where $rel\_diff_{j,k}$ is the relative difference at level j of the value chain for indicator k, and $indic_{CERT,j,k}$ and $indic_{REF,j,k}$ are the value of indicator k at level j of the value chain for the certified and the reference product respectively.

For bargaining power distribution and for environmental indicators, the opposite of the relative difference is used so that a higher performance of certified food (eg. higher gross margin, lower water footprint) consistently corresponds to a positive relative difference.

In a second step, "value chain averages" are computed to evaluate the difference in performance for the entire value chain (Eq. 2). For most indicators, "value chain averages" are simple averages of the indicator over the value chain levels for which it was estimated (farm, processing and, where relevant, retail). There are, however, two exceptions.

The first exception concerns indicators expressed on a *per ton* basis, that is the environmental indicators and the labour to production ratio. Because life cycle assessment underlays these indicators, the value representative for the whole value chain must be calculated cumulatively. If one ton of ham requires 5 tons of live hog, the "value chain average" sums the footprint of 5 tons of live hog at farm level and 1 ton of ham at processing level rather than averaging the footprints of one ton of live hog and one ton of ham. This cumulative aggregation also allocates the footprint to all products (eg. ham versus the rest of the carcass at processing level) based on their relative economic value. For environmental indicators, this economic allocation is embedded in the original indicators. For labour to production ratio, the formula is provided in Eq. 2.

The indicator on value chain stability is the second exception. Because a value chain is only as stable as its weakest level (Muller et al., 2021), its "value chain average" is the minimum of the "bargaining

**Table 1**
List of indicators for sustainability assessment.

| | Sustainability pillar | Indicator type | Indicator sub-type (code) | Level of analysis along the value chain |
|---|---|---|---|---|
| Systematic | Economic | Price premium | Price premium (Ec1.1, EUR $kg^{-1}$) | One value per level of the value chain |
| | | Profitability and value added distribution | Gross Operating Margin (Ec1.3, % of turnover) | |
| | | Trade | Share of value exported within Europe (Ec1.5, % of turnover) | Single value for the whole value chain |
| | | Local multiplier | Local multiplier (Ec2.1, no unit) | |
| | Environmental | Carbon footprint | Carbon footprint per unit of product (En1.1, $kgCO_2e\ ton^{-1}$) | Single value for the whole value chain |
| | | Foodmiles | Distance travelled per unit of product (En2.1, ton.km $ton^{-1}$) | |
| | | Water footprint | Blue water footprint (ground water consumption, En 3.3, $m^3\ kg^{-1}$) | |
| | | | Grey water footprint (water pollution by nitrates, En 3.2, $m^3\ kg^{-1}$) | |
| | Social | Employment | Labour to production ratio (So 1.1, AWU $ton^{-1}$) | One value per level of the value chain |
| | | Governance | Bargaining power distribution (So2.1, no unit) | Single value for the whole value chain |
| | | Social capital | Educational attainment (So3.1, no unit) | One value per level of the value chain |
| | | | Generational change (So5.1, no unit) | |
| | | | Gender equality (So5.2, no unit) | |
| Complementary | Economic | Profitability and value added distribution | Gross Value-added (Ec1.2, % of turnover) | One value per level of the value chain |
| | | Profitability and value added distribution | Net result (Ec1.4, % of turnover) | |
| | | Trade | Share of value exported outside Europe (Ec1.6, % of turnover) | Single value for the whole value chain |

(*continued on next page*)

**Table 1** (*continued*)

| Sustainability pillar | Indicator type | Indicator sub-type (code) | Level of analysis along the value chain |
|---|---|---|---|
| | | Share of volume exported within Europe (Ec1.7, % of production) | |
| | | Share of volume exported outside Europe (Ec1.8, % of production) | |
| Environmental | Carbon footprint | Carbon footprint per hectare (En1.2, $kgCO_2e\ ha^{-1}$) | One value per level of the value chain |
| | Foodmiles | Emissions from transportation per unit of product (En2.2, $kgCO_2e\ ton^{-1}$) | |
| | Water footprint | Green water footprint (total water requirements, En3.1, $m^3\ kg^{-1}$) | |
| Social | Employment | Turnover to labour ratio (So1.2, EUR $AWU^{-1}$) | One value per level of the value chain |
| | Governance | Stability of the value chain level (So2.2, no unit) | |
| | Social capital | Wage level (So3.2, EUR $AWU^{-1}$) | |
| | | Gender equality index (So5.3, no unit) | |

power" indicator across value chain levels (Eq. 2).

$$\begin{cases} \textbf{All indicators except environmental indicators and labour to production}: VC_{average} = \dfrac{\sum_{j=1}^{n} rel\_diff_j}{n} \\ \textbf{Environmental incators}: VC_{average} = rel\_diff_n \\ \textbf{Labour to production ratio}: \begin{cases} VC_{average} = \dfrac{cum_{indic\,CERT} - cum_{indic_{REF}}}{cum_{indic_{REF}}} \\ cum_{indic\,X} = \dfrac{indic_{x,farm}}{final_{prod_{ratio}} \times (1 + coproducts_{farm})} + \dfrac{indic_{x,proc}}{(1 + coproducts_{proc})} \end{cases} \\ \textbf{Value chain stability}: \begin{cases} VC_{average} = \dfrac{cum_{indic\,CERT} - cum_{indic_{REF}}}{cum_{indic_{REF}}} \\ cum_{indic\,X} = min(indic_{x,farm}, indic_{x,proc}) \end{cases} \end{cases} \quad (2)$$

where $VC_{average}$ is the value chain average difference, $rel\_diff_j$ is the relative difference in performance at level j of the value chain (Eq. 1), n is the lowest level of the value chain where the indicator could be estimated (most often the processing level), $cum\_indic_X$ is the cumulative indicator over different value chain levels for product X (either certified or reference product), $indic_{X,farm}$ and $indic_{X,proc}$ are the indicator value for product X at the farm and processing levels respectively, final_prod_ratio is the amount of raw product at farm level (eg. live hog) necessary for one ton of final product (eg. ham), and coproducts_farm and coproducts_proc are the value of coproducts (eg. rest of the carcass) expressed as a percentage of the value of the main product (eg. ham) at farm and processing levels respectively.

### 2.3. Marginal performance change and price threshold for profitability

#### 2.3.1. Marginal performance change per percentage point of price premium

Marginal performance improvement per percentage point of price premium is obtained by dividing the relative performance difference between certified products and their reference products by their relative price difference (Eq. 3). It is an indicator of how much the performance improves for a given cost to the consumer. For example, the marginal performance improvement of a certified product with a 10% higher gender equality index than its reference product and 20% price premium is 0.5. Based on this simple indicator, it can be considered to be more efficiently using consumer money to improve gender equality than a certified with 20% higher gender equality index and a 100% price premium (marginal performance change = 0.2).

$$marg\_perf_{j,k} = \frac{rel\_diff_{j,k}}{rel\_diff_{j,price}} \quad (3)$$

where $marg\_perf_{j,k}$ is the marginal performance at level j for indicator k and $rel\_diff_{j,k}$ is the relative difference at level j of the value chain for indicator k (Eq. 1).

#### 2.3.2. Price threshold for profitability

Most of the performance improvements rely upon the existence of a price premium, without which firms have no incentive to comply with technical specifications. One way of assessing the scaling-up potential of certified food is therefore the price premium level which perfectly balances the extra costs of production. This price threshold equalizes the profitability per unit of product between the certified and conventional alternatives. It is obtained by expressing the additional costs of producing certified food as a percentage of the price of the reference product (Eq. 4).

$$price\_threshold_j = \frac{unit\_costs_{CERT,j} - unit\_costs_{REF,j}}{price_{REF,j}} \quad (4)$$

where $price\_threshold_j$ is the price threshold for profitability at level j,

$unit\_costs_{CERT,j}$ and $unit\_costs_{REF,j}$ are the costs of producing one unit of the product at level j of the value chain for the certified and the reference product respectively and $price_{REF,j}$ is the price of one unit of the reference product at level j of the value chain.

*2.4. Statistics*

The statistical analysis relies on non-parametric tests based on rank. The Wilcoxon signed-rank test to test whether a median is different from zero and the Kruskal-Wallis test to test whether different certifications (PDO, PGI, organic) belong to the same population. Because of the small sample size – 26 at most – these tests are better suited than classical parametric tests: they are less sensitive to outliers and they don't rely on the normality assumption which is difficult to ascertain in small samples.

These tests do not account for the uncertainty of the indicator estimates themselves, which could come from sampling error of primary variables used to estimate the indicator, modelling uncertainty (eg.

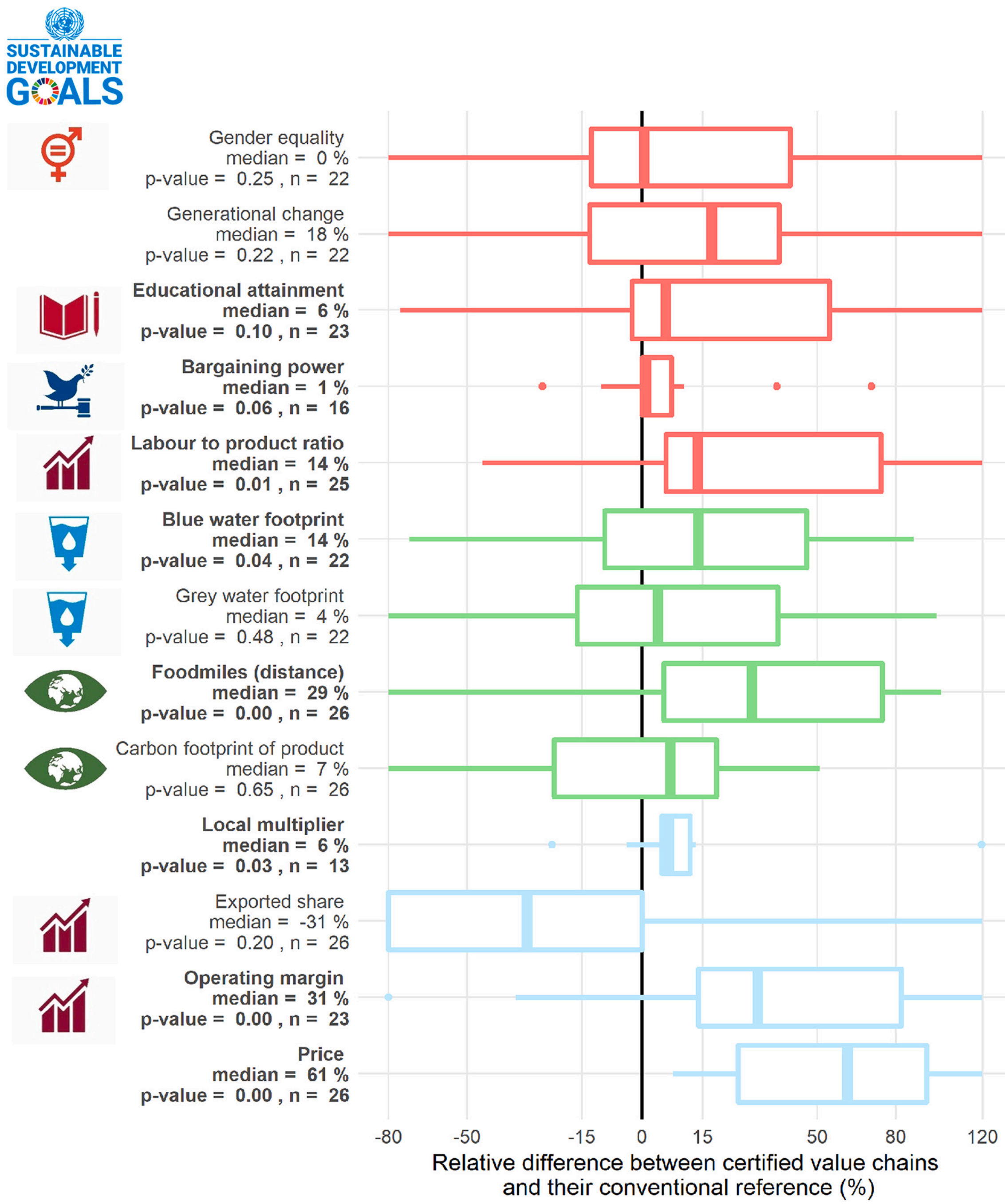


**Fig. 1.** Performance difference between certified products and their conventional reference. The median performance difference between certified products and their conventional reference is expressed in percentage (%) under each key indicator, with positive results suggesting a higher performance and negative results pointing to a lower performance (see SM 1 for details and formulas). The *p*-value indicates the probability that the median is different from zero (Wilcoxon signed-rank test). Indicators for which certified food is significantly different from its reference (i.e. p-value <0.1) are mentioned in bold. n indicates the number of certified products for which the indicator has been calculated. Boxes indicate the second and third quartiles with the median as a vertical bar within them. Whiskers indicate the largest values which is not further than 1.5 times the interquartile distance from the box. Points are outliers. The logo on the left-hand side indicates for which UN Sustainable Development Goal the indicator is relevant. This relevance is explained in SM 2, Table S2.1.

carbon and water footprint), … These uncertainties are challenging to quantify exhaustively. The risk of systematic bias is however greatly reduced by the design of the analysis: the use of relative differences of estimates based on the same method is robust to additive modelling errors and even reduces the effect of non-additive biases.

For carbon footprint, a sensitivity analysis has been undertaken on two subjective modelling choices. Although these choices substantially changed the absolute values of the indicator, the relative differences were very similar to those presented here and the overall conclusions were unchanged (Bellassen et al., 2021). The R code used to compile indicators and conduct statistical tests is provided (SM 9).

## 3. Results and discussion

### 3.1. Sustainability performance of certified food

Certified food never performs significantly worse than conventional food on the 13 systematic indicators (Fig. 1). This is still true for the broader set of 25 indicators (SM 3, Fig. S 3.1): only water requirement (green water footprint) is significantly higher (worse) for certified food, but the relevance of this indicator is debated, especially where rainwater is abundant (Schyns et al., 2019). For two thirds of the key indicators, the performance of certified food is significantly higher than conventional food.

Economically, certified products capture a price premium (+61%) and manage to translate it into a higher value added (+14%) and operating margin (+31%). This higher performance trickles down in the territory, although only to a small extent (local multiplier +6%): many feedstocks are locally sourced for both certified food and their reference products so that local sourcing constraints from the technical specifications do not translate into large differences in local multiplier effect. Dairy products are a typical example: cheese or yoghurt factories tend to source their milk locally even in conventional value chains due to high transportation costs.

Socially, certified food creates more jobs (+14%) but, thanks to its price premium, its labour productivity – expressed in euros of turnover per unit of labour – is nevertheless higher (+32%) which translates into significantly higher wages (+32%). The higher labour intensity is explained by lower economies of scale – firms involved in certified value chains tend to be smaller than their conventional counterparts – and from technical specifications that often limit the automation of work. However, certified value chains do not attract more female workers and may be attracting more young workers (+18%) but with too much variability for this difference to be significant ($p$-value = 0.22).

The environmental performance of certified products is broadly similar to their conventional reference. More precisely, certified products pollute less on a per hectare basis (−27% GHG emissions and − 23% water pollution, see SM 3 and SM 4), thanks to technical specifications that often limit or – for organic products – forbid the use of synthetic fertilizers for example. But when expressed per ton, which is most common for *footprint* indicators, the higher performance is diluted by the lower yield of certified farms (−19%, see (Bellassen et al., 2021) for details). This lower productivity is particularly acute for organic products in our sample (−36%), an order of magnitude which is consistent with existing meta-analysis dedicated to the yield of organic farming. Seufert et al. (2012) report an average yield difference of −25%, and − 34% when organic and conventional systems are "most comparable". Ponisio et al. (2015) report an average different of −19%.

Among the key environmental indicators, certified food only performs better on *foodmiles*, thanks to lower exports and local sourcing. While local sourcing is driven by the technical specifications of both geographical indications and organic farming (for animal products), the reason for lower exports differs: many geographical indications are only recognized in their domestic market, leading them to neglect international outlets which do not offer a price premium. For organic farming, there is a divide between high-income countries (eg. France, Germany) where domestic supply struggles to match domestic demand (little to no exports) and middle-income countries where organic supply chains are almost entirely dedicated to exports (eg. Serbia).

### 3.2. Certified food as an efficient way of producing public goods?

The relatively high marginal performance improvement per percentage point of price premium depicts the Quality policy of the European Union – here the certification of organic and GI products – as an efficient way of producing positive economic, environmental and social externalities. Where significantly different from zero, we find that the marginal performance improvement per percentage point of price premium, averaged per indicator across the value chain, is between 0.3 and 0.6 (Fig. 2), except for local multiplier (0.09) and bargaining power distribution (0.04). This is only slightly lower than the own-price elasticity of food (Femenia, 2019) and is similar to the more relevant price-elasticity of demand in sugar soda (nutritional impact) (Guyomard et al., 2018) or the simulated response to a carbon tax (climate impact) (Bonnet et al., 2016; Caillavet et al., 2016). For many indicators however, the variability is large with some extreme values. This highlights the absence of direct causality in our experimental design regarding the relationships between price premium and over-performance and moderates the strength of the evidence provided by these pseudo-elasticity estimates. Moreover, these estimates neglect transaction costs (Bellassen et al., 2015) and windfall effects (Chabé-Ferret and Subervie, 2013), both of which have been shown to weigh heavily on the cost-efficiency of any policy, be it certification-based or not.

Marginal performance improvement per percentage point of price premium are slightly higher at farm level than at processing level: three dimensions – operating margin, blue water footprint and educational attainment – are significantly higher than zero instead of two – operating margin and labour-to-product ratio – at processing level, and generational change is the only indicator for which the median marginal performance improvement is lower at farm level (0.04) than at processing level (0.06). This argues for focusing policy intervention at farm level rather than processing level, especially as environmental indicators are cumulative, with the bulk of their value already determined at farm level.

### 3.3. Price threshold for the profitability of certified food

The median value across value chain levels which equalizes the unit profitability of a certified product and its reference is 26% of the reference price. This is much below the median price premium of 62% captured by certified food, indicating a good resistance of certified chains to decreasing premiums. The processing level may be the weak link of certified value chains with median extra costs amounting to 52% of the reference price (see SM 4 and (Monier-Dilhan et al., 2021) for details). However, this simple assessment of the scaling-up potential must be cautiously interpreted as it does not account for current "volume strategies" and future economies of scale. Indeed, for equal profit per unit of product, conventional firms are likely more profitable as their sales strategies are more oriented towards mass production, with an ability to compensate low profits per unit by a large amount of units. To the contrary, up-scaled certified food chains would likely reap more economies of scale than the current ones, and therefore decrease unit costs.

Scaling-up would also create other challenges than decreasing price premiums (eg. land requirements associated with reduced yields (Muller et al., 2017; Searchinger et al., 2018)). On the other hand, all extra-costs need not be covered by the price premium: public subsidies or payments for environmental services can also contribute.

### 3.4. Differences in performance between quality signs

PDO and organic value chains both get an edge on attractiveness to

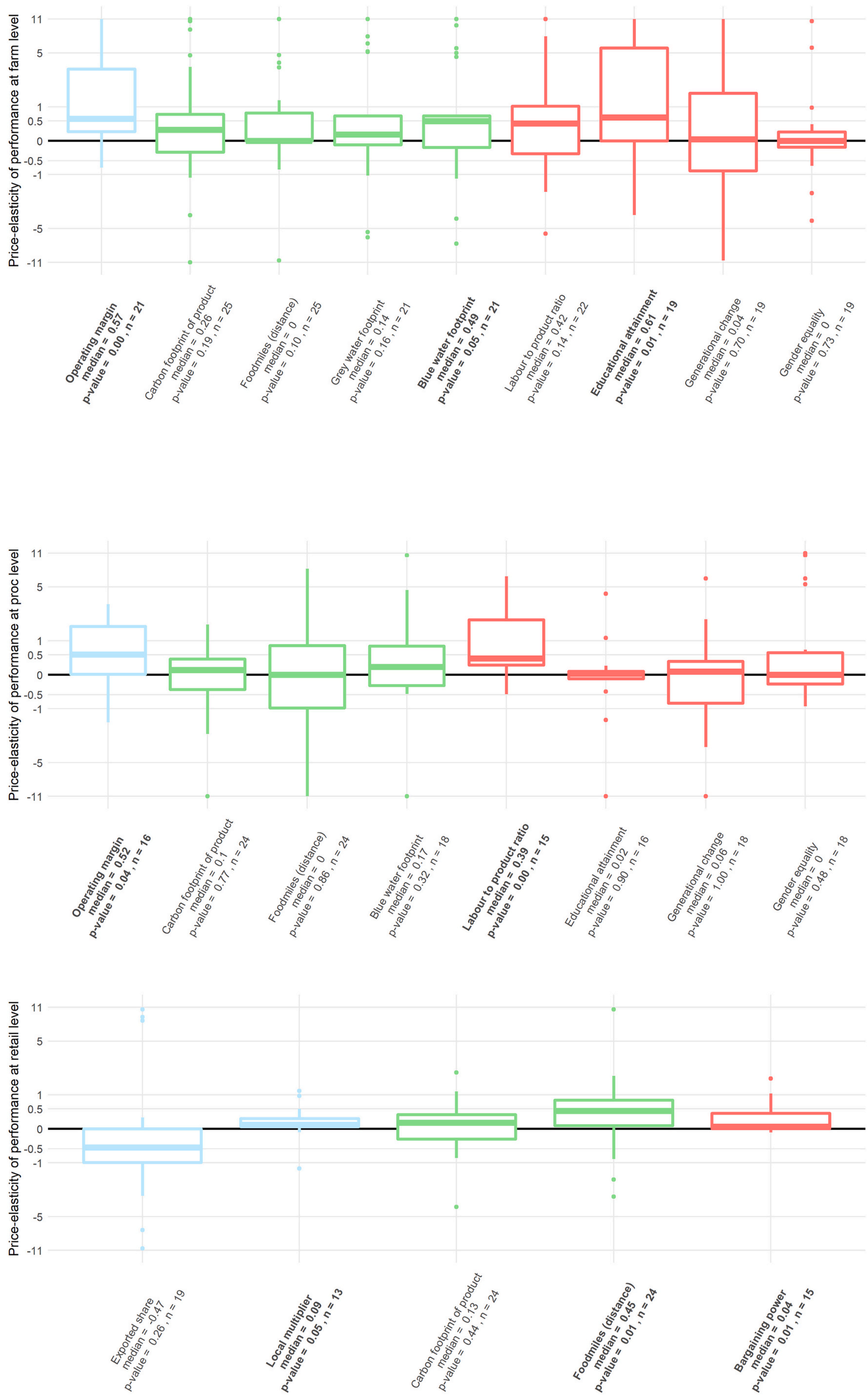


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**Fig. 2.** Marginal performance improvement of certified products per percentage point of price premium at farm, processing and retail levels. The marginal performance improvement shows how many percentage points are gained for a given indicator per percentage point of price premium of the certified food. It is estimated here in a non-causal way by dividing the relative difference in performance by the relative difference in price for each product and indicator. Indicators pertaining to the entire value chain (export, bargaining power distribution and local multiplier) are displayed in the "retail" frame. Sample size (n) varies between value chain level because not all levels exist in all value chains and because data was not available for some levels in some value chains. The *p*-value indicates the probability that the median is different from zero (Wilcoxon signed-rank test). Indicators for which the marginal performance improvement is significantly different from zero (i.e. p-value <0.1) are in bold. n indicates the number of certified products for which the indicator has been calculated. Three indicators at retail level for which the sample size is smaller than 5 are not displayed. Marginal performance improvement is bounded by [−11;11] for convenience of display. For the three product x level combinations where the price premium of the certified product is – very slightly – lower than zero, the marginal performance improvement is assumed to be infinite (eg. +∞ when the difference in performance is positive).

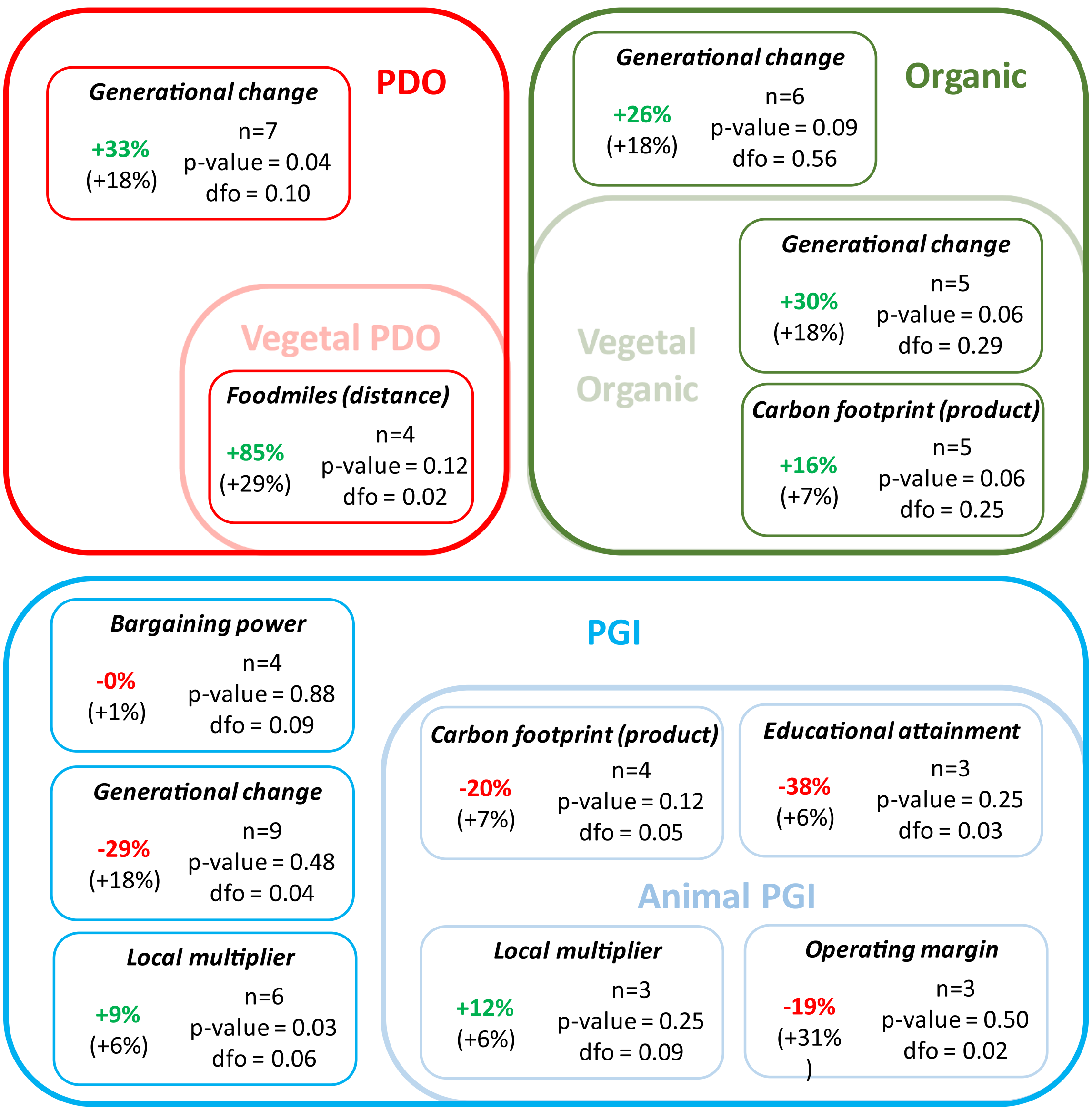


**Fig. 3.** Sustainability performance of specific subgroups. The median difference in performance for the subgroup (eg. PDO) between certified products and their reference (in %) appears in color above the median difference of the entire sample in brackets. "n" indicates the number of certified products of the subgroup, "*p*-value" the probability that the median difference in performance between the subgroup and their reference products is different from zero (p-value of the Wilcoxon signed rank test) and "dfo" stands for "different from others" and provides the probability that the subgroup is different from the rest of the population (Kruskal-Wallis test). Display is restricted to the subgroup x indicator combinations for which either the latter is lower than 0.1 or the former is lower than 0.1 while the *p*-value for the entire population is higher than 0.1.

young workers, with a significantly better performance of 33% and 26% respectively, compared with a non-significant 18% difference for the entire sample (Fig. 3). This confirms and broadens existing evidence for organic farmers and could be related to the better economic performance of these two value chains (eg. price premium of 73%, 58% and 40% for organic, PDO and PGI respectively with a *p*-value of the Kruskal-Wallis test close to 0.2 for organic and PGI). Other less documented features of certified value chains such as the preservation of cultural heritage could also contribute to attract young workers (Vandecandelaere et al., 2018).

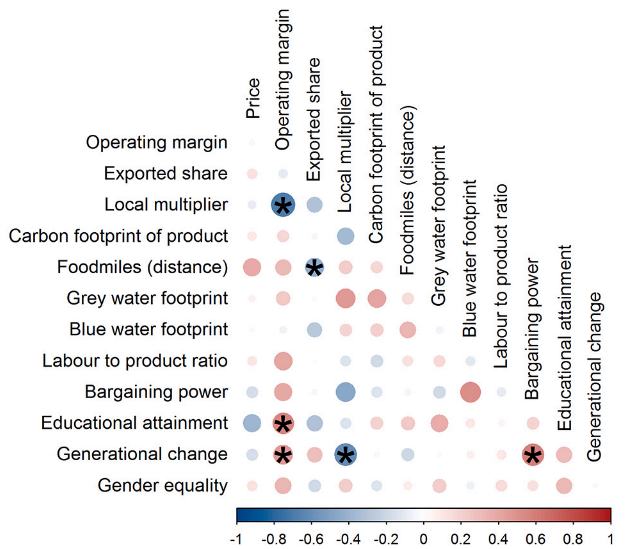


**Fig. 4.** Correlation between indicators. The higher the absolute value of the Spearman correlation coefficient, the larger the corresponding circle. A star indicates that the coefficient is significantly different from zero (p-value <0.05).

Organic vegetal products perform 16% better than their conventional reference products regarding climate mitigation (SM 4 and (Bellassen et al., 2021)). This substantially reinforces existing but weak evidence on the relative merit of organic farming for this sector (Meier et al., 2015). It is explained by the ban on mineral fertilizers: in the vegetal sector, mineral fertilizers are responsible for 40% of GHG emissions so that even large deficits in yield do not dilute the benefits from their absence.

Finally, for several indicators including bargaining power distribution and generational change, PGI value chains perform far worse than other quality signs, and similarly to conventional products (Fig. 3). Indeed, the technical specifications of PGIs are often restricted to processing and do not cover farming practices. However, one must not overemphasize this result: the understanding of the difference between PDO and PGI is not always clear for stakeholders and regulators, so that several products which would likely qualify as PDOs only seek PGI recognition.

### *3.5. Synergies and trade-offs between sustainability indicators*

High margins are associated with a younger and more educated workforce (Fig. 4): higher margins probably attract these workers, but younger and more qualified workers may also be more efficient and generate higher margins. To the contrary, high margins are negatively associated with a lower local multiplier, which may be explained by a more expensive local supply. Beyond significance level, one can also note that operating margin is positively correlated with almost all other indicators: when margins are high, it is likely easier for value chains to "invest" in environmental and social performance.

Beside higher margins, younger workers and entrepreneurs are also associated with a more evenly distributed bargaining power and a lower local multiplier. The youth may be more innovative in the contractual relationship with other value chain levels – e.g. through long-term contracts – and more involved in collective undertakings such consortia or unions. This may be mediated by educational attainment, which is also higher for younger workers.

Finally, foodmiles performance is trivially deteriorating with increasing exports.

### *3.6. Limits and possible improvements*

Several improvements and additions could be undertaken on the set of indicators. Most notably, our indicator for water pollution – grey water footprint – is restricted to nitrates. Pesticides were excluded due to difficulties in data collection in some countries, but proved feasible in several instances. Another interesting addition would be biodiversity. We did not find any biodiversity indicator robust enough to provide relevant information across all sectors: vegetal, terrestrial animal and seafood products. A possibility could be to introduce sector-specific indicators: fish population dynamics, for example, are a key sustainability indicator for wild catch seafood value chains.

Another crucial improvement would be to increase sample size. 26 paired products, each relying on primary variables averaged over multiple farms/firms, is a large sample compared to existing studies (see SM 7), especially if one excludes meta-analysis which tend to focus on a few indicators and are subject to methodological heterogeneity. However, it remains too modest to draw definitive conclusions on the relative merits of certified food. Moreover, increasing sample size would reduce uncertainty and thus possibly allow to identify other synergies and trade-offs between sustainability indicators. Most importantly, it would pave the way towards a more robust assessment of the causality of performance differences.

Two strategies could be explored to increase sample size. The obvious first strategy would be to enrich our database by repeating the same assessments over new value chains in new countries. The unit cost of assessing one value chain and its reference – around 3 person.months – is accessible for value chain representatives willing to assess their sustainability performance. By opening the method, tools and database, we hope that the database thrive on contributions from future users.

The second strategy would be to estimate our indicators from existing institutional databases (eg. FADN for European farms, Amadeus for European processors). This would however require two key improvements in these databases: the identification of all quality signs with an adequate consideration of representativeness and the addition of a few necessary variables (eg. energy use, age-distribution of the workforce, …) for the assessment of the environmental and social performance.

When this will happen, more causal assessments of the benefits or harms of certification will become possible, using propensity-score matching or quasi-natural experiments. These techniques reduce the subjectivity in the choice of counterfactual/reference firms which is an important limit to all existing studies on the relative performance of GI and organic value chains, including the present one.

Finally, while our analysis focuses on the EU, there is no obstacle to using the same method for the assessment of the sustainability of food value chains elsewhere. As a matter of fact, it has been successfully used to assess eight products in South-East Asia. Moreover, our results are consistent with existing literature for the indicators for literature in other parts of the world exists (eg. value added (Arfini et al., 2006; Crowder and Reganold, 2015; London Economics, 2008; Vandecandelaere et al., 2018), carbon footprint of organic products (Meier et al., 2015), …). This is a good sign for the global relevance of our findings, but extending the geographical coverage of our sample would be necessary to ascertain this.

## 4. Conclusion

In conclusion, EU certified food are shown to perform better than conventional value chains for two thirds of our key indicators, and this performance comes at a reasonable price premium compared with other policy interventions. Most economic and social indicators are significantly higher for certified products, although median differences are modest, typically around 10–20%. On the most common environmental indicators, certified and conventional value chains display similar performances as lower pollution per hectare is offset by lower yields. Organic certification is likely strong on its original claim to prevent the air and water from being polluted by pesticides, but this aspect was not assessed in our study.

Cumulatively, our findings provide a justification the policy interventions by the EU to support these standards, although not necessarily the expected one. Indeed, consumers may expect a higher environmental performance which is not confirmed for the most common indicators. However, some economic and social aspects which could be demanded by the consumers of certified food, such as local spillover, employment and bargaining power are improved at a reasonable cost compared with other public interventions.

Our findings also legitimate recent initiatives by the organic or GI standards to broaden their objectives such as including environmental clauses in the technical specifications of GIs (INAO, 2016) or including social clauses in the technical specifications of private organic standards (The Organic Research Centre, UK and Padel, 2018).

## Data availability

Both raw data and estimated indicators have been deposited in an open dataset and can be downloaded from https://data.inrae.fr/dataset.xhtml?persistentId=doi:10.15454/OP51SJ.

## Code availability

Code to estimate the indicators, perform the statistical tests and display the figures has been deposited in the aforementioned open dataset.

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## Author contributions

VB and FA had the original idea, VB designed the study, coordinated data collection and indicator estimation, conducted the statistical analysis and wrote most the first draft of the manuscript, MH and MDr contributed to the first draft of the manuscript, TP, SM and MDo estimated the economic indicators, VB, MDr and AB estimated the environmental indicators, MH, PM, MDu and MV estimated the social indicators, VB, MDr, JMG, LG, VH, AMR, KM, ON, JP, BR, MT, AT, MV, GV and FA managed data collection in their respective countries, all authors contributed to the final version of the manuscript.

## Declaration of Competing Interest

Authors declare no competing interests.

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The authors would like to thank all the people and institutions who collected or provided raw data for this publication. Unfortunately, they are too numerous to be exhaustively listed here but they will hopefully recognize themselves through the list of data sources and the associated book. Statistical analysis were conducted using the R software.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolecon.2021.107244.

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