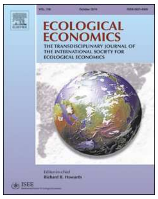
Ecological Economics 176 (2020) 106718

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon



Fairtrade, Agrochemical Input Use, and Effects on Human Health and the Environment

Jorge Sellare[a,b,*], Eva-Marie Meemken[c,d], Matin Qaim[a]

[a] *Department of Agricultural Economics and Rural Development, University of Goettingen, Platz der Goettinger Sieben 5, 37073 Goettingen, Germany*
[b] *Center for Development Research (ZEF), University of Bonn, Genscherallee 3, 53113 Bonn, Germany*
[c] *Department of Food and Resource Economics, University of Copenhagen, Rolighedsvej 25, 1958 Frederiksberg, Denmark*
[d] *CH Dyson School of Applied Economics and Management, Cornell University, Warren Hall, 14853 Ithaca, USA*

ARTICLE INFO

Keywords:
Agrochemicals
Certification
Fairtrade
Health
Pesticides
Sustainability standards
Toxicity

ABSTRACT

It is often assumed that voluntary sustainability standards – such as Fairtrade – could not only improve the socioeconomic wellbeing of smallholder farmers in developing countries but could also help to reduce negative health and environmental impacts of agricultural production. The empirical evidence is thin, as most previous studies on the impact of sustainability standards only focused on economic indicators, such as prices, yields, and incomes. Here, we argue that Fairtrade and other sustainability standards can affect agrochemical input use through various mechanisms with possible positive and negative health and environmental effects. We use data from farmers and rural workers in Cote d'Ivoire to analyze effects of Fairtrade certification on fertilizer and pesticide use, as well as on human health and environmental toxicity. Fairtrade increases chemical input quantities and aggregated levels of toxicity. Nevertheless, Fairtrade reduces the incidence of pesticide-related acute health symptoms among farmers and workers. Certified cooperatives are more likely to offer training and other services related to the safe handling of pesticides and occupational health, which can reduce negative externalities in spite of higher input quantities. These results suggest that simplistic assumptions about the health and environmental effects of sustainability standards may be inappropriate.

1. Introduction

Global food demand will continue to grow in the coming decades with concomitant challenges for sustainable agricultural supply (Gouel and Guimbard, 2019). In the past, several factors have contributed to growth in agricultural supply, with substantial differences across geographic regions. In many parts of the world, production increases during the last 50 years were strongly associated with a more intensive use of agrochemicals (Christiaensen, 2017; Meemken and Qaim, 2018a). While chemical fertilizers and pesticides help to increase crop yields, their misuse can lead to soil, water, and air pollution causing serious problems for the environment and human health (Elahi et al., 2019; Li et al., 2019; Sheahan et al., 2017; Stoner and Eitzer, 2013). Appropriate public policies can reduce negative environmental and health externalities. In addition, voluntary sustainability standards – such as Fairtrade, Organic, UTZ, or Rainforest Alliance – could potentially help, especially in developing countries where related public policies are often absent or poorly enforced.

During the last decade, voluntary sustainability standards grew in importance for all major tropical food commodities, with cocoa seeing the biggest increase in its share of certified area (Willer et al., 2019). However, to what extent sustainability standards actually deliver on their promises remains an open question (Meemken, 2020; Oya et al., 2018). Several studies analyzed effects of sustainability standards on economic indicators, such as crop yields, prices, profits, and household income (Akoyi and Maertens, 2018; Beuchelt and Zeller, 2011; Chiputwa et al., 2015; Jena et al., 2017; Meemken et al., 2017; Sellare et al., 2020; van Rijsbergen et al., 2016; Vanderhaegen et al., 2018). Effects on environmental and health indicators were analyzed much less.

A few studies on selected environmental effects exist for Organic standards, suggesting that Organic certification (sometimes in combination with other standards) leads to more environmentally-friendly production and decreases in the use of chemical fertilizers and pesticides (Blackman and Naranjo, 2012; Ibanez and Blackman, 2016; Vanderhaegen et al., 2018). However, Organic standards have a particular focus on the environment and ban the use of any chemical inputs, which is not the case for most other sustainability standards. Hence,

---

[*] Corresponding author.
E-mail address: jsellare@uni-bonn.de (J. Sellare).

https://doi.org/10.1016/j.ecolecon.2020.106718
Received 24 February 2020; Received in revised form 6 May 2020; Accepted 18 May 2020

these effects cannot be generalized. We are aware of only two studies that analyzed effects of sustainability standards other than Organic on environmental indicators with somewhat mixed results: Vanderhaegen et al. (2018) used data from farmers in Uganda showing that UTZ-Rainforest Alliance-4C triple certification increases the likelihood of farmers using agrochemicals, whereas Elder et al. (2013) used data from Rwanda concluding that Fairtrade certification has no effect on chemical input use.

We add to this existing literature by analyzing effects of Fairtrade on chemical fertilizer and pesticide use with data from farmers and rural workers in Cote d'Ivoire, the world's largest exporter of cocoa. Unlike previous studies, we do not only look at chemical input quantities, but also at toxicity by calculating the pesticide environmental impact quotient (EIQ) and the hazard quotient (HQ). In addition, we evaluate effects of Fairtrade on pesticide-related health symptoms as reported by farmers and rural workers, similar to the approach used by Asfaw et al. (2010) in their analysis of the health effects of GlobalGAP certification in Kenya.

While less stringent than Organic, Fairtrade involves certain regulations and measures to reduce negative environmental and health effects of agrochemicals. For instance, certain types of toxic pesticides are banned (Fairtrade, 2019; Fairtrade, 2014). At the same time, it is possible that Fairtrade increases agrochemical input use through price incentives, agricultural extension, and other services often provided by Fairtrade-certified cooperatives. Which of these effects dominates is an important question that we address empirically with our data from Cote d'Ivoire. Most previous studies on the effects of sustainability standards used data from only a small number of purposively selected cooperatives. We use data from 50 randomly selected cooperatives, which facilitates the analysis of cooperative-level mechanisms and also adds to external validity. Possible issues of endogeneity in the impact evaluation are addressed through instrumental variable approaches.

2. Fairtrade and Agrochemical Input Use

It is often assumed that Fairtrade and other sustainability standards lead to reductions in the use of chemical fertilizers and pesticides, but this is not necessarily true in every situation. In fact, there are various mechanisms through which Fairtrade could affect the use of agrochemical inputs and their effects on human health and the environment. In this section, we briefly discuss the different mechanisms, before evaluating the effects empirically in subsequent sections.

First, Fairtrade standards have several concrete regulations related to agrochemical input use that must be met by certified cooperatives and their member farmers (Fairtrade, 2019, 2014). Chemicals marked as ‘red’ in Fairtrade's list of hazardous materials are prohibited. This list mainly refers to pesticides and is based on classification systems of the World Health Organization (WHO) and other internationally accepted institutions (Fairtrade, 2018). In addition, Fairtrade farmers receive training on integrated pest management, in order to learn about economic thresholds and non-chemical measures of pest control. These regulations are expected to reduce chemical input use, at least in situations where pesticide use is commonplace.

Second, Fairtrade certification also requires training of farmers on the safe utilization of hazardous materials and the use of protective clothes by all persons handling pesticides. Furthermore, Fairtrade regulations involve a buffer zone for the application of pesticides of at least 10 m from other human activity (Fairtrade, 2019). While these measures do not necessarily reduce chemical input quantities, they are expected to reduce the direct human exposure to pesticides and thus negative health impacts.

Third, Fairtrade cooperatives often provide general agricultural extension and agronomic training to help farmers increase their crop productivity (Meemken and Qaim, 2018b; Sellare et al., 2020). Such extension services are frequently financed through the Fairtrade premium, an amount of money paid to certified cooperatives dependent of the quantity of produce marketed through Fairtrade channels. In addition, cooperatives often use the Fairtrade premium to facilitate farmers' access to inputs through bulk purchases, subsidized distribution, and sometimes other forms of financial or credit assistance (Loconto et al., 2019). Smallholders in Africa often use low amounts of purchased inputs due to human and financial capital constraints. In such situations, the services offered by Fairtrade cooperatives may increase agrochemical input use.

Fourth, Fairtrade offers a floor price for the certified output, which is usually higher than the free market price. Higher output prices increase the profit-maximizing levels of input use. Hence, this mechanism may lead to an increase in the quantities of agrochemical inputs.

Which of these mechanisms dominates in a particular context depends on various farm-, household-, and cooperative-level variables and on the broader socioeconomic context. In the following, we analyze the situation in the cocoa sector of Cote d'Ivoire.

3. Materials and Methods

3.1. Study Area

This study uses data from a survey conducted in 2018 in the Southeast of Cote d'Ivoire, a region that is part of the old West African cocoa belt. This region was selected because of the large number of Fairtrade certified and non-certified cocoa cooperatives operating there. The Southeast of Cote d'Ivoire is characterized by relatively old cocoa plantations, depleted soils, and a high incidence of various pests and diseases, such as mirids, black pods, stem borers, and the swollen shoot virus (Foundjem-Tita et al., 2017). Most cocoa farmers use chemical pesticides to control pests and diseases, even though affordable access to agrochemicals is often difficult for the smallholder producers. Cocoa farmers are typically organized in cooperatives, which offer certain services to their members and through which the cocoa is also marketed (Foundjem-Tita et al., 2017). Usually, several cooperatives are operating in the same locations. Farmers are free to choose which of the cooperatives in their vicinity they want to be members of. In addition to logistical considerations and expected costs and benefits, factors related to kinship and other social ties often influence the decision of which cooperative to join (Sellare et al., 2020).

One important service that many cooperatives provide to their members is facilitating access to agricultural inputs. Agrochemicals are not generally subsidized in Cote d'Ivoire, but the *Conceil du Café et du Cacao* (CCC) distributes certain quantities of agrochemicals through the cooperatives, which then further distribute these inputs to their members at subsidized rates. However, the quantities are rationed, and irregularities in the distribution are commonplace. Beyond their role in input provision, cooperatives sometimes also provide agricultural extension services and awareness building for the safe use of agrochemicals. Such training services are often implemented together with government extension agencies, development organizations, or other public and private partners. Some of the cooperatives also offer pesticide spraying services for member farmers, meaning that farmers can consult a cooperative specialist who supports them in scouting their cocoa fields for pests and implements the spraying operations.

3.2. Sampling and Data Collection

One of the key objectives of our study design was to capture a lot of heterogeneity at the cooperative level, in order to increase external validity and be able to analyze cooperative-level mechanisms. Hence, we decided to sample from a larger number of cooperatives than previous studies on the effects of sustainability standards had done. With the help of different international, national, and local organizations, we compiled a list of all active cocoa cooperatives in the Southeast of Cote d'Ivoire. From this list, we randomly selected 25 Fairtrade certified and 25 non-certified cooperatives, leading to a total of 50 cooperatives.[1] In each of the 50 cooperatives, we interviewed the cooperative leader in order to collect data on cooperative characteristics and the types of services offered to their members. In addition, in each cooperative we randomly sampled 10 farmers and 10 workers, leading to a total sample of 500 farmers and 500 workers.

Farmers decide what types and quantities of inputs are applied on their cocoa fields. Hence for the analysis of input use, we do not include the data from the workers. However, workers may apply pesticides or be affected otherwise by exposure to agrochemicals, so for the analysis of pesticide-related health symptoms, we use both the data from farmers and workers. There are two different types of workers, namely farm workers (locally known as *aboussant*) and cooperative workers (Meemken et al., 2019). Farm workers are employed by farmers to carry out field operations, and they typically live near to the cocoa fields. The group of cooperative workers is more heterogeneous and includes cooperative staff working in administration, logistics, and agriculture-related tasks. Many of the cooperative workers are hardly exposed to agrochemicals, but especially those involved in spraying services are exposed to pesticides to a significant extent.

The personal interviews with all respondents were conducted between May and June 2018 by a team of local enumerators, who were selected, trained, and monitored by the researchers. The structured questionnaires were programmed for use with tablet computers. We used separate questionnaires for farmers and workers, although some of the modules – such as those related to general household characteristics, income, asset ownership, and exposure to pesticides – were identical.

Questions on details of agrochemical input use were included only in the farmer questionnaire. Farmers reported the types and quantities of fertilizers and pesticides (insecticides, fungicides, and herbicides) they had used in their cocoa fields during the past 12 months. For the pesticides used, the brand names or local names of all substances used were also captured. For each substance, we later verified active ingredients with the help of local agronomists and input dealers. For the analysis of pesticide use, out of the total of 500 farmer observations we had to drop 31 because respondents did not remember the quantities of the pesticides applied.

In order to obtain information about pesticide-related health symptoms, we first asked farmers and workers whether they had been exposed to pesticides directly during the last 12 months or they had entered a cocoa field within three days after spraying. Of the 500 farmers, 130 reported such type of exposure. Of the 500 workers, 125 (104 farm workers and 21 cooperative workers) were exposed to pesticides. For these 255 exposed respondents, we followed up by asking whether they had experienced any pesticide-related health symptoms during a period of 24 h after exposure. For these questions we used a list of common health symptoms as further explained below.

3.3. Measurement of Outcome Variables

In order to evaluate how Fairtrade affects the use of agrochemical inputs and their impacts on the environment and human health, we use three sets of outcome variables, namely (i) agrochemical input quantities, (ii) aggregated pesticide toxicity, and (iii) pesticide-related health symptoms. Agrochemical input quantities are calculated separately for chemical fertilizers and pesticides and are measured in kg per hectare of cocoa. Pesticide quantities include the quantities of insecticides, fungicides, and herbicides used.

There is no uniform measure of pesticide toxicity, as impacts on soils, plants, aquatic organisms, insects, and mammals differ. We use two indicators of aggregated pesticide toxicity, namely the environmental impact quotient (EIQ) and the hazard quotient (HQ). EIQ is a multidimensional measure of the environmental and health effects of pesticides and was developed by Kovach et al. (1992). It was extensively used in the recent literature to evaluate environmental and health effects of various pest control strategies (Abedullah Kouser and Qaim, 2015; Kromann et al., 2011; Midingoyi et al., 2019; Veettil et al., 2017). The EIQ is calculated as:

$$EIQ = \sum_{ai=1}^{N} EIQ_{ai} * [dosage\ ha^{-1}] * Proportion_{ai} \tag{1}$$

where EIQ_{ai} is the base EIQ for each active ingredient, $dosage\ ha^{-1}$ is the amount of formulation in kg per hectare, and $Proportion_{ai}$ is the proportion of each active ingredient in the pesticide formulation. The higher the EIQ, the greater is the aggregated environmental and health toxicity of the pesticides used.

The EIQ combines different types of toxicity and environmental impacts (soil, water, aquatic organisms, mammals, etc.) in one indicator, which can be seen as an advantage. However, in doing so, it assigns scales and weights to the various components, which can also lead to possible misinterpretation, depending on what the concrete purpose is (Kniss and Coburn, 2015; Peterson and Iii, 2014). The HQ is narrower, as it only considers toxicity to mammalian species (including humans), but is easier to interpret and uses more straightforward data for the measurement of acute toxicity, such as the lethal dose of a substance to kill 50% of the test animals (LD_{50}) (Kniss, 2017; Nelson and Bullock, 2003; Stoner and Eitzer, 2013). We calculate HQ as follows:

$$HQ = \sum_{ai=1}^{N} \frac{Amount_{ai}}{Toxicity_{ai}} \tag{2}$$

where N is the total number of pesticide active ingredients applied to cocoa, $Amount_{ai}$ is the quantity of each active ingredient applied, and $Toxicity_{ai}$ is the acute rat LD_{50} via oral administration, expressed in mg per kg of animal weight.[2] A smaller LD_{50} means higher toxicity. However, as toxicity appears in the denominator, a larger HQ indicates a more toxic combination of pesticides.

Pesticide-related health symptoms are indicators of actual human health effects, which are not only a function of pesticide toxicity but also of handling practices. We analyze the self-reported number of acute health symptoms experienced by farmers and workers, similar to what has been used in other studies on the health effects of pesticide use (Asfaw et al., 2010; Kouser and Qaim, 2011). In particular, the following symptoms are considered: general weakness, vomiting, excessive sweating, stomach pain, sleeplessness, skin irritation, headache, fever, eye irritation, diarrhea, coughing, breathlessness, other respiratory problems, and other symptoms to be specified. Our outcome variable is the sum of the number of all symptoms reported by each respondent.

3.4. Regression Models

We analyze the effect of Fairtrade on the outcome variables using regression models of the following type:

$$y_{ijk} = \alpha + \beta FT_{jk} + \gamma X_{ijk} + \theta W_{jk} + \delta D_k + \varepsilon_{ijk} \tag{3}$$

---

[1] Of the 25 Fairtrade certified cooperatives in our sample, 16 were additionally certified under UTZ and/or Rainforest Alliance (RA). We cannot analyze the effects of UTZ and/or RA separately, because we did not sample cooperatives that are only UTZ/RA certified without also being Fairtrade certified. However, in the statistical analysis we test whether UTZ/RA has additional effects or changes the effects of Fairtrade in any way. Note that in 2018, UTZ and RA legally merged under the name Rainforest Alliance. However, as of April 2020 the new joint standard has not been launched in practical terms.

[2] Note that other measures of toxicity can be used in principle to calculate the HQ, also including measures of chronic toxicity (Kniss, 2017). We concentrate on acute toxicity, as reliable data on chronic toxicity are not available for many of the active ingredients relevant in the local context.

where y_{ijk} is the respective outcome variable for household i belonging to cooperative j in district k. We estimate separate models for each of the outcome variables (i.e., quantity of fertilizer and pesticides, EIQ, HQ, number of health symptoms). The main explanatory variable of interest is FT_{jk}, which is a dummy variable indicating whether or not cooperative j is Fairtrade certified. A statistically significant β would imply that Fairtrade has an effect on the respective outcome variable, also after controlling for possible confounding factors. In the estimations, we control for a vector of exogenous household-level variables, X_{ijk}, such as farmer age, education, and asset ownership. Furthermore, we control for cooperative characteristics, W_{jk}, such as the age of the cooperative and the number of service providers, as these may also affect farmers' behavior with and without Fairtrade certification (Sellare et al., 2020). Lastly, we include a set of district dummies, D_k, to account for possible geographical differences in terms of infrastructure and market access. In all estimations the error term, ε_{ijk}, is clustered at the cooperative level.

Depending on the particular outcome variable, we use different model specifications and functional forms. Some of the farmers do not use any fertilizers and pesticides, so that the variables measuring agrochemical quantities and toxicity levels are censored at zero. Such corner solution models can be estimated with a double-hurdle specification as follows (Ricker-Gilbert et al., 2011):

$$q_{ijk}^{d} = \pi_0 + \pi_1 FT_{jk} + \pi_2 X_{ijk} + \pi_3 W_{jk} + \pi_4 D_k + u_{ijk}, \text{ where } q_{ijk}^{d} = \begin{cases} 1 \text{ if } q_{ijk} > 0 \\ 0 \text{ otherwise} \end{cases} \tag{4}$$

$$q_{ijk} = \omega_0 + \omega_1 FT_{jk} + \omega_2 X_{ijk} + \omega_3 W_{jk} + \omega_4 D_k + v_{ijk}, \quad \text{given } q_{ijk}^{d} = 1 \tag{5}$$

In the first hurdle in eq. (4), ${q_{ijk}}^{d}$ is a dummy variable that represents the farmer's choice whether or not to use the particular type of agrochemical. In the second hurdle in eq. (5), q_{ijk} is a continuous variable representing the quantity of agrochemicals used (or their toxicity), conditional on the first hurdle being passed. u_{ijk} and v_{ijk} are normally distributed and independent error terms.[3]

The number of pesticide-related health symptoms is a count variable drawn from a Poisson distribution. Therefore, we use an exponential conditional mean model as follows:

$$y_{ijk} = exp(\alpha + \beta FT_{jk} + \gamma X_{ijk} + \theta W_{jk} + \delta D_k + \varphi R_{ijk}) + \varepsilon_{ijk} \tag{6}$$

As this model includes observations from farmers, farm workers, and cooperative workers, we include an additional set of two dummy variables, R_{ijk}, indicating to which group the particular observation belongs. We use the group of farmers as the reference category.

3.5. Identification Strategy

As Fairtrade certification is not randomly assigned to cooperatives and farmers, the variable FT_{jk} in the regression models is potentially endogenous, which could lead to biased estimates. Cooperatives decide whether or not they want to be certified, and farmers decide which cooperative they want to be member of. In all specifications, we control for several cooperative characteristics and also include farmer-level measures such as individual risk aversion (Dohmen et al., 2011) that proxy for possible unobserved heterogeneity. Nevertheless, correlation between FT_{jk} and the error terms cannot be ruled out, so that we use instrumental variable (IV) approaches to test and control for endogeneity.

In particular, we use three instruments for FT_{jk}, building on previous work by Meemken et al. (2019) and Sellare et al. (2020) and exploiting different dimensions of social networks that influence the certification decision. These instruments are: (i) the share of Fairtrade certified farmers in a 5 km radius; (ii) the distance to the closest Fairtrade certified cooperative; and (iii) the mobile phone provider of the cooperative leader. These instruments are further explained and tested for validity in the following.

The first instrument, the share of certified farmers in a 5 km radius, captures household-level social network effects, as farmers located closer to other certified farmers are more likely to learn about certification and its possible advantages.[4] Farmers cannot get Fairtrade certification individually, but they can decide to join (or leave) a Fairtrade certified cooperative. Our data confirm a significant correlation between the share of certified farmers in the neighborhood and own certification (Table A2 in the Online Appendix), which is the key condition for instrument relevance. In addition, for an instrument to be valid, it must not affect the outcome variables directly. One could expect that locations with more Fairtrade certified cooperatives and farmers are those that also have more extension offices or better infrastructure and access to markets, all of which could influence farmers' input use independent of own certification. However, government extension offices are spread throughout the study area. Moreover, our data show that there is no pronounced geographic clustering of certified cooperatives, meaning that certified and non-certified cooperatives are found in the same locations. Using a simple falsification test, as proposed by Di Falco et al. (2011), we find that the share of certified farmers in a 5 km radius is not significantly correlated with agrochemical input use or pesticide toxicity (Table A2).[5]

Our second instrument, the distance to the headquarters of the closest Fairtrade certified cooperative, is defined with respect to the respondent's household and also captures network effects. Farmers who live close to the headquarters of a certified cooperative are more likely to learn about Fairtrade and join this cooperative. Also for workers, the closer they live to the headquarters of a certified cooperative, the more likely they will work there. Table A2 in the Online Appendix confirms the expected negative correlation between this distance measure and own Fairtrade certification status, whereas the instrument is not significantly correlated with any of the outcome variables. Even though living closer to the headquarters of a certified cooperative can be associated with better access to inputs and training, this effect works through cooperative membership and therefore own certification, as cooperatives rarely offer related services to non-members.

The third instrument, the mobile phone provider of the cooperative leader, captures network effects at the cooperative level. In total, there are three network providers operating in the study area, namely Orange, MTN, and Moov. All three offer similar services at similar costs, so the choice for the individual mainly depends on the strength of the network signal in a particular location and on which provider others in the personal social network are subscribed to. There are economic advantages of communicating with people who have the same network provider, since the providers offer discounts for calls and text messages exchanged within their networks. Our data show that cooperatives whose leader is subscribed to Orange are more likely to be certified. Hence, it is likely that more information about Fairtrade is exchanged within the Orange network than within other networks. Table A2 in the Online Appendix confirms the positive correlation between the cooperative-level instrument and own certification status. One could

---

[3] The tobit model is a specific case of the double-hurdle model where the influencing factors in both hurdles are identical. Table A1 in the Online Appendix shows likelihood ratio tests, the results of which suggest that in most cases the two-equation double-hurdle model is preferred over the single-equation tobit specification.

[4] Some of the cooperative workers, whose observations are included in the analysis of health symptoms, live elsewhere (e.g., in a nearby city). In those cases, we do not consider the location of the own household but use the cooperative mean of the share of certified farmers in a 5 km radius.

[5] While the instrument is individually significant in the health symptom regression, the falsification test shows that all three instruments together are jointly insignificant at the 5% level (Table A2).

argue that the decision of the cooperative to become certified might have influenced the leader's decision of the mobile phone provider, which would make the instrument endogenous. However, this is not the case in our context, as people rarely switch their mobile phone providers. In fact, only three of the 25 certified cooperative leaders in our sample switched their phone provider after the cooperative became certified. The instrument is not directly correlated with any of the outcome variables (Table A2).

Using a Wald test we also show that our three instruments are jointly correlated with Fairtrade certification (Table A2). Furthermore, we show that the three instruments are not jointly correlated with any of the outcome variables at the 5% significance level. As we have more instruments than endogenous regressors, we can also test whether our instruments are uncorrelated with the error term with a test of overidentifying restrictions. Hansen's J test statistic indicates that our instruments are valid (Table A3).

For the double-hurdle models to analyze agrochemical input quantities and toxicity levels, we use the three instruments in a control function (CF) framework (Wooldridge, 2015). The CF approach entails first regressing the endogenous variable on the instruments and all exogenous covariates. The residuals from this first-stage regression are then included in the outcome models. The significance of the residuals in the outcome models tests for endogeneity. If the residuals are insignificant, the exogeneity hypothesis cannot be rejected and estimation without the residuals included leads to consistent and more efficient results. If the residuals are statistically significant, however, the exogeneity hypothesis is rejected and inclusion of the residuals controls for endogeneity bias. Following previous research (Benali et al., 2018; Rao and Qaim, 2013; Ricker-Gilbert et al., 2011; Woldeyohanes et al., 2017), we test for endogeneity in both hurdles of the double-hurdle model (Table A4 in the Online Appendix) and include the residuals in those cases where the exogeneity hypothesis is rejected at the 5% level.

For the exponential model to analyze pesticide-related health symptoms, we use a nonlinear IV approach based on the generalized method of moments estimator (IV-GMM) (Cameron and Trivedi, 2013; Hirvonen and Hoddinott, 2017). This is an appropriate approach for nonlinear models, even when the model is over-identified with clustered errors (Mullahy, 1997; Wooldridge, 2001). The exogenous instruments are used to create additional moment conditions and solve a minimization problem, namely that the correlation between the endogenous variable and the error term is as close to zero as possible.

4. Results and Discussion

4.1. Descriptive Statistics

Table 1 shows descriptive statistics for agrochemical input use and related indicators by certification status. Fairtrade certification is associated with significantly higher chemical input quantities per hectare of cocoa. On average, certified farmers use almost twice as much fertilizer as non-certified farmers. Certified farmers also use 25% more pesticides (total quantities of insecticides, fungicides, and herbicides) than non-certified farmers. This is not necessarily an indication that certified farmers overuse agrochemicals, as it is also possible that non-certified farmers underuse fertilizers and pesticides. Higher input intensities contribute to higher cocoa yields, as can also be seen in Table 1. Nevertheless, they potentially also contribute to higher levels of environmental and health toxicity.

We identified 20 different pesticide active ingredients that cocoa farmers commonly use in different combinations. These active ingredients are listed in Table 2 together with their Fairtrade color classifications, WHO classifications, and levels of toxicity in terms of EIQ and LD_{50}. Interesting to note is that EIQ and LD_{50} values are not significantly correlated. As explained above, LD_{50} only looks at mammalian toxicity, whereas EIQ also tries to evaluate other environmental risks. For some of the active ingredients in Table 2, notable disparities are observed. For instance, of the products considered, the fungicide Carbendazim has one of the highest toxicity levels when evaluated with the EIQ, but the lowest toxicity level in terms of LD_{50}. Hence, both indicators are not directly comparable, and the LD_{50} (as well as the HQ) should not be used to draw conclusions about toxicity for non-mammalian organisms (Kniss, 2017).

Table 1
Agrochemical input use and related indicators by Fairtrade certification status.

	(1) N	(2) Full sample	(3) Certified	(4) Non-certified	(5) Mean difference
Number of fertilizer applications	500	0.94 (0.95)	1.20 (0.98)	0.67 (0.84)	0.54***
Fertilizer (kg/ha)	492	37.91 (78.67)	48.49 (78.48)	27.49 (77.62)	21.00***
Number of pesticide applications	500	2.51 (1.41)	2.62 (1.46)	2.40 (1.36)	0.23*
Total pesticide use (kg/ha)	469	1.92 (2.09)	2.14 (2.50)	1.71 (1.61)	0.43**
Insecticides (kg/ha)	489	1.01 (0.82)	1.14 (0.94)	0.89 (0.66)	0.24***
Fungicides (kg/ha)	476	0.66 (1.65)	0.84 (2.09)	0.49 (1.07)	0.35**
Herbicides (kg/ha)	487	0.27 (0.76)	0.18 (0.67)	0.36 (0.83)	−0.18**
Cocoa yields (kg/ha)	500	540.31 (250.36)	573.58 (265.70)	507.03 (229.76)	66.55***
Environmental impact quotient (EIQ)	469	20.20 (36.41)	23.98 (45.19)	16.71 (25.39)	7.27**
Hazard quotient (HQ)	469	747.01 (1157.08)	864.66 (1355.52)	638.53 (927.42)	226.12**
Number of acute health symptoms[a]	255	1.83 (2.69)	1.20 (2.61)	2.30 (2.66)	−1.10***

Note: Mean values are shown with standard deviations in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$.

[a] Health symptoms refer to both farmers and workers. Data are shown only for those that reported having been exposed to pesticides.

Comparing actually applied quantities of each active ingredient between certified and non-certified cocoa farmers in our sample reveals that Fairtrade certification is associated with significantly higher aggregated toxicity, measured in terms of both EIQ and HQ (Table 1). At the same time, Fairtrade certification is associated with a significantly lower number of pesticide-related acute health symptoms experienced by farmers and rural workers. Fewer health problems in spite of higher levels of pesticide toxicity in Fairtrade certified cocoa point at safer pesticide application practices. Fig. 1 shows a breakdown of the data by health symptom. Certified farmers and workers reported lower frequencies of health problems for almost all symptoms considered.

A bit more context about the local division of labor and farmers' and workers' exposure to chemical pesticides may be useful for the interpretation of the results. In the study area in Cote d'Ivoire, many of the routine operations in cocoa production, such as pruning, fertilization, and harvesting, are carried out by farm workers (*aboussant*) with lesser involvement by the farmers themselves (Meemken et al., 2019). In principle, farm workers also apply chemical pesticides, but for pest control, farmers often also use spraying services offered by many cooperatives, meaning that the pesticides are applied by cooperative field workers or extension agents. In our sample, only 15% of the farmers and 25% of the farm workers mentioned that they were directly involved in pesticide applications during the 12 months prior to the survey. However, farmers and farm workers may also be exposed to pesticides more indirectly. Most farmers live in villages that are

Table 2
List of pesticide active ingredients used by farmers and various toxicity classifications.

Active ingredients	Main use	FT classification[a]	WHO classification[b]	EIQ	LD_{50} (mg/ kg)[c]
Acetamiprid	Insecticide	–	II	28.73	146
Bifenthrin	Insecticide	Orange	II	44.35	54.5
Chlorantraniliprole	Insecticide	Orange	U	18.34	5000
Cypermethrin	Insecticide	Orange	II	36.35	250
Deltamethrin	Insecticide	Orange	II	28.38	135
Diazinon	Insecticide	Yellow	II	44.03	300
Imidaclopride	Insecticide	Orange	II	36.71	450
Lambda-cyhalothrin	Insecticide	Orange	II	44.17	56
Profenofos	Insecticide	Yellow	II	59.53	358
Thiacloprid	Insecticide	Yellow	II	31.33	396
Thiamethoxam	Insecticide	Orange	II	33.3	1563
Mefanoxam, metalaxyl-M	Fungicide	–	II	19.07	670
Carbendazim	Fungicide	Orange	U	50.5	10,000
Copper hydroxide	Fungicide	Yellow	II	33.2	1000
Copper oxide	Fungicide	–	U	33.2	7792
Mancozeb	Fungicide	Orange	U	25.72	8000
Mandipropamid	Fungicide	–	U	27.14	5000
2.4-D dimethylamine	Herbicide	–	II	20.67	625
Glyphosate	Herbicide	Orange	III	15.33	4230
Paraquat	Herbicide	Red	II	24.73	150

[a] In the Fairtrade classification, red means ‘prohibited,’ orange means ‘restricted,’ and yellow means ‘flagged’.
[b] II = Moderately hazardous; III = Slightly hazardous; U = unlikely to present acute hazard.
[c] Lethal dose for 50% of the population based on the acute toxicity for rats via oral administration.

typically located at some distance to the cocoa fields. In contrast, farm workers often live in houses or huts near the cocoa fields, increasing the likelihood of being exposed to pesticides. Indeed, 41% of the farm workers in our sample reported having been exposed to pesticides directly or indirectly, compared to only 26% of the farmers in the sample.

Tables A5 and A6 in the Online Appendix show descriptive statistics for the control variables used in the regression analysis. For farmers

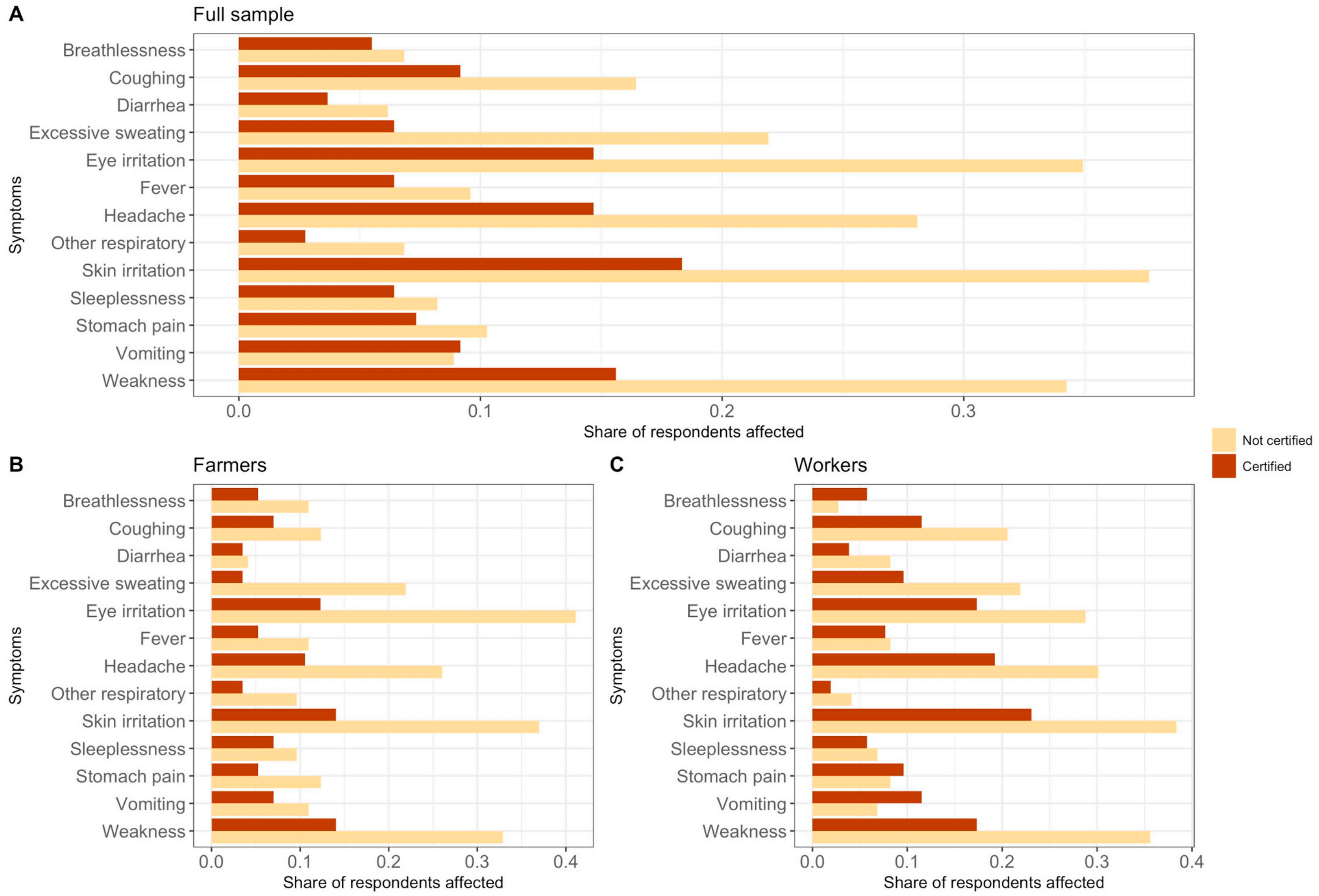


Fig. 1. Incidence of pesticide-related acute health symptoms among respondents who were exposed to pesticides (N = 255).

Table 3
Effects of certification on agrochemical input use (double-hurdle marginal effects).

			(1)	(2)
			Fertilizer use	Pesticide use
Certification (1/0)	First hurdle (1/0)	Probit ME	0.18***	-9e-3
			(0.06)	(0.03)
	Second hurdle (kg/ha)	Conditional ME	4.33	0.35**
			(26.96)	(0.18)
		Unconditional ME	21.12	0.31*
			(14.55)	(0.18)
Observations			492	469

Note: Average marginal effects (ME) are shown with delta-method standard errors in parentheses. $^{*}p < .1$, $^{**}p < .05$, $^{***}p < .01$.
All regressions include household and cooperative-level control variables. Full results are shown in Tables A7 and A8 in the Online Appendix.

(Table A5), a few significant differences between certified and non-certified can be observed in terms of household and cooperative characteristics (Table A5). For instance, Fairtrade certified cooperatives are older than non-certified cooperatives. Also, certified cooperatives make a larger share of the decisions democratically, and they cooperate with more external partners to provide inputs, training, and other services to their members. In terms of cocoa farm characteristics, such as the size of the landholdings, pest infestation levels, or age of the cocoa trees, most of the differences are small and not statistically significant. For the sample of workers (Table A6), no significant differences are observed.

4.2. *Effects of Fairtrade on Chemical Input Quantities*

Table 3 shows marginal effects of Fairtrade certification on fertilizer and pesticide quantities, as derived from double-hurdle model estimation. We start the discussion with fertilizer. The first-hurdle estimation results suggest that certification increases the probability of using chemical fertilizer by 18 percentage points. This is a relatively large effect. Many of the non-certified farmers do not use any chemical fertilizer on their cocoa fields, often because fertilizers are inaccessible or too expensive for them. The estimation results suggest that Fairtrade certification improves farmers' access to chemical fertilizers. However, the second-hurdle estimates for fertilizer are not statistically significant, suggesting that certification has no effect on fertilizer quantity. The conditional marginal effect (ME) is conditional on the first-hurdle being passed; the estimate is positive but relatively small in magnitude. The unconditional ME considers both hurdles together. The estimate for the unconditional ME is much larger, suggesting that certification possibly increases fertilizer quantities, but the standard error is also relatively large, so the estimate is not statistically significant.

We now look at the results for pesticides in Table 3. Fairtrade certification does not significantly affect the probability of using pesticides (first hurdle), but – conditional on using pesticides – certification increases the quantity of pesticides by 0.35 kg/ha (second hurdle). The unconditional ME suggests additional pesticide use of 0.31 kg/ha, which is equivalent to an 18% increase over the mean pesticide use by non-certified farmers. These results are plausible in the local context. Due to high pest and disease pressure, over 90% of the sample farmers use chemical pesticides in cocoa production anyway, with or without certification. But certification raises farmers' awareness and knowledge about pest control, facilitates access to pesticides, and provides incentives to use additional quantities. According to local agronomists, at least the mean application rates observed in our sample do not point at an overuse of chemical pesticides.

To gain a better understanding of the institutional factors that contribute to higher agrochemical input use, we ran auxiliary regressions where we included farmers' access to and use of various cooperative services as additional explanatory variables. Results of these auxiliary regressions are shown in Table A9 in the Online Appendix. As expected, access to agricultural credit and participation in agricultural training increase the likelihood of using fertilizer significantly. Similarly, the availability of subsidized fertilizer and pesticides through the cooperatives also increases the likelihood of using these inputs. Furthermore, access to cooperative spraying services increases the pesticide and fertilizer quantities used. All of these services are more likely to be offered in Fairtrade certified cooperatives, as we will show in more detail further below. At the same time, cocoa prices do not seem to affect agrochemical input use significantly, probably because cocoa prices are regulated by the state and actually observed price differences are small (Sellare et al., 2020).

Table 4
Effects of certification on aggregated pesticide toxicity (double-hurdle marginal effects).

			(1)	(2)
			EIQ	HQ
Certification (1/0)	First hurdle (1/0)	Probit ME	-6e-3	-6e-3
			(0.03)	(0.03)
	Second hurdle (continuous)	Conditional ME	5.86	285.00**
			(4.31)	(112.37)
		Unconditional ME	5.24	258.87**
			(4.16)	(106.96)
Observations			469	469

Note: Average marginal effects (ME) are shown with delta-method standard errors in parentheses. EIQ, environmental impact quotient; HQ, hazard quotient. $^{*}p < .1$, $^{**}p < .05$, $^{***}p < .01$.
All regressions include household and cooperative-level control variables. Full results are shown in Tables A10 and A11 in the Online Appendix.

4.3. *Effects of Fairtrade on Aggregated Pesticide Toxicity*

Table 4 shows the effects of Fairtrade certification on the aggregated EIQ and HQ. Both indicators are calculated based on the quantities of pesticides applied. As shown above, certification does not affect the probability of using pesticides. Hence, it is not surprising that the first-hurdle estimates of the toxicity models do not show significant effects either. For EIQ, the second-hurdle results are positive but statistically insignificant. However, for HQ the second-hurdle results are significant and quite large in magnitude. The unconditional ME of 259 points suggests that Fairtrade certification increases the HQ by 40% in comparison to the mean value observed for non-certified farmers.

That certification has significant effects on the HQ but not on the EIQ can be explained by the differences in what exactly these two indicators measure (see above). The relatively large Fairtrade effect on HQ is not only due to higher overall pesticide quantity but also to differences in the pesticide mix that certified and non-certified farmers use. Fig. A1 in the Online Appendix shows that certification is positively correlated with active ingredients such as Thiacloprid and Lambda-cyhalothrin. Especially the latter is very toxic for mammalian species in terms of its LD_{50} (Table 2). The use of Lambda-cyhalothrin is not recommended by Fairtrade, but it seems that through certain mechanisms certified farmers have better access to this active ingredient than non-certified farmers. In fact, Lambda-cyhalothrin is flagged ‘orange’ in the Fairtrade list of hazardous materials and its use by certified farmers should be phased out by 2020 (Fairtrade, 2019).

4.4. *Effects of Fairtrade on Pesticide-Related Health Symptoms*

Aggregated toxicity, as analyzed above, is a measure of the potential impact of pesticides on the environment and human health. Actual health effects may differ, as these also depend on the level of exposure to the toxic substances. Table 5 shows the effect of Fairtrade

Table 5
Effects of certification on the number of pesticide-related acute health symptoms.

	Number of reported health symptoms (marginal effect)
Certified (1/0)	-0.92^{**} (0.36)
Observations	255

Note: Clustered standard error shown in parentheses. Estimates based on exponential IV-GMM model. $^{**}\ p < .05$. Regression includes household and cooperative-level control variables. Full results are shown in Table A3 in the Online Appendix.

certification on the number of pesticide-related health symptoms reported by farmers and rural workers. Fairtrade reduces the number of health problems significantly, in spite of the fact that larger quantities of pesticides and active ingredients with higher mammalian toxicity are used. This positive health effect can likely be explained by better training about the safe use of pesticides and more widespread use of protective devices among Fairtrade certified farmers and workers. The marginal Fairtrade effect of −0.92 shown in Table 5 implies a 40% reduction in the annual number of pesticide-related health symptoms.

4.5. Effects of Fairtrade at the Cooperative Level

As argued above, effects of Fairtrade on farmers' agrochemical input use and environmental and health impacts are likely channeled through mechanisms at the cooperative level, at least to a large extent. In particular, expected cooperative-level mechanisms include improved services related to input provision and training, which are partly funded through the Fairtrade premium. Fig. 2 shows the share of cooperatives in our sample that offer certain types of services to their members, differentiating between cooperatives with and without Fairtrade certification. We compare the 25 certified with the 25 non-certified cooperatives and test for significant differences using Fisher's exact test. In addition, we compare the 25 certified cooperatives before and after they became Fairtrade certified, building on cooperative records and leadership recall data. We use McNemar's test for paired data to test for significant differences in this within-cooperative comparison.

As can be seen in Fig. 2, certified cooperatives are more likely than non-certified cooperatives to provide fertilizers and pesticides to their members at subsidized rates and to offer training on input use and the safe handling of pesticides, protective clothing, and spraying services. Most of these differences are statistically significant. We showed above that agricultural training and the provision of inputs at subsidized rates contribute to higher agrochemical input use. However, by also offering spraying services, protective clothing, and training on occupational health and safety, cooperatives can reduce negative health impacts in terms pesticide-related health symptoms. Comparing the 25 certified cooperatives before and after certification, significant differences are observed for all variables shown in Fig. 2. This means that the differences between certified and non-certified cooperatives can probably be interpreted as Fairtrade effects.

4.6. Role of Other Standards

So far, we concentrated only on Fairtrade certification. However, there are two other sustainability standards that are also widely observed for cocoa production in the Southeast of Cote d'Ivoire, namely UTZ and Rainforest Alliance (RA). As mentioned above, of the 25 Fairtrade certified cooperatives in our sample, 16 were also certified under UTZ and/or RA standards. Similar to Fairtrade, UTZ and RA have certain regulations concerning the use of agrochemicals and promote alternative practices of pest and disease control. However, in terms of pesticide regulations, Fairtrade standards are stricter than those of UTZ and RA (Rainforest Alliance, 2020). In this subsection, we test whether UTZ and RA have additional effects on any of the outcome variables considered or significantly change the effects of Fairtrade. We do so by re-estimating our regression models and including an UTZ/RA dummy

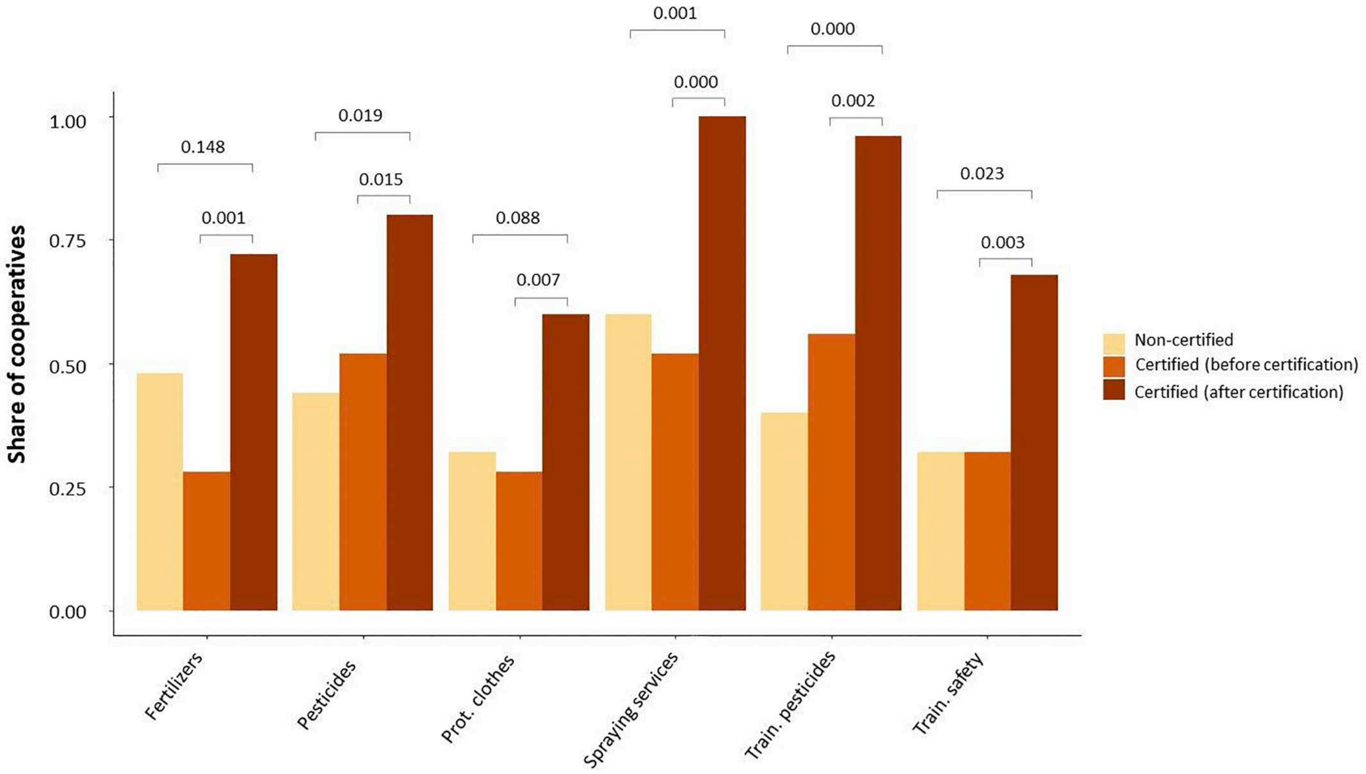


Fig. 2. Share of cooperatives offering services related to input provision and training by certification status.
Each group includes 25 cooperative observations. Differences are tested for statistical significance with *p*-values shown above the respective bars.

Table 6
Effects of Fairtrade on agrochemical input use, toxicity, and health controlling for UTZ/RA.

	Fertilizer (kg/ha)		Total pesticide use (kg/ha)		EIQ		HQ		Health symptoms
	Cond. ME [a]	Uncond. ME [a]	Cond. ME [a]	Uncond. ME [a]	Cond. ME [a]	Uncond. ME [a]	Cond. ME [a]	Uncond. ME [a]	ME[b]
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Fairtrade (1/0)	36.87	37.59**	0.38	0.29	3.99	2.96	282.95*	239.63	−1.03**
	(25.63)	(18.01)	(0.24)	(0.24)	(5.28)	(5.05)	(169.22)	(157.86)	(0.51)
UTZ/RA (1/0)	−67.68**	−33.97*	−0.05	0.04	3.46	4.19	3.79	34.47	0.25
	(29.29)	(19.13)	(0.27)	(0.26)	(6.27)	(6.16)	(181.65)	(164.88)	(0.73)
Observations	492	492	469	469	469	469	469	469	255

Note: Average marginal effects (ME) are shown with delta-method standard errors in parentheses. $^{*}p < .1$, $^{**}p < .05$, $^{***}p < .01$.
All regressions include household and cooperative-level control variables. Full results are shown in Tables A12-A14 in the Online Appendix.

[a] Regressions were estimated with double-hurdle models.

[b] Regression was estimated with IV-GMM model.

as an additional explanatory variable. This dummy takes a value of one if the respondent certified under Fairtrade was additionally also certified under UTZ and/or RA, and zero otherwise. As mentioned, we do not have any farmers or workers in our sample that were certified under UTZ/RA and not also under Fairtrade. Results of these additional regressions are summarized in Table 6.

Columns (1) and (2) of Table 6 suggest that UTZ/RA leads to a reduction in the use of fertilizer. In all other models, the coefficients of the UTZ/RA dummy are small in magnitude and statistically insignificant. The Fairtrade effects, on the other hand, remain very similar to those estimated above. For fertilizer quantity, the Fairtrade effect increases and turns statistically significant after controlling for UTZ/RA (column 2 of Table 6). For pesticide quantity, the Fairtrade effect turns statistically insignificant, but remains similar in magnitude. For pesticide-related health symptoms, both the magnitude and the significance level of the Fairtrade effect remain unchanged. Hence, the main findings for Fairtrade are quite robust: Fairtrade certification leads to an increase in agrochemical input use and aggregated toxicity, but reduces the incidence of pesticide-related health problems.

5. Conclusion

In this article, we have analyzed the effects of Fairtrade certification on agrochemical input use and related impacts on the environment and human health. Even though Fairtrade focuses primarily on the social dimension of sustainability, it also has certain environmental objectives and related rules and regulations. For instance, Fairtrade bans certain pesticides that are particularly toxic and requires certified farmers to be trained in the safe handling of agrochemicals. Very few previous studies have evaluated the effects of Fairtrade on agrochemical input use (Elder et al., 2013). We are not aware of any study that has looked at environmental and health impacts beyond pesticide quantity. Hence, our study adds to the existing literature.

Conceptually, we have discussed different mechanisms how Fairtrade certification can either increase or decrease fertilizer and pesticide use and related externalities. While the Fairtrade regulations as such may rather reduce the use of toxic agrochemicals, the Fairtrade premium and related services offered by certified cooperatives may facilitate and incentivize higher input intensities. Indeed, our empirical results from Cote d'Ivoire show that Fairtrade increases agrochemical input use. Fairtrade also leads to higher aggregated levels of toxicity, which proxy potential negative impacts on the environment and human health. At least to some extent, these effects are driven by Fairtrade cooperatives being more active in agricultural training and in facilitating chemical input provision to their member farmers.

However, interestingly, higher pesticide quantities among Fairtrade certified farmers do not lead to more health problems. On the contrary, our data show that Fairtrade significantly reduces the incidence of pesticide-related acute health issues experienced by farmers and rural workers. This is plausible against the background of Fairtrade cooperatives being more likely to provide protective devices and other services for spraying, as well as training on the safe handling of pesticides.

These empirical results cannot be generalized beyond Cote d'Ivoire, as the role of the underlying mechanisms may differ from one place to another. However, a conclusion that can be generalized is that simplistic assumptions about the health and environmental effects of Fairtrade and other sustainability standards are inappropriate, as there are various possible mechanisms that can work in opposite directions. Cooperatives and the services they offer play an important role and should be the key entry point for interventions to further improve the outcomes of sustainability certification.

Our study has two limitations that should be addressed in follow-up research. First, while we went beyond pesticide quantities and also analyzed aggregated levels of toxicity, the environmental impact quotient (EIQ) and the hazard quotient (HQ) only capture potential and not actual environmental and health impacts of pesticide use. Actual health impacts were additionally analyzed by looking at pesticide-related symptoms, but we were not able to examine actual environmental effects, which would require soil, water, and biodiversity measurements. Second, the cooperative-level effects deserve further scrutiny. We improved upon previous research by sampling a larger number of cooperatives, but our main focus was on the farmer and worker level. Future research should focus more on the cooperative level, possibly with panel data to be able to analyze possible changes through sustainability certification over time.

Acknowledgments

This research was funded by the German Research Foundation (DFG), grant numbers RTG 1666 (GlobalFood) and ME 5179/1-1. Additional financial support was received from the foundation fiat panis.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolecon.2020.106718.

References

Akoyi, K.T., Maertens, M., 2018. Walk the talk: private sustainability standards in the Ugandan coffee sector. J. Dev. Stud. 54, 1792–1818. https://doi.org/10.1080/00220388.2017.1327663.

Asfaw, S., Mithöfer, D., Waibel, H., 2010. Agrifood supply chain, private-sector standards, and farmers' health: evidence from Kenya. Agric. Econ. 41, 251–263. https://doi.org/10.1111/j.1574-0862.2010.00443.x.

Benali, M., Brümmer, B., Afari-Sefa, V., 2018. Smallholder participation in vegetable exports and age-disaggregated labor allocation in Northern Tanzania. Agric. Econ. 49, 549–562. https://doi.org/10.1111/agec.12441.

Beuchelt, T.D., Zeller, M., 2011. Profits and poverty: certification's troubled link for Nicaragua's organic and fairtrade coffee producers. Ecol. Econ. 70, 1316–1324. https://doi.org/10.1016/j.ecolecon.2011.01.005.

Blackman, A., Naranjo, M.A., 2012. Does eco-certification have environmental benefits? Organic coffee in Costa Rica. Ecol. Econ. 83, 58–66. https://doi.org/10.1016/j.ecolecon.2012.08.001.

Cameron, A.C., Trivedi, P.K., 2013. Regression Analysis of Count Data, 2nd ed. Cambridge University Presshttps://doi.org/10.1017/CBO9781139013567.

Chiputwa, B., Spielman, D.J., Qaim, M., 2015. Food standards, certification, and poverty among coffee farmers in Uganda. World Dev. 66, 400–412. https://doi.org/10.1016/j.worlddev.2014.09.006.

Christiaensen, L., 2017. Agriculture in Africa – telling myths from facts: a synthesis. Food Policy 67, 1–11. https://doi.org/10.1016/j.foodpol.2017.02.002.

Di Falco, S., Veronesi, M., Yesuf, M., 2011. Does adaptation to climate change provide food security? A micro-perspective from Ethiopia. Am. J. Agric. Econ. 93, 829–846. https://doi.org/10.1093/ajae/aar006.

Dohmen, T., Falk, A., Huffman, D., Sunde, U., Schupp, J., Wagner, G.G., 2011. Individual risk attitudes: measurement, determinants, and behavioral consequences. J. Eur. Econ. Assoc. 9, 522–550. https://doi.org/10.1111/j.1542-4774.2011.01015.x.

Elahi, E., Weijun, C., Zhang, H., Nazeer, M., 2019. Agricultural intensification and damages to human health in relation to agrochemicals: application of artificial intelligence. Land Use Policy 83, 461–474. https://doi.org/10.1016/j.landusepol.2019.02.023.

Elder, S.D., Zerriffi, H., Le Billon, P., 2013. Is Fairtrade certification greening agricultural practices? An analysis of Fairtrade environmental standards in Rwanda. J. Rural. Stud. 32, 264–274. https://doi.org/10.1016/j.jrurstud.2013.07.009.

Fairtrade, 2014. Fairtrade Standard for Hired Labour. Fairtrade International, Bonn.

Fairtrade, 2018. Hazardous Materials List. Fairtrade International, Bonn.

Fairtrade, 2019. Fairtrade Standard for Smallscale Producer Organizations. Fairtrade International, Bonn.

Foundjem-Tita, D., Degrande, A., Donovan, J., Stoian, D., Kouamé, C., 2017. Baseline for Assessing the Impact of Fairtrade Certification on Cocoa Growers and Cooperatives in Côte d'Ivoire. World Agroforestry Center, Nairobi.

Gouel, C., Guimbard, H., 2019. Nutrition transition and the structure of global food demand. Am. J. Agric. Econ. 101, 383–403. https://doi.org/10.1093/ajae/aay030.

Hirvonen, K., Hoddinott, J., 2017. Agricultural production and children's diets: evidence from rural Ethiopia. Agric. Econ. 48, 469–480. https://doi.org/10.1111/agec.12348.

Ibanez, M., Blackman, A., 2016. Is eco-certification a win–win for developing country agriculture? Organic coffee certification in Colombia. World Dev. 82, 14–27. https://doi.org/10.1016/j.worlddev.2016.01.004.

Jena, P.R., Stellmacher, T., Grote, U., 2017. Can coffee certification schemes increase incomes of smallholder farmers? Evidence from Jinotega, Nicaragua. Environ. Dev. Sustain. 19, 45–66. https://doi.org/10.1007/s10668-015-9732-0.

Kniss, A.R., 2017. Long-term trends in the intensity and relative toxicity of herbicide use. Nat. Commun. 8, 14865. https://doi.org/10.1038/ncomms14865.

Kniss, A.R., Coburn, C.W., 2015. Quantitative evaluation of the environmental impact quotient (EIQ) for comparing herbicides. PLoS One 10, e0131200. https://doi.org/10.1371/journal.pone.0131200.

Kouser, S., Qaim, M., 2011. Impact of Bt cotton on pesticide poisoning in smallholder agriculture: a panel data analysis. Ecol. Econ. 70, 2105–2113. https://doi.org/10.1016/j.ecolecon.2011.06.008.

Kovach, J., Petzoldt, C., Degni, J., Tette, J., 1992. A Method to Measure the Environmental Impact of Pesticides. NYS IPM.

Kromann, P., Pradel, W., Cole, D., Taipe, A., Forbes, G.A., 2011. Use of the environmental impact quotient to estimate health and environmental impacts of pesticide usage in Peruvian and Ecuadorian potato production. J. Environ. Prot. 2, 581. https://doi.org/10.4236/jep.2011.25067.

Li, M., Wiedmann, T., Hadjikakou, M., 2019. Towards meaningful consumption-based planetary boundary indicators: the phosphorus exceedance footprint. Glob. Environ. Change 54, 227–238. https://doi.org/10.1016/j.gloenvcha.2018.12.005.

Loconto, A., Silva-Castañeda, L., Arnold, N., Jimenez, A., 2019. Participatory Analysis of the Use and Impact of the Fairtrade Premium. Laboratoire Interdisciplinaire Sciences Innovations Sociétés, Paris.

Meemken, E.-M., 2020. Do smallholder farmers benefit from sustainability standards? A systematic review and meta-analysis. Glob. Food Secur. 26, 100373. https://doi.org/10.1016/j.gfs.2020.100373.

Meemken, E.-M., Qaim, M., 2018a. Organic agriculture, food security, and the environment. Annu. Rev. Resour. Econ. 10, 39–63. https://doi.org/10.1146/annurev-resource-100517-023252.

Meemken, E.-M., Qaim, M., 2018b. Can private food standards promote gender equality in the small farm sector? J. Rural. Stud. 58, 39–51. https://doi.org/10.1016/j.jrurstud.2017.12.030.

Meemken, E.-M., Spielman, D.J., Qaim, M., 2017. Trading off nutrition and education? A panel data analysis of the dissimilar welfare effects of organic and Fairtrade standards. Food Policy 71, 74–85. https://doi.org/10.1016/j.foodpol.2017.07.010.

Meemken, E.-M., Sellare, J., Kouame, C.N., Qaim, M., 2019. Effects of Fairtrade on the livelihoods of poor rural workers. Nat. Sustain. 2, 635–642. https://doi.org/10.1038/s41893-019-0311-5.

Midingoyi, S.G., Kassie, M., Muriithi, B., Diiro, G., Ekesi, S., 2019. Do farmers and the environment benefit from adopting integrated pest management practices? Evidence from Kenya. J. Agric. Econ. 70, 452–470. https://doi.org/10.1111/1477-9552.12306.

Mullahy, J., 1997. Instrumental-variable estimation of count data models: applications to models of cigarette smoking behavior. Rev. Econ. Stat. 79, 586–593. https://doi.org/10.1162/003465397557169.

Nelson, G.C., Bullock, D.S., 2003. Simulating a relative environmental effect of glyphosate-resistant soybeans. Ecol. Econ. 45, 189–202. https://doi.org/10.1016/S0921-8009(03)00011-9.

Oya, C., Schaefer, F., Skalidou, D., 2018. The effectiveness of agricultural certification in developing countries: a systematic review. World Dev. 112, 282–312. https://doi.org/10.1016/j.worlddev.2018.08.001.

Peterson, R.K.D., Iii, J.J.S., 2014. A probabilistic analysis reveals fundamental limitations with the environmental impact quotient and similar systems for rating pesticide risks. PeerJ 2, e364. https://doi.org/10.7717/peerj.364.

Abedullah Kouser, S., Qaim, M., 2015. Bt cotton, pesticide use and environmental efficiency in Pakistan. J. Agric. Econ. 66, 66–86. doi:https://doi.org/10.1111/1477-9552.12072.

Rainforest Alliance, 2020. Annex 5: Rainforest Alliance Development of the New Agrochemicals Approach (Public Consultation No. Draft Version 2.0). Rainforest Alliance.

Rao, E.J.O., Qaim, M., 2013. Supermarkets and agricultural labor demand in Kenya: a gendered perspective. Food Policy 38, 165–176. https://doi.org/10.1016/j.foodpol.2012.11.008.

Ricker-Gilbert, J., Jayne, T.S., Chirwa, E., 2011. Subsidies and crowding out: a double-hurdle model of fertilizer demand in Malawi. Am. J. Agric. Econ. 93, 26–42. https://doi.org/10.1093/ajae/aaq122.

van Rijsbergen, B., Elbers, W., Ruben, R., Njuguna, S.N., 2016. The ambivalent impact of coffee certification on farmers' welfare: a matched panel approach for cooperatives in Central Kenya. World Dev. 77, 277–292. https://doi.org/10.1016/j.worlddev.2015.08.021.

Sellare, J., Meemken, E.-M., Kouamé, C., Qaim, M., 2020. Do sustainability standards benefit smallholder farmers also when accounting for cooperative effects? Evidence from Côte d'Ivoire. Am. J. Agric. Econ. 102, 681–695. https://doi.org/10.1002/ajae.12015.

Sheahan, M., Barrett, C.B., Goldvale, C., 2017. Human health and pesticide use in sub-Saharan Africa. Agric. Econ. 48, 27–41. https://doi.org/10.1111/agec.12384.

Stoner, K.A., Eitzer, B.D., 2013. Using a Hazard quotient to evaluate pesticide residues detected in pollen trapped from honey bees (Apis mellifera) in Connecticut. PLoS One 8, e77550. https://doi.org/10.1371/journal.pone.0077550.

Vanderhaegen, K., Akoyi, K.T., Dekoninck, W., Jocqué, R., Muys, B., Verbist, B., Maertens, M., 2018. Do private coffee standards 'walk the talk' in improving socio-economic and environmental sustainability? Glob. Environ. Change 51, 1–9. https://doi.org/10.1016/j.gloenvcha.2018.04.014.

Veettil, P.C., Krishna, V.V., Qaim, M., 2017. Ecosystem impacts of pesticide reductions through Bt cotton adoption. Aust. J. Agric. Resour. Econ. 61, 115–134. https://doi.org/10.1111/1467-8489.12171.

Willer, H., Sampson, G., Voora, V., Dang, D., Lernoud, J., 2019. The State of Sustainable Markets 2019: Statistics and Emerging Trends. ITC, Geneva.

Woldeyohanes, T., Heckelei, T., Surry, Y., 2017. Effect of off-farm income on smallholder commercialization: panel evidence from rural households in Ethiopia. Agric. Econ. 48, 207–218. https://doi.org/10.1111/agec.12327.

Wooldridge, J.M., 2001. Applications of generalized method of moments estimation. J. Econ. Perspect. 15, 87–100.

Wooldridge, J.M., 2015. Control function methods in applied econometrics. J. Hum. Resour. 50, 420–445. https://doi.org/10.3368/jhr.50.2.420.