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# RTG 1666 GlobalFood

Transformation of Global Agri-Food Systems:
Trends, Driving Forces, and Implications for Developing Countries

**University of Goettingen**

# GlobalFood Discussion Papers

No. 137

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January 2020

RTG 1666 GlobalFood · Heinrich Düker Weg 12 · 37073 Göttingen · Germany
www.uni-goettingen.de/globalfood

**ISSN (2192-3248)**

Suggested Citation:

Flachsbarth, I., N. Grassnick, B. Brümmer (2020). The uneven spread of Global G.A.P. certification. GlobalFood Discussion Paper 137, University of Goettingen. http://www.uni-goettingen.de/de/213486.html.

# The uneven spread of Global G.A.P. certification

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**Abstract**

GlobalG.A.P. compliance has often become a key requirement for farmers to access high-value global markets. Yet, the global spread of certification is highly uneven among countries. We assess the drivers and dynamics behind these unequal patterns, applying panel data regressions. Findings show that global agricultural trade networks remain relevant, but are no longer sufficient in explaining certification. Fostering a favourable business environment – via providing secure land tenure and a functioning judicial system – as well as investing in transportation and information infrastructure may facilitate farmers' participation in certification schemes. Stringency of existing public regulations is helpful for overcoming entry barriers.

Keywords: global agricultural supply chains, GlobalG.A.P., private food standards, organisational innovations, agricultural sector transformation

JEL Classification: O31, Q13, Q18

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This research was financially supported by the German Research Foundation (DFG) through the Global-Food Program (grant number RTG 1666). We thank the GlobalGAP Head Office, Cologne for providing us data on certification. Further, we highly appreciate the valuable comments on our econometric approach which we received from Dr. Jennifer Lorenz (Chair of Statistics and Econometrics at the University of Göttingen).

# 1 Introduction

Food quality and safety standards[1] have become an integral part of global and local agri-food value chains (Swinnen, 2007). Supermarket chains and agri-food companies want to drive down transaction costs and secure sufficient supply of high-quality food, demanded by an increasing number of discerning consumers worldwide (Reardon et al., 2012). Thus, large supermarket chains and agri-food companies, and increasingly also smaller retail chains, demand compliance with increasingly stringent standards from the entire down-stream value chain – including requirements for food quality and safety, as well as for environmental sustainability and for labour standards (Halabi and Lin, 2017).

According to the International Trade Centre Standards Map database, there exist about 236 private food standards worldwide (ITC, 2015). This study focuses on the GlobalG.A.P.[2] standard (hereafter named GlobalGAP) which is one of the most prominent global business-to-business (B2B) private agri-food pre-farm gate process standard (Henson et al., 2011). The number of GlobalGAP certified farmers increased by almost sixfold between the mid-1990s and 2011 (Swinnen, 2016) and more than doubled between 2008 and 2015 (GlobalGAP, 2018). Nowadays, more than 30 European and 15 non-European retail chains, predominantly located in high-income countries, require proof of GlobalGAP certification (mostly of fruits and vegetables) from their suppliers (GlobalGAP, 2018). Also in developing countries, the retail-sector has undergone a tremendous transformation from traditional retail systems to modern grocery stores with the associated demand for high-quality certified food (Reardon et al., 2003,1; Weatherspoon and Reardon, 2003). Thus, for farmers around the world to successfully access high-value modern retail markets, it is essential to comply with the private food quality standard and to get certified (Fiankor et al., 2019). This is especially pertinent considering the continuing relevance of agriculture for livelihoods in rural areas of developing countries.[3]

However, the global spread of GlobalGAP – and other important certification schemes – is observed to be uneven. While some regions perform well in adjusting to the sector's transformation, other world regions lag behind and show low or zero certification rates of farmers. These unequal patterns of the global diffusion of food quality standards remain poorly understood, as the underlying macroeconomic determinants of standard adoption have not been thoroughly investigated. The existing literature mainly focuses on farm level determinants of adoption decisions of standards in specific countries (see e.g. Asfaw et al., 2009; Kersting and Wollni, 2012; Kleinwechter and Grethe, 2006). The literature explaining global diffusion patterns at the macro-level is scarce and rely on cross-sectional data only. For the agricultural sector, to the best of our knowledge, the only studies analysing the global scale of diffusion are conducted by Herzfeld et al. (2011) and Mohammed and

[1] Note that we use the terminology food quality standard and certification interchangeably in our study.

[2] GlobalG.A.P. stands for Global Good Agricultural Practices. For details on the private standard see http://www.globalgap.org.

[3] In the development context, there is an ongoing scientific debate on whether standards are catalyst or barriers to trade. High certification costs and technical requirements for GlobalGAP certified farmers may act as market entry barriers for the poorest farmers. In contrast, the most productive farmers gain more market share (e.g. Handschuch et al., 2013). Since our study uses country-level data, we cannot shed light on these intra-country heterogeneities. Instead, we focus on the macro-environment either hampering or fostering standard adoption.

Zheng (2017). Herzfeld et al. (2011) mainly find that third-party certification for export purposes reinforce already existing trade relations, but potentially hamper new entrants. In addition, Mohammed and Zheng (2017) find large distance to Europe and the US to impede standard adoption rates. Both studies use cross-sectional data, and thus provide a snapshot of only one year and neglect the dynamics of standard diffusion.

This study attempts to close the knowledge gap that exists at the global macro-scale. Specifically, we answer the following research questions (RQ): (1) what are the factors explaining why some countries are left out of the GlobalGAP market, i.e. show zero certified farmers? (2) What factors drive high certification rates? Since GlobalGAP is not limited to certain products (anymore), but continuously gaining relevance for many agricultural products, our analysis considers the aggregate scope 'crops' to capture all certified farmers globally. This allows us to make more general statements on the GlobalGAP diffusion process across countries.

We conceptualise these two RQ on the grounds of Rogers' 1995 model of the diffusion of innovations. The GlobalGAP standard can be viewed as an organisational innovation, because farmers choose to adapt standard-specific novel processes to be able to comply with the strict requirements to get certified. Based on this, we derive our data generating process (DGP) and we develop specific hypotheses for an array of macro-variables regarding their effect on the two RQs. Our empirical model uses a global panel dataset from 2008 to 2014, with the number of certified crop producers per country as the dependent variable. To the best of our knowledge, our study is the first macro-study on the topic using panel data. This allows us to incorporate dynamics and to minimise modeling problems arising from endogeneity. To answer the two RQs, we use two dependent variables: (1) a binary variable (adopting or non-adopting country); and (2) an integer non-negative number counting the certified farmers per country and year. In the former we apply a logit model, while the latter requires a negative binomial model which deals with overdispersion appropriately. The time dimension in our data allows us to use a random effects model with an AR1 error structure to reduce problems related to temporal and spatial autocorrelation. Thus, the panel structure allows for superior econometric models compared to those used in the above mentioned cross-sectional studies.

The remaining paper is organised as follows: Section 2 develops the conceptual framework and hypotheses. Section 3 explains the empirical model and the underlying data. Section 4 presents and discusses the empirical results, before Section 5 concludes and gives policy recommendations. We also refer to the Appendix for a detailed background information on the evolution and meaning of the private food standard GlobalGAP (see Appendix section A) and on existing scientific literature regarding the adoption and diffusion process of private food standards (see Appendix section B). Also, supporting information on methods and the descriptive results are provided in the Appendix for the sake of brevity.

# 2 Conceptual framework and hypotheses

The DGP for analysing the spread of GlobalGAP certification, is grounded on the concepts from the field of organisational innovations. In our context, we refer to innovations as 'new firm practices', i.e. innovative production processes and technologies as defined by Nelson and Winter (1982). We understand the GlobalGAP standard as an innovation, because it aims at the adoption of 'safe and sustainable [production] practices' by agricultural producers worldwide (GlobalGAP, 2015, p.2). Within the field of organisational innovations, we are specifically interested in the underlying process of GlobalGAP diffusion across and within different countries. Here we distinguish two definitions of diffusion: (1) those factors that make standard adoption generally (im)probable in a country (see RQ one in introduction) and (2) those macro factors explaining a fast spread within a country (see RQ two). There is a sizeable theoretical literature aiming at explaining the diffusion process of innovations, but with a great diversity in behavioural and informational assumptions. In our context, choosing among the vast amount of theoretical models[4] for the DGP is difficult, because we follow an explorative approach, rather than concentrating on a specific variable. Thus, we consult different theories within the field of organisational innovations to appropriately derive all relevant variables and the corresponding hypotheses.

A useful starting point for studying the diffusion process of GlobalGAP as an innovation offers the well-established theoretical model by Rogers (1995). Accordingly, the certification process consists of four phases. The main mechanisms in each phase are briefly described in the following paragraphs. For further explanation see Table 1 and Appendix section C.

During the information phase (1) the producer is, by chance, exposed to information of the existence of the private food standard and gains first understanding of the requirements to comply. Awareness of the standard is necessary before making a certification decision. The information effect is often modelled by network or contagion theories, which is borrowed from the epidemiology literature (Young, 2009). Examples of such network models can be found in Bass (1969), Bass (1980), Easley and Kleinberg (2010), Valente et al. (2015) or Ferrier et al. (2016). These models consider social network structures relevant for initiating and accelerating the diffusion process. Networks compose 'nodes', which are the different agents within a social network, and 'links' connecting these agents. These links can be understood as channels of information, required in the decision-making process of adoption, flowing quickly from one farmer to another. Thus, we use proxies for facilitated information flow at the macro level.

A notable limitation of contagion models is that they provide no clear reason why a producer would adopt an innovative practice. During the next phase – the persuasion phase (2) – the producer is in the process of bringing about an adoption decision based on rational evaluation of associated costs and benefits. Proxy variables at the macro-level relate to aspects of market power, degree of agricultural sector development, risk taking behaviour and the homemarket effect.

After the described two phases, the producer has decided that adoption is generally beneficial. It follows the implementation phase (3). Despite having perceived the standard as favourable, the cost of implementation can still vary across countries which leads to comparative advantages of some countries over others.[5] Thereby, (a high rate of) adoption

[4]For a literature review and comparison between determinants of adoption of technological or organisational innovations see e.g. Alänge et al. (1998), Young (2009) and Sunding and Zilberman (2001).

[5]Since GlobalGAP certified produce is in large part produced for export markets, the notion of comparative advantages of countries is of key relevance in modeling adoption decisions.

becomes more probable in some countries than in others. Variables that serve this context are describing the macroeconomic conditions and the business environment in countries. Further infrastructure matters as well as the (sectoral) policy setting.

The last phase - confirmation phase (4) - is characterised by maintaining the certification after successful adoption. Since GlobalGAP certification needs to be renewed annually, this phase is of particular importance for the spread of the standard, but not useful for explaining the extensive margin of RQ one. Relevant variables should proxy the financial capacity of farmers and financial support to farmers.

Table 1 gives an overview of all relevant variables that play a role in each of Rogers' 1995 phases in the specific GlobalGAP context and derives the corresponding hypotheses. For the sake of brevity, we refer to Appendix section C for a more complete description of the concrete pathways and the relevant variables in the GlobalGAP diffusion process.

Admittedly, there is a discrepancy between our scale of analysis at the country-level and the scale of Rogers' 1995 model that operates at the micro-level. But since adoption decisions take place precisely at the micro-level, a theoretical micro-foundation seems appropriate. Instead of using micro-level data, we identify those (macro) factors which frame individual behaviour, but are beyond the reach of individual producers.[6] This approach, obviously, obscures within-country heterogeneity. However, arguing similarly to Herzfeld et al. (2011), this simplification still yields important between-country variation in variables relevant for the diffusion process. Due to this scale problem, we apply the conceptual framework for both RQs in analogy. This means that some farmers of the same country will still be in phase (1) while others are already certified and in phase (4). The lack of farm-level data makes a-priori assumptions about which phase is allocated to RQ one[7] – the probability of no-adoption in some countries – or RQ two – the intensification of certification – impossible.

# 3 Empirical model and data

## 3.1 Empirical models

The DGP derived above holds for both RQs, but we need two different empirical models respectively. RQ one requires a logit estimation due to its binary dependent variable. To account for unobserved country heterogeneity and spatial dependency, we apply a random effects[8] logit model. The conditional probability of the panel binary choice model is as

[6]Ideally we would need to use farm-level data for each country and combine it with macro-data.

[7]Note: The wording, e.g. "increase in adoption probability" or similar expressions, equivalently refer to the reverse hypothesis of the likelihood to be in the group of "zero certified farmers country" relevant for RQ one.

[8]The non-zero and statistically significant $\rho$ is reported in the Appendix regression Table D2. It confirms that a random effects logit model is superior over the pooled model. Alternatively to a random effects specification of our model, we could use a fixed effects specification with less strict assumptions about exogeneity. Since this would entail the incidental parameter problem (Wooldridge, 2002), we stick to random effects.

Table 1: Conceptual framework and hypotheses

| **Rogers' phases** | **Channel** | **Variable** | **Hypothesis** | **Ground** |
|---|---|---|---|---|
| 112cm Information phase | Local network ties | Certification rate neighbours | + | Awareness about existence of standard is needed to consider adoption. Sharing experience reduces uncertainty about initial investment risks. |
| | | Urbanisation rate | + | Agglomeration economies drive down costs and network effects facilitate information flow about the standard. |
| | Global network ties | Trade networks with EU, geographical distance to EU | + | Awareness of the existence of the standard. Cohesion of organisational practices between markets. |
| | | Colonial history with EU6 | + | Common culture with most important GlobalGAP demanding countries and knowledge of 'binding' documentation language reduces transaction costs. |
| | Infrastructure | Transport (road density) | + | Better market access accelerates information flow. |
| | | ICT | + | Better ICT eases information flow. |
| | Structure agricultural sector | Horticultural production share | + | Historical relevance of GlobalGAP in horticulture makes GlobalGAP more likely. |
| 112cmPersuasion phase | Market power | Trade with EU | + | EU retail chains (as largest world market) increasingly require GlobalGAP certification by suppliers |
| | Sophistication in agriculture | Agricultural capital stock | + | Countries with high degree of input use and mechanisation have comparatively lower initial investment costs and higher productivity. |
| | | Agricultural export share | + | Countries with traditionally well-established export sector have comparatively lower initial investment costs. |
| | Risk taking behaviour | GDP per capita | + | Wealthier farmers (usually located in richer countries) usually show lower level of risk aversion and are more likely to take initial investment risk. |
| | Home market effect | Population size | + | If home demand is large, the produce can also be sold in home markets. |
| | | Urbanisation | + | Domestic supermarkets located in urban centres will likely increase the demand for high quality produce. |
| 132cmImplementation phase | Macroeconomic conditions | Inflation rate | - | High inflation reduces investment and thereby prevents adoption decisions. |
| | | Exchange rate | - | An overvalued exchange rate reduces returns on investment in the tradables sector, e.g. GlobalGAP produce, and thereby can prevent adoption decisions. |
| | Business environment | Doing-business indicators | + | High quality of business environment drives innovative action in countries, due to lower costs and makes certification more profitable. |
| | | Conflict related deaths | - | An insecure environment hampers (international) investment decisions. |
| | Infrastructure | Transport (road density) | + | Better infrastructure reduces trade costs and thereby increases competitiveness. |
| | | land locked | - | Higher transportation costs |
| | | ICT | + | Lower costs of documentation and traceability. |
| | Agricultural sector policies | Public regulations (MRLs) | + | Existing public regulations in the food sector reduce initial investment costs. |
| | | Development flows to agriculture | + | Developing countries' agricultural sector supported by donors are likely to have comparatively higher developed agricultural systems and smallholders are supported in paying certification fees. |
| | | ISO membership | + | Existing ISO certification in the food sector reduces initial investment costs. |
| 32cmConfirmation phase | Financial capacity | GDP per capita | + | Wealthier countries have likely more wealthy farmers that can bear the annual certification costs. |
| | Financial support | Development flow to agriculture | + | Recurrent certification fees are supported by donors. |

Note: The conceptual framework serves as the DGP for both research questions. A positive sign in the column "Hypothesis" refers to: (RQ 1) either a higher probability of *NOT* being in the zero certification group of countries, or (RQ 2) a higher probability of an increasing number of certified farmers.

follows:

$$Pr(y_{i,t} = 1|x_{i,t}, \alpha_i) = \mathbf{x}_{i,t}^{'}\beta + \alpha_i + \epsilon_{i,t}, \tag{1}$$

where $Pr(y_{i,t} = 1)$ is the probability of a positive certification rate due to farmers' decision to adopt GlobalGAP, $i$ indexes country, $t$ ($t$ = 2009, ..., 2014) indexes year, $\alpha$ is the random intercept of country $i$, $\epsilon_{i,t}$ is the uncorrelated zero-mean residual, and $\mathbf{x_{i,t}}$ are explanatory variables (including a constant) with their corresponding coefficients $\beta$ as defined below.

To empirically model the second RQ, we apply a count data model, because the dependent variable is an integer non-negative number. Generally, Poisson models can deal with count data if the assumption of an underlying Poisson process is fulfilled (Winkelmann, 2008). This, however, may be violated in our case, as the variance of our dependent variable exceeds its mean by far[9]. If equidispersion cannot be achieved by including relevant regressors in the Poisson specification, we need to specify a negative binomial model taking the form:

$$\begin{aligned}
&Pr(Y_{i,} = y_{i,t}|x_{i,t}, u_i) = \frac{\Gamma(y_{i,t} + \theta)}{\Gamma(y_{i,t} + 1)\Gamma(\theta)} r_{i,t}^{\theta}(1 - r_{i,t}^{y_{i,t}}),\\
&r_{i,t} = \theta(\theta + exp(\sigma_i)\lambda_{i,t}),\\
&\lambda_{i,t} = exp(\alpha + \mathbf{x}_{i,t}^{'}\beta + \epsilon_{i,t}),
\end{aligned} \tag{2}$$

where $y_{i,t}$ is the number of certified farmers producing any permanent or temporary crop per country and year (including zeros), $u_i$ is the random effect over country $i$ which is incorporated to account for unobserved heterogeneity; $\theta$ is the overdispersion parameter to be estimated and serves as a more formal test of overdispersion (Greene, 2008). Following specification tests (see Appendix section D), we consider temporal autocorrelation which makes our error term $\epsilon_{i,t} = \rho\epsilon_{i,t-1} + \omega_{i,t}$, with $\mid \rho \mid < 1$ being the autocorrelation parameter and $\omega_{i,t}$ is the error term with $\omega_{i,t} \sim_{iid} N(0, \sigma^2)$.

Additionally, the high share of zeros in our dependent variable (45 percent) may add to the problem of overdispersion. Sometimes a zero-inflated count data model can appropriately deal with many zeros, but only if the zero counts belong to two different DGPs (Winkelmann, 2008). Herzfeld et al. (2011) precisely argue that there are heterogenous groups of countries in their cross-country dataset. They assume one group to show structural zeros in which standard adoption is infeasible or where GlobalGAP plays no economic role. The other group of countries may show zeros, but with the option to gain certification status at a later point in time. We question the assumption that the zero-certified countries in our panel dataset belong to two different DGPs for various reasons: first, the dependent variable is not a latent variable, since there is no interest in underreporting. Second, over the years GlobalGAP has evolved towards global market relevance, also because global retail chains are increasingly harmonizing their standards. There are hardly any countries without any benefit or interest per se in GlobalGAP certification. Our data shows that even some small island states, far away from the core GlobalGAP European market, show

[9]The mean of the dependent variable is 602 and its variance 6690634.

positive certification numbers these days. This indicates all 'zero-countries' are somehow structurally left out of the market, i.e. forming one group of zeros with the same DGP. And third, our panel data structure allows us to observe the adoption behaviour of farmers in different countries over several years. We find that non-adopting countries either show zeros in every year, or they switch from zero to a very low number of farmers, which should be driven by similar processes.[10]

First, we take out those variables with a variance inflation factor (VIF) above four. A high correlation of explanatory variables does not bias the results, but makes the point estimate imprecise. Thus, we skip the following variables to reduce multicollinearity issues: Distance to EU, Climate zones, Hectares of cropland. We initially included Distance to EU to control for proximity to major GlobalGAP markets. Climate zones was meant to serve as a control for agricultural production potential. Hectares of cropland was meant to control for size effects of agricultural production. Since this is an important control variable, we keep this variable in the logit model despite mulitcollinearity and as an offset variable in our final negative binomial model (for details see 3.2). To formally check for the preferred model specification, we start testing the Poisson assumption of equidispersion of the dependent variable. A rejection of equidispersion takes us to proceed with the negative binomial model. We compare a specification with and without random effects. Furthermore, we test whether zero-inflation remains to be a problem after having incooperated the dispersion parameter in the estimation. Model selection is based on the Akaike Information Criterion (AIC) and likelihood ratio tests. Further, we check the behaviour of the residuals of each model using the R package DHARMa (Gelman and Hill, 2006; Hartig, 2019). Finally, we compare the unrestricted model (Eq. 3 below) with the parsimonious models (Eq. 4 and Eq. 5 below) by a likelihood ratio test. For details of model selection see Appendix section D. The results section 4 only presents the final model.

## 3.2 Data

Our global panel dataset contains information on the number of certified farms per country and year for a time period between 2008 and 2014. Corresponding to the conceptual framework, we define the regressors with the corresponding parameters to be estimated in both (full) models as follows:

$$\begin{aligned}\mathbf{x}_{i,t}^{'}\beta =& \beta_0 + \beta_1 \mathrm{GGAPN}_{i,t-1} + \beta_2 \mathrm{Urban}_{i,t} + \beta_3 \mathrm{ExEU}_{i,t-1} + \beta_4 \mathrm{Colony}_i + \beta_5 \mathrm{Road}_{i,t} \\ &+ \beta_6 \mathrm{www}_{i,t} + \beta_7 \mathrm{FV}_{i,t-1} + \beta_8 \mathrm{Agcap}_{i,t-1} + \beta_9 \mathrm{ExCrop}_{i,t-1} + \beta_{10} \mathrm{GDPpc}_{i,t} \\ &+ \beta_{11} \mathrm{GDPpc}_{i,t}^2 + \beta_{12} \mathrm{Pop}_{i,t} + \beta_{13} \mathrm{I}_{i,t} + \beta_{14} \mathrm{XR}_{i,t} + \beta_{15} \mathrm{DB}_{i,t} + \beta_{16} \mathrm{Conflict}_{i,t} \\ &+ \beta_{17} \mathrm{lock}_i + \beta_{18} \mathrm{MRL}_{i,t} + \beta_{19} \mathrm{DevAg}_{i,t} + \beta_{20} \mathrm{ISO}_{i,t}\end{aligned} \qquad (3)$$

[10]We additionally specify a panel zero-inflated negative binomial model to test the above described assumption. However, specification tests are ambiguous (see Appendix section D1) and the model in its panel version is still somewhat underdeveloped leading to high instability of the model. Therefore, we highly question the results' reliability. Our estimation results in stage one provided unrealistically high coefficients and model conversion was problematic. Results can be obtained from authors upon request.

The preferred and more parsimonious logit equation is as follows:

$$\begin{aligned} \mathbf{x}_{i,t}^{'}\beta = & \beta_0 + \beta_1 \text{GGAPN}_{i,t-1} + \beta_2 \text{Urban}_{i,t} + \beta_3 \text{Colony}_i + \beta_4 \text{www}_{i,t} + \beta_5 \text{FV}_{i,t-1} \\ & + \beta_6 \text{ExCrop}_{i,t-1} + \beta_7 \text{GDPpc}_{i,t} + \beta_8 \text{DB}_{i,t} + \beta_9 \text{MRL}_{i,t} + \beta_{10} \text{ISO}_{i,t} \end{aligned} \tag{4}$$

The preferred and more parsimonious negative binomial equation is as follows:

$$\begin{aligned} \mathbf{x}_{i,t}^{'}\beta = & \beta_0 + \beta_1 \text{GGAPN}_{i,t-1} + \beta_2 \text{Urban}_{i,t} + \beta_3 \text{ExEU}_{i,t-1} + \beta_4 \text{Colony}_i + \beta_5 \text{Road}_{i,t} \\ & + \beta_6 \text{www}_{i,t} + \beta_7 \text{ExCrop}_{i,t-1} + \beta_8 \text{DB}_{i,t} + \beta_9 \text{Conflict}_{i,t} + \beta_{10} \text{DevAg}_{i,t} \\ & + \beta_{11} \text{ISO}_{i,t} \end{aligned} \tag{5}$$

Note that all continuous covariates are z-transformed for normalisation purposes. This facili-tates model conversion and allows for easier comparability of the estimated coefficients. To avoid estimation problems arising from reverse causality, some variables are lagged by one year in the regressions. This has the downside of loosing one estimation year, leaving us with data for the time period from 2009 through 2014. As a size control, we also include cropland in hectares in the logit model. In the negative binomial model, we apply cropland as an offset variable, so interpretation of estimated coefficients refers to 'number of certified producers per hectare cropland'.

In the following, we describe the covariates which are relevant for our model specifications in its restricted from (Eqs. 4 and 5).

The covariate $GGAPN_{i,t-1}$ serves as a proxy for local network ties (information phase) and measures the sum of the number of neighbouring countries' certified crops producers in the previous year. Local network ties are also proxied by the percentage of the urban population to total population ($Urban_{i,t}$). At the same time, urbanisation rate proxies the homemarket effect (persuasion phase). Global network ties to the EU are represented by two variables: First, the binary variable $Colony_i$ (information phase), equalling one if the country has a colonial relationship with one of the top GlobalGAP consumer markets – the EU6 countries, namely Belgium, France, Germany, Italy, Netherlands, Spain. Second, $ExEU_{i,t-1}$ gives the one-year lag of the crop export share to EU27 in world crop exports (information phase). Existing trade networks with the EU ($ExEU_{i,t-1}$) do not only proxy facilitated information flow, but simultaneously proxy market power behaviour of EU retailers over farmers worldwide (persuasion phase).

As infrastructure variables (information phase and implementation phase) we include road density per km ($Road_{i,t}$) and the share of population with fixed broadband subscription ($www_{i,t}$).

As a proxy for the degree of the sector's sophistication serves the one-year lagged variable of country $i$'s total crops export share in total exports $ExCrop_{i,t-1}$ (persuasion phase). $GDPpc_{i,t}$ is as a proxy for the sectors aggregate risk taking behaviour as well as general financial capacity of the countries' farmers (persuasion phase and confirmation phase).

The general business environment of a country is proxied by a Doing-Business (DB) indicator ($DB_{i,t}$) (implementation phase). A principal component analysis (PCA) is applied

Table 2: Descriptives 2009-2016

| | Non-certified producers | | | | Certified producers | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Variable** | **Mean** | **sd** | **min** | **max** | **Mean** | **sd** | **min** | **max** | **Difference** | **Source** |
| **GlobalGAP producers (no.)** | 0 | 0 | 0 | 0 | 1166.60 | 3581.96 | 1 | 32550 | -1166.60*** | GlobalGAP |
| **GlobalGAP producers neighbouring countries (sum)** | 922.34 | 2486.56 | 0 | 16328 | 3637.34 | 8063.13 | 0 | 65410 | -2715.00*** | GlobalGAP |
| **Export share crops EU - world** | 0.31 | 0.31 | 0 | 1 | 0.44 | 0.3 | 0 | 0.99 | -0.13*** | UN Comtrade |
| **Fruits and vegetables area share** | 0.21 | 0.23 | 0.01 | 0.99 | 0.17 | 0.22 | 0.01 | 1.63 | 0.05** | FAOSTAT |
| **Net agricultural capital stock per agr. GDP** | 1.84 | 2.35 | 0.08 | 19.19 | 2.44 | 2.06 | 0.18 | 13.81 | -0.60*** | FAOSTAT, Worldbank |
| **Export share crops - total exports** | 0.08 | 0.15 | 0 | 0.91 | 0.07 | 0.1 | 0 | 0.7 | 0.01 | UN Comtrade |
| **Inflation rate** | 0.05 | 0.07 | -0.05 | 0.62 | 0.05 | 0.05 | -0.08 | 0.39 | 0.01* | Worldbank |
| **Exchange rate (LCU/USD)** | 732.48 | 2484.7 | 0 | 19068.42 | 673.96 | 2768.34 | 0 | 25941.66 | 58.52 | Worldbank |
| **Doing Business (principal component)** | -0.55 | 1.31 | -3.62 | 3.29 | 0.62 | 1.27 | -3.72 | 3.19 | -1.17*** | Worldbank |
| **Maximum Residue Limits (Index 0-1)** | 0.01 | 0.03 | 0 | 0.25 | 0.09 | 0.13 | 0 | 0.77 | -0.08*** | Homologa Database |
| **Development flows to agr. per agr. GDP** | 0.01 | 0.02 | 0 | 0.18 | 0.01 | 0.02 | 0 | 0.13 | 0.01*** | FAOSTAT, Worldbank |
| **Conflict related deaths per Mio. persons** | 8.83 | 58.55 | 0 | 709.39 | 4.22 | 29.76 | 0 | 521.73 | 4.61 | UCDP, Worldbank |
| **Urban population (population share)** | 47.8 | 23.93 | 8.55 | 100 | 62.42 | 20.85 | 14.19 | 97.82 | -14.62*** | Worldbank |
| **Road density (per km2)** | 0.59 | 0.97 | 0.01 | 5.42 | 0.85 | 1.31 | 0.02 | 9.68 | -0.26*** | CIA, Worldbank |
| **Fixed broadband subscriptions (population share)** | 0.05 | 0.09 | 0 | 0.37 | 0.13 | 0.14 | 0 | 1.05 | -0.08*** | Worldbank |
| **GDP per capita ('000 current USD)** | 10275.72 | 18974.67 | 204.94 | 119225.38 | 16254.20 | 19718.03 | 341.31 | 103059.25 | -5978.48*** | Worldbank |
| **Colonial history with EU6 (1=yes)** | 0.35 | 0.48 | 0 | 1 | 0.35 | 0.48 | 0 | 1 | 0.01 | Cepii |
| **ISO membership (1=yes)** | 0.31 | 0.46 | 0 | 1 | 0.8 | 0.4 | 0 | 1 | -0.49*** | ISO |
| **Landlocked (1=yes)** | 0.25 | 0.43 | 0 | 1 | 0.17 | 0.38 | 0 | 1 | 0.08*** | Cepii |
| **Cropland (in million ha)** | 3.35 | 12.92 | 0 | 123.84 | 12.54 | 28.39 | 0 | 169.72 | -9.19*** | FAOSTAT |

to generate one single variable ($DB_{i,t}$) that comprises information of four DB indicators (relevant for our purpose) released by the World Bank, namely registering property, getting credit, trading across borders and enforcing contracts. The PCA reveals that this component explains around 68% of the variation. The investment climate is also influenced by a country's political stability (implementation phase) which is proxied by the number of conflict related deaths normalised by population size ($Conflict_{i,t}$).

We use three sector policies which we hypothesise to influence certification decisions. First, existing domestic public regulations in the food market are proxied by the applied maximum residual limits (MRL) of pesticides (implementation phase). Since pesticide regulations vary substantially across products and pesticides, we transform the absolute value of the MRL given in mg/kg and construct a strictness indicator which makes MRL regulations comparable across countries and products. We follow Ferro et al. (2015) and construct the index as follows:

$$R_{i,p,t} = \frac{1}{N(a)} \sum_{n(a)=1}^{N(a)} \frac{MAX_{p,a,t} - MRL_{i,p,a,t}}{MAX_{p,a,t} - MIN_{p,a,t}} \tag{6}$$

where $MAX_{p,a,t} = max_{i \in I}\{MRL_{i,p,a,t}\}$ is the maximum MRL for product $p$, pesticide $a$, and year $t$ across all countries and $MIN_{p,a,t} = min_{i \in I}\{MRL_{i,p,a,t}\}$ is the corresponding minimum MRL. $MRL_{i,p,a,t}$ is the country $i$'s specific MRL regulation for pesticide $a$, for product $p$ in year $t$. This index is a normalisation of the product specific pesticide regulation to values between zero (least strict) and one (most strict) countries, relative to the whole sample. Since we need one strictness index for all products produced in one country, we take the weighted mean over all products according to their production share within one country. This gives us the final index used in the regressions as mentioned in Eq. 3:

$$MRL_{i,t} = \frac{\sum_{n(p)=1}^{N(p)} R_{i,p,t} * Q_{i,p,t}}{\sum_{n(p)=1}^{N(p)} Q_{i,p,t}} \tag{7}$$

where $Q_{i,p,t}$ is the produced quantity of product $p$, in country $i$ in year $t$.

The second sector policy variable included is development flows to agriculture ($DevAg_{i,t}$) (implementation phase and confirmation phase) which is normalised by the country's agricultural GDP. Finally, a country's ISO membership status is included as a dummy variable ($ISO_{i,t}$) (implementation phase).

Additionally, the following covariates are included in the unrestricted model specification (Eq. 3). We hypothesise that a country being landlocked plays a role in deciding for certification (implementation phase) and is measured by a dummy variable ($lock_i$). The horticultural production share (over total crop production) within countries (information phase) is given by the lagged variable $FV_{i,t-1}$. As a proxy for agricultural productivity we use the lag of agricultural capital stock (normalised by agricultural GDP) $Agcap_{i,t-1}$ (persuasion phase). To control for the effect of macroeconomic conditions (implementation phase), the inflation rate ($I_{i,t}$) and the exchange rate ($XR_{i,t}$) are included. In the unrestricted model we additionally include $GDPpc^2_{i,t}$ as a proxy for the sectors aggregate risk taking behaviour as well as general financial capacity of the countries' farmers (persuasion phase and confirmation phase). The squared term is only included in the negative binomial regression to account for concavity. A size control variable which can also serve as a proxy for the home market effect is the number of inhabitants per country $Pop_{i,t}$ (persuasion phase). In the logit regression for RQ one, we exclude the squared term of the GDP variable ($GDPpc^2_{i,t}$), because there should not be a concave behaviour when the dependent variable is binary. We further exclude $Pop_{i,t}$ in the logit model, because it behaves highly collinear with the cropland variable which needs to be used as a size control (for details see above).

Our baseline sample includes 168 countries[11] which are listed in Appendix Table E1. Since GlobalGAP is developed and quasi-mandatory in the EU, EU crop producers are more likely to comply to it. Thus, to ensure that our results are not solely driven by the EU, we re-estimate the baseline model (see column (1) in Tables 3 and 4) excluding all EU countries (see column (2) in Tables 3 and 4). Furthermore, we explore the dynamics of the diffusion process by interacting all variables with a dummy equalling one for time period 2012-2014 (see column (3) in Tables 3 and 4). This shows if different drivers are relevant in later than in earlier years.

The descriptive statistics of all variables, their units measured, and the corresponding data sources are provided in Table 2. The sample is divided into countries showing at least one certified producer versus countries without any certificates. Assuming non normal distributions of the dummied variables, we use Wilcoxon rank sum tests, while we use a t-test for all other variables to test for statistical significance of the differences in the means of the two country groups. We find them all being statistically different, except for colonial history, conflict related deaths, crops export share to world in total exports and exchange rate.

# 4 Results and discussion

Our empirical modeling exercise sheds light on the underlying forces of some of the distributional and growth patterns of GlobalGAP certificates around the world. The Appendix section F illustrates the descriptive results. This section is confined to presenting the empirical modeling results only. Table 3 shows the results of the logit model. The model identifies those determinants which explain the probability of showing at least one certified farmer, we call this overcoming the *barriers to entry* the certification market. Here, odds ratios are reported with a value above one meaning an increase in the odds of entering the certification market if the covariate increases by one standard deviation. Reversely, a value below one means that the odds of certification decreases with a one standard deviation increase of the covariate. For the logit model, we limit the interpretation of the estimated odds ratios to positive effect or negative effect and increasing or decreasing effect (when looking at interaction terms). The reason for not interpreting it in percent changes is that the signs and general tendencies are robust across different model specifications, but the

[11] We had to drop 27 countries due to missing data of important variables. However, most of these countries are small island states with only very limited agricultural production potential.

magnitudes vary.

The negative binomial model presented in Table 4 shows why some countries show higher certification rates compared to others, we call this the *spread* of certification. Here, incidence rate ratios are reported which can be interpreted as a factor change of the dependent variable due to a one standard deviation increase in the independent variable. Again, values below one can be interpreted as a negative effect on certification rates, while values above one as a positive effect. The negative binomial estimations give us more confidence to also interpret the magnitude of estimates, because they are more stable and magnitudes more moderate than the logit estimations.[12] Only the dynamic changes, via interaction terms, are limited to a 'more/less than the first period' interpretation. Each variable in both Tables 3 and 4 is assigned to the corresponding Rogers' phases derived in Section 2. Additionally the Appendix Table D2 shows the corresponding coefficients for the restricted and unrestricted full sample specification.

## 4.1 Global results

Regarding RQ one – or what are the factors explaining why some countries are left out of the GlobalGAP market – in the full sample (Table 3 column 1), we find positive and statistically significant effects for the variables *Sum of GlobalGAP producers in neighbour countries*, *Colonial history with EU6*, *Urbanisation*, *Share of fixed broadband subscription*, *Crop export share over total exports*, *Doing business*, and *ISO membership*. This means that variables from the first three of Roger's stages can all pose relevant entry barriers to GlobalGAP at the macro-level. The only negative covariate is *GDP per capita* which is a surprising result at first sight. This effect is driven by high income countries without considerable amount of agricultural land.[13] In other words, close local and global network ties, adequate information infrastructure, high focus on agricultural trade, a favourable business environment and membership of an international standard setting community increase the probability of initiating the certification process. The latter effect was also found by Herzfeld et al. (2011) in their cross-sectional analysis. Furthermore, the positive effect of urbanisation is expected as less urbanised countries are typically also among the poorer countries where the supermarket revolution is still in its earlier stages of development (Reardon et al., 2003,1).

Regarding RQ two (Table 4 column 1) – or why do some countries show higher certification rates – different variables of the four Roger phases play a role. This is not surprising as our analysis considers the aggregate macro-level which means that some farmers might still be in the information or persuasion phase while others have already entered the implementation or confirmation phase. While all phases are relevant, our results indicate that Roger's phases two and three are slightly more important than access to information networks during phase one. Specifically, local network ties (i.e. GlobalGAP producers in neighbour countries) are not statistically significant. This hints at information about GlobalGAP certification from nearby peers becoming less relevant once a country entered the certi-

[12]Since RQ two wants to find the drivers of changes in certification numbers, magnitudes seem more relevant here then for the logit model where we have a binary dependent variable.

[13]If we run the regression omitting countries with very high GDP per capita and very low agricultural land – e.g. oil exporting countries – the sign switches to be positive. The results can be obtained from authors upon request.

Table 3: Determinants of the probability to adopt GlobalGAP (RQ one)

| VARIABLES | Standard deviation | Full sample (1) RQ1 Logit Odds ratios | Non-EU (2) RQ1 Logit Odds ratios | 2nd period (3) RQ1 Logit Odds ratios | Roger's phases / Trend |
|---|---|---|---|---|---|
| GlobaGAP neighbouring countries (lag) | 6079.966 | 9.023* | 8.922 | 21.431** | I |
| | | (11.66) | (13.44) | (28.714) | |
| Fruits and vegetables area share (lag) | 0.228 | 0.291 | 0.208* | 0.118*** | I |
| | | (0.223) | (0.169) | (0.075) | |
| Colonial history with EU6 (dummy) | | 14.96* | 144.8*** | 13.156* | I |
| | | (21.99) | (263.6) | (19.430) | |
| Urbanisation | 23.309 | 4.032* | 5.649* | 15.111*** | I, II |
| | | (2.965) | (5.037) | (13.672) | |
| Fixed broadband subscriptions | 0.130 | 13.10*** | 10.22** | 9.919** | I, III |
| | | (12.25) | (10.03) | (10.639) | |
| Crops export share (lag) | 0.125 | 2.127* | 2.002 | 7.814*** | II |
| | | (0.864) | (0.868) | (4.650) | |
| GDP per capita | 19625.962 | 0.091*** | 0.260 | 0.041*** | II, IV |
| | | (0.065) | (0.282) | (0.039) | |
| Doing Business indicator | 1.408 | 3.129* | 2.548 | 4.636* | III |
| | | (1.986) | (2.191) | (3.733) | |
| Maximum Residue Limits | 0.109 | 11.16 | 65.17** | 23.599** | III |
| | | (17.21) | (119.3) | (36.519) | |
| ISO membership (dummy) | | 32.63*** | 10.11** | 121.16*** | III |
| | | (34.75) | (11.09) | (162.890) | |
| Cropland | 23.681 | 3.201 | 4.326* | 3.006 | |
| | | (4.411) | (3.771) | (2.683) | |
| 2nd period | | | | 0.336 | |
| | | | | (0.324) | |
| GlobaGAP neighbouring countries (lag) | | | | 0.972 | |
| *2nd period | | | | (1.351) | |
| Fruits and vegetables area share (lag) | | | | 3.052** | ↑ |
| *2nd period | | | | (1.478) | |
| Colonial history with EU6 (dummy) | | | | 1.054 | |
| *2nd period | | | | (1.247) | |
| Urbanisation | | | | 0.251** | ↓ |
| *2nd period | | | | (0.176) | |
| Fixed broadband subscriptions | | | | 1.176 | |
| *2nd period | | | | (1.271) | |
| Crops export share (lag) | | | | 0.077*** | ↓ |
| *2nd period | | | | (0.071) | |
| GDP per capita | | | | 1.312 | |
| *2nd period | | | | (1.181) | |
| Doing Business indicator | | | | 1.473 | |
| *2nd period | | | | (0.854) | |
| Maximum Residue Limits | | | | 0.306 | |
| *2nd period | | | | (0.441) | |
| ISO membership (dummy) | | | | 1.204 | |
| *2nd period | | | | (1.221) | |
| Constant | | 0.647 | 0.668 | 0.791 | |
| | | (0.702) | (0.852) | (0.948) | |
| Observations | | 985 | 826 | 985 | |
| Random effects | | YES | YES | YES | |

Note: *** p<0.01, ** p<0.05, * p<0.1

I = Information phase, II = Persuasion phase, III = Implementation phase, IV = Confirmation phase; standard deviation of full sample; Trend in last column refers to the arrows after interaction terms only.

Table 4: Determinants of intensification of GlobalGAP certification (RQ two)

| VARIABLES | Standard deviation | Full sample (1) NB IRR | Non-EU (2) NB IRR | 2nd period (3) NB IRR | Roger's phases / Trend |
|---|---|---|---|---|---|
| GlobaGAP neighbouring countries (lag) | 6079.966 | 1.13 | 1.28 | 1.2 | I |
| | | (0.17) | (0.431) | (0.188) | |
| Colonial history with EU6 (dummy) | | 2.55 | 3.52* | 2.34 | I |
| | | (1.685) | (2.57) | (1.573) | |
| Export Share to EU (lag) | 0.315 | 1.29* | 1.35 | 1.43** | I, II |
| | | (0.184) | (0.249) | (0.208) | |
| Urbanisation | 23.309 | 1.89* | 1.89 | 1.89* | I, II |
| | | (0.674) | (0.754) | (0.688) | |
| Road density | 1.191 | 2.73*** | 2.41* | 2.15** | I, III |
| | | (0.874) | (1.244) | (0.718) | |
| Fixed broadband subscriptions | 0.130 | 1.69*** | 1.51 | 1.94*** | I, III |
| | | (0.338) | (0.501) | (0.436) | |
| Crops export share (lag) | 0.125 | 1.45** | 1.46** | 1.62*** | II |
| | | (0.242) | (0.277) | (0.272) | |
| Doing Business indicator | 1.408 | 2.27*** | 2.66*** | 2.05*** | III |
| | | (0.561) | (0.83) | (0.51) | |
| Conflict related deaths | 44.086 | 1.06 | 1.07 | 1.16** | III |
| | | (0.061) | (0.071) | (0.074) | |
| ISO membership (dummy) | | 1.48 | 1.48 | 1.63 | III |
| | | (0.41) | (0.483) | (0.494) | |
| Development flows to agriculture | 0.019 | 0.74*** | 0.75*** | 0.66*** | III, IV |
| | | (0.061) | (0.071) | (0.06) | |
| 2nd period | | | | 1.31 | |
| | | | | (0.282) | |
| GlobaGAP neighbouring countries (lag) | | | | 0.99 | |
| *2nd period | | | | (0.065) | |
| Colonial history with EU6 (dummy) | | | | 1.12 | |
| *2nd period | | | | (0.207) | |
| Export Share to EU (lag) | | | | 0.79*** | ↓ |
| *2nd period | | | | (0.07) | |
| Urbanisation | | | | 1.03 | |
| *2nd period | | | | (0.125) | |
| Road density | | | | 1.37*** | ↑ |
| *2nd period | | | | (0.163) | |
| Fixed broadband subscriptions | | | | 0.88 | |
| *2nd period | | | | (0.083) | |
| Crops export share (lag) | | | | 0.75*** | ↓ |
| *2nd period | | | | (0.073) | |
| Doing Business indicator | | | | 1.12 | |
| *2nd period | | | | (0.134) | |
| Conflict related deaths | | | | 0.68*** | ↓ |
| *2nd period | | | | (0.082) | |
| ISO membership (dummy) | | | | 0.71 | |
| *2nd period | | | | (0.163) | |
| Development flows to agriculture | | | | 1.37** | ↑ |
| *2nd period | | | | (0.171) | |
| Observations | | 985 | 827 | 986 | |
| Random effects | | YES | YES | YES | |

Note: *** p<0.01, ** p<0.05, * p<0.1; I = Information phase, II = Persuasion phase, III = Implementation phase, IV = Confirmation phase; standard deviation of full sample; IRR = Incidence rate ratio: to be interpreted as a factor increase if IRR-value is above one and decrease if IRR-value is below one; NB = Negative binomial; Cropland is included as an offset variable, thus interpretation of results should be 'number of certified farmers per hectare'; Trend in last column refers to the arrows after interaction terms only.

fication market. On the other hand, the variables *Share of fixed broadband subscription* and *Road density* are highly significant and high in magnitude. This hints at the internet as an important information source about GlobalGAP requirements. The positive effect of transportation infrastructure is likely explained by the fact that it is often perishable certified fruits and vegetables which need to be transported long distances to markets.

Furthermore, ISO membership is insignificant when looking at the spread of GlobalGAP. This means that being involved in the standard setting community enhances the chances of entering the certification market with at least one farmer, but for accelerating the spread, factors more directly related to GlobalGAP are decisive.

The variables *Urbanisation*, *Crop export share over total exports* and *Doing business* are statistically significant and also have a positive effect on the intensity of GlobalGAP certification. Our results go hand in hand with results by Mohammed and Zheng (2017) on urbanisation, Masood and Brümmer (2014) on internet access and Neumayer and Perkins (2005) on regulatory burden. This means that factors, such as access to credit, secure property rights, functioning contract enforcement, and efficient trading across borders are of high relevance for pushing the certification process in countries. This is not surprising for various reasons: Firstly, credit is often needed to finance the entry costs. Secondly secure property rights also reflect the land tenure situation in a country which is found to be decisive in explaining farm investment decisions (Deininger and Jin, 2006). Third, GlobalGAP is in fact a contract between a farmer and a retailer or wholesaler, and thus reliable contract enforcement is a prerequisite for GlobalGAP. Finally, easy and cheap trading across borders can operate in favour of GlobalGAP certification rates, because most of the certified produce is traded internationally. As expected, the *Export share to EU* explains an increasing number of GlobalGAP certificates. Our findings regarding a countries trade pattern are in line with Herzfeld et al. (2011) who find that higher net agricultural exports and stronger trading relations with EU increase the number of GlobalGAP certificates.

Together with a favourable business environment, good transport infrastructure has the greatest effect (in magnitude) on the number of certified farmers in a country. This is expected, since most certified produce is (still) not sold in local markets, but in distant locations. Each of these determinants more than doubles the number of farmers certified (ceteris paribus) when it increases by one standard deviation. Relating this information to concrete countries, we find that certification doubles if the doing business indicator increased from e.g. Senegal's (or Egypt's) level to the level which Greece (or Austria) showed in the year 2009 (2014). Another way to show the relevance of the business environment is taken from the example of Peru: The country increased its doing business performance by 0.25 points between 2009 and 2014. Ceteris paribus, this is equivalent to a 22 percent increase which translates into 279 more certified farms. Thus, good infrastructure is one key element for the further spread of certificates within a country, but there are others. Keeping the example of Peru, a higher focus on the agricultural sector – proxied by its *Crop export share over total exports* – increased total certification numbers by 15 percent (or 188 farmers) between 2009 and 2014, because the trade share had increased substantially.

Surprisingly, development flows to agriculture significantly reduce the number of certified

GlobalGAP farmers. This result can be partially explained by the fact that development aid to agriculture is rather spent on emergency food assistance and on agricultural and rural development strategies. On average each of the aforementioned sectors account for 10 percent of aid for agriculture. By contrast, industrial crops or export crops only add up to less than one percent of development aid spent on agriculture during the period 2008-2014 (OECD, 2018).

## 4.2 Non-EU results

Column 2 in both Table 3 and Table 4 shows the results for the Non-EU sample. Our main results are not driven by EU countries with their high certification rates. All variables for the Non-EU sample show the same sign and for RQ two even very similar magnitudes. This is also the case for most variables which explain entry into the certification market (RQ one). Only *Colonial history with EU6* and *Maximum Residue Limits* show much higher coefficients. This is reasonable, because the EU countries are almost all certified, but naturally cannot have a colonial history with the EU. By contrast, it is the non-EU countries with strong historical ties to the EU which are among the group of certified countries. Also, non-EU countries usually face laxer MRLs compared to stricter MRLs in the EU. Since GlobalGAP requirements are adapted to European MRLs, stricter MRLs in non-EU countries lower the initial investment costs to comply with GlobalGAP, making market entry more probable. The *ISO membership* coefficient is lower in the non-EU sample which can be partially explained by the indirect harmonisation effect between ISO and GlobalGAP due to a large participation share of EU governments in the international standard setting community. Nevertheless, the coefficient remains positive and significant, which is in line with Curzi et al. (2018) who states that the harmonisation effect is particularly relevant in low and middle income countries which make up 84 percent of the non-EU subsample.

## 4.3 Dynamics

Considering the dynamics in explaining the probability of entering the certification market (Table 3 column 3), urbanisation and crops export share stay relevant in time period 2 (2012-2014), but to time period 1 (2009-2011) the effects decrease ($\text{Odds-ratio}_{Interaction} < 1$). During the first time period, the share of fruits and vegetables in total crop production significantly decrease the probability of entering the certification market. This result may be driven by some countries, e.g. Nigeria, Burma or Algeria, which show increasing fruits and vegetables production areas, but no certification. In later years the negative effect is less pronounced – due to an ever increasing number of countries with horticultural production entering the GlobalGAP market – but the effect cannot be reversed completely.

The dynamics in the intensification process of certification reveal (Table 4 column 3) that a good transportation infrastructure becomes even more relevant over time. A denser road network of 1.2 km per squared km land increases the expected certification rate by 115 percent during 2009 to 2011 and another 37 percent between 2012 and 2014. This increasing relevance in functioning roads can be explained by an increasing quantity of certified produce which needs more and more buyers to be reached by road. Development flows to agriculture decrease the rate of certification, however less in later than in earlier years.

As expected conflicts turn to have a statistical significant negative effect on certification during the later period. However, in earlier years conflicts had a positive effect which could be partially explained by on average higher death rates by certified countries during the years 2009-2011, e.g. driven by countries such as Ivory Coast and Colombia (due to the FARC conflict). The relevance of crop export shares over total exports decreases over time. Also, trade relations with the EU play a less important role in later years which illustrates the increasing global orientation of GlobalGAP. While Herzfeld et al. (2011) specifically emphasises the relevance of EU trade networks in explaining the global distribution of GlobalGAP, we show this more nuanced picture which shows that EU trade remains relevant, but becomes less pertinent.

To get a quick grasp of the main determinants driving the spread of certification or explaining market access restrictions, Table 5 summarises the main elements giving an interpretation of the total effect and the dynamics.

# 5 Conclusions

In response to a widening set of consumer concerns in many countries of the world, retailers increasingly demand compliance of stringent standards with requirements for food quality and safety, for environmental sustainability and for labour standards. The GlobalGAP standard is one of the most prominent global private agri-food pre-farm gate process standard. Thus, many agricultural producers across the world are embracing GlobalGAP as an entry ticket to high-value (mostly) European and increasingly also other markets. However, the global spread of the GlobalGAP certification scheme is highly unequal. While some regions perform well in adjusting to the sector's transformation, other world regions lag behind and show low certification rates of farmers.

This study investigates the underlying forces behind these unequal patterns of the global diffusion of food quality standards. Our scale of analysis is the macro-level; we, derive the set of potential macro-level drivers of adoption based on theoretical considerations at the micro-level. We build on the theoretic framework of adoption of organisational innovations, which provides an appropriate base for answering two RQs: first, we investigate why some countries do not show any certified farmers, despite the high global relevance of GlobalGAP. And second, we show why some regions adopt more intensively than others. Our panel data structure, covering the years 2009 to 2014, allows us to include dynamic processes in our model.

Our findings show that similar factors drive the processes behind why countries enter the GlobalGAP market or why some countries show much higher certification rates than others. We want to highlight five main macro factors supporting the certification process. First, existing network ties to the EU and a strong focus on agricultural export sectors are crucial, but with a decreasing relevance over time. This highlights that GlobalGAP certification has become relevant far beyond the already debated export markets by Herzfeld et al. (2011), Masood and Brümmer (2014) and Mohammed and Zheng (2017). With the ongoing supermarket revolution in developing countries, domestic markets enter the scene for GlobalGAP produce. So the second driver for both entering GlobalGAP markets for the first time and the further spread is urbanisation. More urban societies tend to shift

Table 5: Main findings: Entry barriers to and spread of GlobalGAP

| **Entry barrier** | **Driver of spread** | **Total effect** | **Dynamics** |
|---|---|---|---|
| Missing local and global network ties | Strong global network ties | • Nearby certified peers → Decreased uncertainty about GlobalGAP's profitability.*<br>• Cultural ties to core GlobalGAP market → Facilitates information flow about GlobalGAP requirements.<br>• Existing trade network with EU → GlobalGAP quasi mendatory EU trade.† | • Relevance of EU network ties for GlobalGAP spread reduces over time for → Relevance of GlobalGAP also for non-EU retailers increases.† |
| Lacking information infrastructure | Functioning Infrastructure | • Internet access → Access to relevant information and essential for operability of documentation and traceability.<br>• Transportation infrastructure → Better market access and reduced trade costs.† | • Road infrastructure becomes increasingly important for GlobalGAP.† |
| Low focus on agricultural trade | High focus on agricultural trade | • Varying levels of export share of crops on total exports → Decisive for initial investment costs needed to enter export market. | • Relevance in agricultural trade decreases over time → Due to accelerated spread of GlobalGAP in(to) regions with relatively low economic focus on agricultural sector. |
| Rural society | Urban society | • More urban societies more likely to have a higher domestic demand for certified produce → Decisive for entering and spreading GlobalGAP certification. | • Urbanisation rate becomes less relevant → Supermarkets increasingly spread into rural areas.* |
| Unfavourable business environment | Favourable business environment | • Functioning business environment (proxied by easy access to credit, secure property rights, functioning contract enforcement and efficient trading across borders) → Decisive for transaction costs related to investment decisions and domestic and international trade (comparative disadvantage over other countries.) | • Unclear trend. |
| Lack of (agricultural) sector policies | Member of international standard setting community | • Strict MRL of pesticide regulations → Differences in domestic and international food quality requirements increase investment costs for farmers.*<br>• Exclusion of international standard committee of ISO → Impedes harmonisation process of standards which equally fit domestic and international markets. | • Unclear trend |

Note: The *Entry barrier* and *Driver of spread* mentioned to the channels and/or variables as described in Table 1 of the conceptual framework. An asterix (*) denotes that the channel is only relevant for overcoming the *Entry barrier*, a cross (†) that the channel is only relevant for explaining the *Driver of spread*. If nothing is mentioned, the channel is relevant for both.

their diets towards a westernised style. Yet, the supermarket revolution is underway to expand into more remote rural areas in every corner of the planet. Thus, we find the effect of urbanisation to be more moderate in later years. Third, our results point to the relevance of promoting a favourable business environment through good governance structures. Especially facilitating access to credit, lowering trade-related transaction costs, secure land tenure rights and good contract enforcement are found to be crucial. Fourth, a prerequisite of the further spread of GlobalGAP certification is also a good information and transportation infrastructure. Some countries simply lag behind in the agricultural sector transformation due to a lack of information flow and because produce cannot be transported in time to important destination markets. Fifth, we find that existing strict public food regulations in some countries facilitate the entry of private standards. This is because the additional initial investment costs to comply with the even stricter pesticide standards, set by GlobalGAP, are comparatively lower in those countries.

Certification entails substantial benefits, such as better working conditions for farmers and workers, an increase in productivity levels and access to high-value (export markets) with their inherent positive effects for farm income, as well as environmental protection. This is especially crucial for countries in which agriculture plays a major role for many livelihoods. In addition, consumers worldwide benefit from increasing food safety and quality. Considering the diverse opportunities of private food standards, promoting the further expansion of GlobalGAP can be desirable from a local as well as global perspective.

Our findings provide important policy recommendations in this sense. First, governments should foster a favourable business environment by guaranteeing land tenure and functioning land and credit markets. Developing judicial and executive power can support contract enforcement which is a prerequisite for GlobalGAP to come into force. Second, connecting rural production areas to urban centres and harbours through infrastructure investments makes certification a beneficial investment for farmers. Third, the expansion of reliable internet in remote areas enables information flow and compliance with the strict requirements of traceability and GlobalGAP documentation. Finally, governments should engage in the development of public standards of good agricultural practices. This gives farmers the need to invest in higher production standards, making GlobalGAP certification an easy to reach target.

One caveat of this study poses the inability to capture heterogeneities within countries. The general debate about whether private food standards and certification is beneficial for farmers usually revolves around the most vulnerable part of the rural population and how to include them into high-value markets. Our scale of analysis fails to capture these within country differences, as high certification rates do not necessarily lead to an inclusion of all population segments. Despite this shortcoming, we still believe that our study provides valuable insights into how to create the enabling macro-economic conditions in order to cope with the inevitable agricultural sector transformation. Country specific case studies should in turn provide insides in how to design more inclusive policies to be accompanied by the mentioned macro-policies.

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# Appendix

## A GlobalGAP background

Nowadays, GlobalGAP is one of the most important international B2B standards.[14] Thus, Unlike Business-to-consumer standards (B2C), B2B standards are imposed by retailers or food companies upon agricultural producers to ensure traceability along the entire supply chain and to reduce transaction costs (Fulponi, 2006). Hence, they are neither visible to the consumer nor used for product differentiation. GlobalGAP was rather developed to protect the retail sector from potential harm through food safety scandals and to secure sufficient supply of high-quality produce in times of increasingly stringent public food safety regulations (Webb, 2015). While GlobalGAP is a complex system of sub-standards[15], this study focuses on the core of the GlobalGAP standards: the IFA standard. It covers Good Agricultural Practices for agriculture, aquaculture, livestock and horticulture production and is designed for primary products on farms. To obtain the IFA certificate, producers have to meet certain compliance criteria, which are categorised into *major must*, *minor must* and *recommendation*, which are controlled annually (Dannenberg, 2012). Most requirements are related to product quality, environmental effects and labour practices / human rights. For instance, GlobalGAP requests the implementation of an integrated pest management, conversation of biodiversity, waste management, safe practices at work and a food safety system in place (GlobalGAP, 2017). Hence, the spread of GlobalGAP compliance (with its strict criteria) has the potential to reduce the use of hazardous pesticides (Asfaw et al., 2009), to improve farmers health (Asfaw et al., 2010a), and to improve on-farm working conditions (Colen et al., 2012) at a global scale. On the other hand, it is the farmers who normally fully defray the compliance costs.[16] Though sometimes technical assistance programs are in place, or export companies partially or fully cover certification costs (Asfaw et al., 2010b; Henson et al., 2011).

GlobalGAP was formerly called 'EurepGAP' and founded in 1997 by European retailers mainly located in Great Britain. Over the last decades, the number of retailers requiring standard compliance by their suppliers grew to 45 with the majority among them still being located in Europe, but increasingly also outside the EU borders. As a reaction, many agricultural producers worldwide adopted the standard eliciting a rebrand to GlobalGAP in 2007 (GlobalGAP, 2018). In 2016, 174,316 suppliers worldwide are certified under GlobalGAP, of which 61.8% are located in Europe which reflects the European origin of the standard. The second highest proportion of GlobalGAP certificates is located in Africa (17.2%), followed by South America (10.8%) and Asia (8%), while North America and Oceania comprise the remaining 2.2%. As a pre-farm gate standard, GlobalGAP focuses on the production processes of livestock, fruits and vegetables, aquaculture, flowers

[14]Note that there are also other globally relevant private standards in food supply chains, such as BRC, SQF, GFSI and IFS. However, there is an increasing tendency towards global standard harmonization. In our context, this means that zero-certified countries are likely also lacking certification to other private standards.

[15]GlobalGAP offers several standards designed for different scopes, such as the Integrated Farm Assurance Standard (IFA), the Chain of Custody Standard (CoC), the Crops for Processing Standard (CfP), the Harmonized Produce Safety Standard (HPSS), the Livestock Transport Standard and the Compound Feed Manufacturing Standard (CFS). The latter target processing steps of agricultural produce or specific aspects of the livestock sector.

[16]So far there is only limited empirical evidence on the effects of private standards in different realms.

and ornamentals, combinable crops, tea and coffee. With 168,060 certified producers in 2016, the fruits and vegetables sector is by far the most important under GlobalGAP (GlobalGAP, 2016).

The fact that large global players, such as Aldi, Edeka, Lidl, Rewe Group or Tesco have all become GlobalGAP members, farmers' compliance is today de facto mandatory to enter the EU market – and increasingly also non-EU markets. This trend is further reinforced by the 'bottle neck' structure of global food supply chains (Dannenberg, 2012, p.106): the market is characterised by few and large (European) retail chains established in oligopolistic market structures. By contrast there are many farmers operating in highly competitive environments at the bottom of the value-chain. The market power enables retail chains to set strict standards to be fulfilled by their suppliers in order to stay in or enter the market (Lee et al., 2012). As a reaction, WTO members already raised concerns about private food standards acting as trade barriers, because some countries might be systematically excluded from markets due to high costs. However, due to the strict private nature of the standard – without any participation of public bodies in the standard setting process – GlobalGAP does not fall under the WTO SPS agreement (Webb, 2015).

In summary, GlobalGAP farm-gate certification has spread globally despite its associated costs. It entails potential advantages, such as increasing food safety and quality for consumers, better working conditions for farmers and workers, an increase in productivity levels with its inherent positive effects for farm income, as well as environmental protection. Given that usually the poorest countries are those with the strongest focus on agriculture in their economies, reaping the mentioned advantages and guaranteeing market access to high-value chains can be of great relevance for their development path. However, especially farmers located in poor developing countries sometimes face difficulties in complying with the high requirements needed for GlobalGAP certification. Thus, understanding what macro-environment facilitates the successful implementation of such food standards can deliver the base for designing more effective policies.

## B Literature review on the adoption and diffusion of private food standards

There has been an increasing number of scientific publications focusing on the realm of food standards with their different ramifications along the agricultural supply chain. However, most studies focus on analysing public standards such as SPS and TBT measures set by the WTO or EU food safety standards (see e.g. Disdier et al., 2008; Kareem et al., 2018). Less attention has been given to private food quality standards, mostly due to a lack of data. Furthermore, empirical studies in this field are mostly conducted on the micro-level and focus on one specific product and/or country. The most relevant micro-studies exploring adoption determinants of the private standard GlobalGAP are Kleinwechter and Grethe (2006), Asfaw et al. (2010a), Kersting and Wollni (2012) and Souza Monteiro and Caswell (2009).

Asfaw et al. (2010a), Kersting and Wollni (2012) and Souza Monteiro and Caswell (2009) agree that farmers with higher educational level are more likely to adopt the standard, because GlobalGAP requires sophisticated record keeping and the implementation of a quality management system. Another supporting factor is an already high level of farming technology which helps to comply with GlobalGAP production process requirements (Asfaw et al., 2010a; Kersting and Wollni, 2012; Kleinwechter and Grethe, 2006). Furthermore, in the specific case of Kenyan and Thai horticultural farmers, Asfaw et al. (2010a) and Kersting and Wollni (2012) show that access to female family labour promotes the adoption of GlobalGAP. This is because horticultural farming includes many labour-intensive work which are tasks usually taken over by women. In addition, Kersting and Wollni (2012) and Kleinwechter and Grethe (2006) agree that proximity to cities increases the diffusion of GlobalGAP certificates.

The micro-literature is inconclusive regarding the effects of agricultural households' access to information and communication technology (ICT), farm size and access to export networks or services. While Kersting and Wollni (2012) and Kleinwechter and Grethe (2006) find clearly positive effects of access to ICT on the adoption decision, Asfaw et al. (2010a) estimates no effect of mobile phone use. Other ambiguous results regard the effect of farms size and export experience. While Asfaw et al. (2010a) find negative effects on the adoption of private food standards in Kenya, Kersting and Wollni (2012) and Kleinwechter and Grethe (2006) find a positive effect of these two variables. The former can be explained by region-specific characteristics, such as Kenyan large-scale farmers specialising on the production of traditional cash crops, rather than on the production of typical GlobalGAP crops, such as fruits and vegetables. As expected, all studies, except for Kersting and Wollni (2012), find that membership in a producer organisation increases GlobalGAP adoption, which can be explained by the option to obtain group certification offered by GlobalGAP. However, Kersting and Wollni (2012) is the only study confirming that also access to public extension services has a positive effect. In the case of Kenyan horticulture farmers public extension services have no effect, because they are replaced by technical services provided by the private sector (Asfaw et al., 2010a). The same holds for Peruvian mango producers who are more likely to adopt GlobalGAP when they receive buyers' support (Kleinwechter and Grethe, 2006).

While the above mentioned case studies provide valuable insides on stanard adoption, results are case specific and overarching macro-factors are mostly ignored. To the best of our knowledge, only four studies (Herzfeld et al., 2011; Masood and Brümmer, 2014; Mohammed and Zheng, 2017; Neumayer and Perkins, 2005) have analysed the determinants of standard adoption at the macro-level. In line with the micro-level studies mentioned above, some macro-level studies also point out the positive effect of urbanisation (Mohammed and Zheng, 2017) and confirm higher numbers of certificates through better education and access to phones (Neumayer and Perkins, 2005). All four agree on positive relations between standard adoption and the export share to Europe, although Mohammed and Zheng (2017) find positive but insignificant results. This is likely driven by the fact that the authors calculate the aggregate effect of 6 different standards, among them standards of higher importance for retailers located in the USA rather than in Europe. In addition, there is consensus about the positive effects of the economic size and aggregate wealth status of a country – measured in GDP or GDP per capita. Herzfeld et al. (2011) estimate an inverse U-shaped relationship between GDP per capita and the adoption rate of GlobalGAP.

Herzfeld et al. (2011) and Masood and Brümmer (2014) find a higher degree of certification in countries that are specialised in the production of fruits and vegetables. This is driven by the fact that initially GlobalGAP started with certifying only fruits and vegetables. Furthermore, certification rates are found to increase with population size and the probability of non-certification is significantly higher for less populated countries (Herzfeld et al., 2011). Other factors which positively influence the spread of standards are institutional quality (Herzfeld et al., 2011; Neumayer and Perkins, 2005) and access to the standards' infrastructure through domestic certification bodies or auditors (Herzfeld et al., 2011; Masood and Brümmer, 2014; Mohammed and Zheng, 2017). In addition, Herzfeld et al. (2011); Masood and Brümmer (2014); Mohammed and Zheng (2017) expect a historical colonial relationship and a common language with the standard setter to decrease transaction costs and thereby to increase certification rates, but empirical results are ambiguous.

Table B1 summarises the main findings of all mentioned micro-level[17] and macro-level studies.

[17]Since the standard diffusion at the macro-level is shaped by aggregate micro-level behaviour, we think it is essential to also highlight the main findings of relevant micro-level studies.

Table B1: Summary of scientific literature explaining food standards adoption and diffusion, 2005-2017

| **Authors** | **Data** | **Standard** | **Model** | **Determinants of standards diffusion** |
|---|---|---|---|---|
| Asfaw et al. (2010) | Micro; cross-section | GlobalGAP | 2-stage standard treatment effect model | *positive effect:* female household members, intrahousehold literacy, agricultural training, radio, group membership, formal contract<br>*negative effect:* land size, export experience<br>*no effect:* public extension services, mobile phone |
| Kersting and Wollni (2012) | Micro; cross-section | GlobalGAP | Bivariate Probit model | *positive effect:* education, export experience, female HH members, farming technology, extension service, mobile phone, farm size (only small effect)<br>*negative effect:* group membership, distance to capital |
| Kleinwechter and Grethe (2006) | Micro; cross-section | GlobalGAP | qualitative / descriptive analysis;<br>t-test / Chi-test / correlation analysis | *positive effect - information stage:* vertical integration, producer organization, cosmpolitanism, telephone / internet access, farm size<br>*positive effect - decision stage:* vertical integration, age<br>*positive effect - implementation stage:* starting point, target level, buyers support |
| Souza Monteiro and Caswell (2009) | Micro; cross-section | GlobalGAP | Discrete choice models | *positive effect:* sales to UK, producer organization, education |
| Neumayer and Perkins (2005) | Macro; panel | ISO 9000 | OLS | Postive effect: lagged ISO 9000, GDP, export share to EU 15, telephone access, colony, education<br>*negative effect:* regulatory burden |
| Herzfeld et al. (2011) | Macro; cross-section | BRC, GlobalGAP | Negative binomial count data model | *GlobalGAP - positive effect:* population, domestic auditor, ISO membership, trade share to standard holder, F&V production, GDP per capita, institutional quality<br>*GlobalGAP - negative effect:* colony with Germany/Netherlands/UK |
| Mohammed and Zheng (2017) | Macro; cross-section | BRC, FSSC 22000, GlobalGAP, ISO 22000, Primus-GFS, SQF | Negative binomial count data model | *Positive effect:* No. Of certification bodies, total food exports, GDP per capita, F&V production, urbanization, agricultural land, common border<br>*negative effect:* distance to standard holder, landlocked<br>*no effect:* food exports to Europe, common language, colony |
| Masood and Brümmer (2014) | Macro, panel | GlobalGAP | Heckman two-stage model | *Positive effect:* common language, domestic auditor, export share to EU, F&V production, internet access<br>*no effect:* GDP per capita, regularity quality |

# C Conceptual framework

This section picks up on the general explanation of the conceptual framework described in section 2. In the following subsections we adapt Rogers' 1995 concept directly to the context of the GlobalGAP diffusion process and derive all relevant variables.

### Information phase

In this phase (1), gaining awareness and information flow matters. For the purpose of studying the global spread of GlobalGAP, the agents within a network are neighbouring certified farmers. At the macro-level this can be proxied by the average number of certificates in neighbouring countries. In this case, geographic proximity acts as the connecting link between farms. These networks allow for faster information flow and the producer can consider past experiences of near-peers before taking an adoption decision. Thus, it is hypothesised that countries surrounded by countries with high certification rates are more likely to (further) transform their agri-food system towards (more) certification. Likewise, well-developed transportation infrastructure, as well as access to information and communication technologies (ICT) increase the likelihood of interaction between potential adopters (Hägerstrand, 1967). Furthermore, geographical proximity and existing trade relationships to Europe – the main GlobalGAP market – enhances information flow and thereby the chances of a country's adoption rate. Generally, trade networks with modern retail chains increase information flows and induce cohesion of organisational practices which reduces transaction costs (Eichengreen and Irwin, 1998).[18]

Johansson (2014, p. 404) argues that 'new product cycles are frequently initiated in metropolitan regions with rich knowledge sources, intense knowledge flows and competent and demanding customers side by side with alert input suppliers'. Similarly, Krugman (1996) developed the theory of agglomeration economies to explain spill-over effects from learning processes and thereby the spread of innovations. Thus, highly urbanised countries are hypothesised to initiate GlobalGAP certification, also because supermarket chains (with GlobalGAP membership) are mostly located in urban centres.

Moreover, eligibility for certification requires the implementation of numerous processes prescribed in documentations usually written in English, Dutch or German in their binding versions, and frequently translated to French and Spanish and Italian[19]. Thus, knowledge of one of the six European languages, proxied by historical colonial status, is hypothesised to favour information flow and thereby the spread of the standard. Finally, GlobalGAP – formerly called EurepGAP – started with good agricultural practices for producers of fresh fruits and vegetables, and, only later on, extended the portfolio of standards to other agricultural sectors. Due to this history, farmers in countries with a higher share of horticultural production were likely exposed earlier to information about GlobalGAP, which enhances the likelihood of early adoption and finding more certified producers here.

[18] Another channel through which information flow is facilitated are frequent FDI or vertical integration in the food sector. However, lacking global data on agricultural-specific FDIs does not allow us to consider this aspect.

[19] GlobalGAP translates its documents to 26 different languages, but sometimes with time delays (GlobalGAP, 2018)

### Persuasion phase

During this phase (2) the producer evaluates the direct costs and benefits of GlobalGAP. These costs include the payment of a yearly certification fee and payments for external auditing. Thus, the presence of nearby auditing facilities may be decisive for the spread of the standard, because it reduces its costs. Unfortunately, we only have information on existing auditing facilities for one time period making its inclusion in the panel dataset imprecise. Furthermore, the variable suffers severely from reverse causality endogeneity with the outcome variable. Hence, we abstain from including this direct cost information. To get certified, ex ante investments are needed, e.g. construction of grading and sanitation facilities or training of employees, as well as changes in the production process, e.g. documentation and water testing. These costs are expected to be comparatively lower for producers located in countries with a traditionally well-developed agricultural sector. Hence, countries with high degree of sophistication in agriculture – proxied the agricultural capital stock – are hypothesised to have (more) certified farms. Countries with a high share of agricultural exports over total exports might display a higher number of certified farms as a larger share of farms located in these countries usually have already paid the sunk cost required to enter high-value markets. This argument is supported by scientific evidence analysing smallholder certification adoption. Here, certification increases with support from exporting firms in financing compliance costs and in providing technical support (Holzapfel and Wollni, 2014).

Besides cost considerations, the distribution of market power determines the certification decision. With the EU being the single most important market on aggregate and EU retailers showing a high concentration GlobalGAP has become a quasi-mandatory standard for farmers to either enter high-value markets or to avoid market exit. Also the level of risk aversion influences certification decisions, because adoption always involves a certain degree of uncertainty due to the payment of the mentioned sunk cost (Abadi Ghadim and Pannell, 1999; Easley and Kleinberg, 2010). At the global macro-level, it is very hard to find appropriate risk aversion proxies. In part, the wealth status reflects attitudes towards risk, mainly because poorer farmers have less opportunities to insure their consumption against exogenous shocks. External circumstances, such as low incomes, little or no insurance, limited access to credit, and thin labour markets limit farmers to low-risk, low-return activities (Yesuf and Bluffstone, 2009). GDP per capita can serve as a rough proxy for wealth, but comes with limitations[20] Moreover, Krugman (1980) shows that countries with a large home market – proxied by population size and urbanisation[21] – are more inclined to show innovative action. The reason is that the producer likely faces a lower risk of malinvestment if home demand for certified produce is high as there is less dependence on export markets.

### Implementation phase

While the persuasion phase was influenced by costs directly related to the standard, the implementation phase considers more general country-specific costs affecting successful

[20] Some countries may show a high GDP per capita, e.g. due to abundance of natural resources, but the peasants and the majority of the population can be very poor.

[21] We would have liked to include more precise variables, such as modern grocery distribution (MGD) by PlanetRetail.com but unfortunately the global data coverage is too low.

implementation of the standard. First of all, general macroeconomic conditions can determine investment decisions (Bleaney, 1996; Ghura and Goodwin, 2000) and thereby the number of certified farms. Stability is typically influenced by decent inflation rates, and exchange rates. High inflation reduces capital accumulation and productivity growth and thereby prevents investment decisions (Fischer, 1993). An overvaluation of the exchange rate reduces the returns to investment in the tradables sector (Bleaney and Greenaway, 2001) and thereby shapes adoption decisions.

Furthermore, according to Tinguely (2013) who builds on the work of Porter (1990), the quality of the business environment in a country drives innovative activity in different industries. The 'Doing-Business-Indicators'[22] provide objective measures of business regulations and their enforcement across 190 economies (The World Bank, 2017). For the purpose of studying agricultural value chains, we specifically include the following indicators as they seem relevant for the adoption process: registering property, access to credit, trading across borders, and enforcing contracts. A lack in access to credit markets as well as insufficient land tenure rights can hamper agricultural transformation (see e.g. Barrett et al., 2010). Due to the fact that GlobalGAP produce is often traded internationally, the time and cost associated with the logistical process of trading goods matter for the implementation of the standard. Moreover, a country's general efficacy and efficiency in enforcing contracts might reduce reluctance to GlobalGAP certification (which in principle is a contract between buyer and supplier). In many world regions, ongoing conflicts inhibit economic activity. We assume that an increase in conflict related deaths decreases certification and especially increases the likelihood of being completely left out of the GlobalGAP market.

Country-specific transaction costs are also affected by infrastructure conditions. Production for distant (domestic and international) markets requires the provision of good transport infrastructure and logistic services. Poorly developed roads reduce a countries competitiveness due to delayed procedures causing higher costs. Accordingly, producers are hypothesised to have lower incentives to adopt standards if adequate infrastructure conditions are absent. The geographic location also determines market access costs. Land locked countries are, thus, hypothesised to show a lower probability of certification. Additionally, advanced administrative systems facilitate proper documentation and plot-level traceability. A high degree of a country's ICT can, thus, support these processes and thereby lead to more certification (Neumayer and Perkins, 2005).

Finally, there are agricultural-specific sector policies that can help transformation towards high-value certified production. Existing public food standards, proxied by the Maximum Residue Limit (MRL), facilitate to meet private standard requirements which reduces initial investment costs. Thus, strong agricultural sector policies are hypothesised to increase the implementation of private food standards. In addition, farmers in countries with ISO membership face lower compliance costs, because some GlobalGAP requirements are based on ISO standards such as ISO 17025 or ISO 7002 (GlobalGAP, 2017). Furthermore, in some developing countries, donor support can be decisive to overcome high certification

[22] Alternatively, one could use governance indicators that are presumed to contribute to a well-functioning business-environment in a country. Since the 'World Governance Indicators' are highly correlated to the mentioned 'Doing-Business-Indicators', we abstain from using them additionally in this study.

fees, which helps to initiate the adoption process.[23]

### Confirmation phase

After the implementation phase, it follows the confirmation phase (4). There are recurring costs associated to the annual certificate renewal. At the macro level, we cannot identify new variables being specific to this process, but it is likely that richer farmers or those that are externally supported[24] can more easily conquer these high recurring costs. Thus, GDP per capita as well as bilateral financial flows to agriculture help to maintain and reinforce certification rates.

## D Model selection

As briefly described in Section 3.1, we conducted various specification tests to find the preferred model for the binary and count model specification, respectively. To start with, we compare a pooled model over a model with random effects in the logit specification. It is likely that the error terms within countries with observations over six years are correlated, in which case the random effects specification is superior to a pooled model. The estimated $\rho$ turns out to be close to one, which suggests that there might substantial residual outcome variation at the country-ID level. The post-estimation likelihood ratio test rejects the null hypothesis of $\rho = zero$ with a value of $\chi^2(1) = 391.80, p = 0.000^{***}$. Hence, we choose a random effects logit specification for RQ one. Furthermore, according to AIC test statistics, the random effects model (AIC=494.48) is superior to the pooled logit model (AIC=884.28).

We also conduct various specification tests of the (full) count data model following Gelman and Hill (2006) and using the DHARMa package in the statistical software R (Hartig, 2019). Results are displayed in Table D1. We go step by step, starting with a Poisson specification with and without random effects. We test for overdispersion, zero-inflation being a special case of overdispersion, as well as spatial and temporal autocorrelation. The statistical tests are underpinned by a graphical inspection of the behaviour of the residuals which can be found in Figures D1, D2, D3, D4 below.

Here, we simulate scaled (standardised) model residuals which are then plotted against fitted values, and against time and in space. In the QQ-plot (Figure D1) the model is deemed valid if the plot comes close to a straight line which is the case only for the two negative binomial regressions. Also the expected zeros should match the simulated zeros as seen in Figure D2 should match to negate problems of zero-inflation in the model. In Figures D3 and D4 residual are plotted against time and in two-dimensional space. There should be no clear trends or clusters if the model in valid model specifications.

[23] Trade policies, and the level of sectoral support by governments, such as consumer support estimates and, especially, producer support estimates, likely also play a role in shaping the general agricultural business environment. Due to missing data for many countries and/or years we cannot consider these factors in our analysis.

[24] However, some producers might as well drop out again if producer support ends and certification-induced productivity improvements were insufficient to stay in the market (Kersting and Wollni, 2012).

Table D1: Specification tests of count models

| | Poission | | Poission with RE | | NB with RE | | NB with RE and AR(1) | |
|---|---|---|---|---|---|---|---|---|
| | Test | p-value | Test | p-value | Test | p-value | Test | p-value |
| **Overdispersion** | 0.546 | 0.000 | 0.182 | 0.000 | 0.045 | 0.037 | 0.046 | 0.030 |
| **Zero-inflation test** | 3.827 | 0.000 | 0.616 | 0.000 | 0.979 | 0.766 | 0.977 | 0.716 |
| **Spatial autocorrelation** | 0.003 | 0.162 | 0.003 | 0.424 | 0.002 | 0.676 | 0.003 | 0.395 |
| **Temporal autocorrelation** | 2.073 | 0.249 | 1.957 | 0.500 | 2.026 | 0.680 | 1.953 | 0.457 |
| **AIC** | 820,065 | | 36,327 | | 7,098 | | 7,037 | |

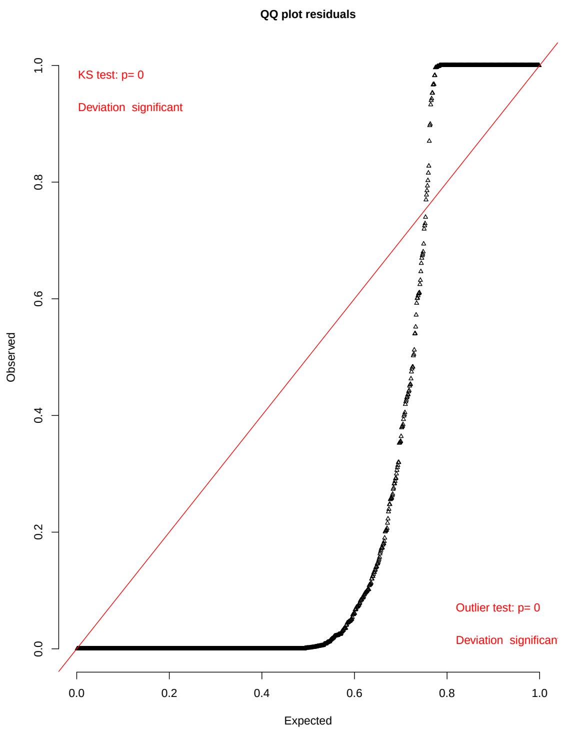
Note: RE = random effects; AR(1) = temporally correlated error structure; Overdispersion test: Kolmogorov-Smirnov test with H0 = equidispersion under fitted model; Zero-inflation test: ratio of true and expected zeros with H0 = no zero inflation under fitted model; Moran's I test for spatial autocorrelation with Ho = no spatial autocorrelation under fitted model; Temporal autocorrelation: Durbin-Watson test with Ho = no temporal autocorrelation under fitted model.

Given that both Poisson specifications suffer from overdispersion, we move to the negative binomial specification with random effects. According to the Kolmogorov- Smirnov test statistics, including the dispersion parameter in the regression improves the model, but does not entirely solve overdispersion. As Figures D1 show, the negative binomial model with random effects substantially improves the model in this respect. The negative binomial model also performs much better with respect to zero-inflation which can be understood as a special case of overdispersion. While the Poisson estimator indicated zero-inflation, the negative binomial estimator does not (see Table D1 and Figure D2. This confirms our in Section 3.1 stated hypothesis that all zeros are 'true' zeros, and hence the absence of two different DGP for observed zero certificates.

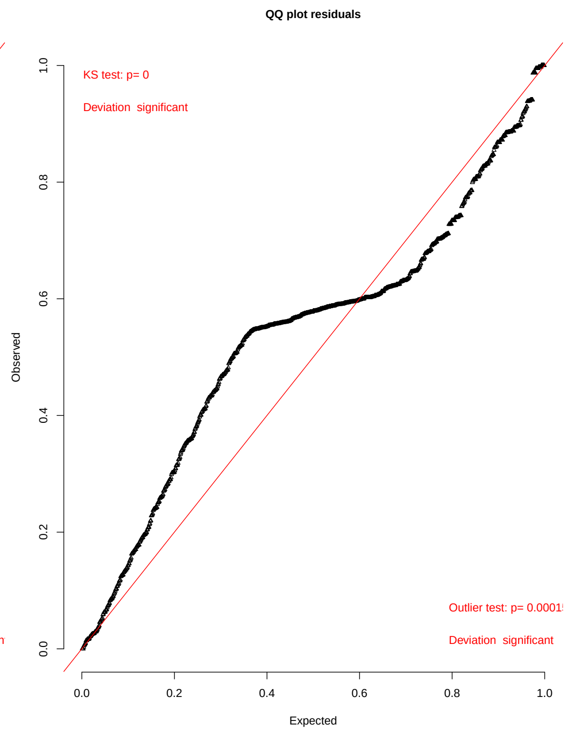
Finally, we estimate a negative binomial specification with an AR(1) error structure to account for temporal autocorrelation. According to statistical specification test results, neither of the four models presented suffer from spatial nor temporal autocorrelation. Nevertheless, we choose a negative binomial specification with random effects and AR(1) error structure as our preferred model due to various factors: First, plotting residuals against time and space (see Figure D3 below) points towards temporarily correlated residuals in the Poisson specification. Second, it shows the lowest AIC test statistic. Lastly, a likelihood ratio test suggests that the model with random effects and AR(1) error structure is superior over the nested negative binomial model with solely random effects: $\chi^2(2) = 64.079, p = 0.000^{***}$.[25]

After selecting an appropriate model type, we refine the specification towards a more parsimonious model. To do so, we omit those variables with z-values<1 in the unrestricted models of both the logit and negative binomial models. For both models, the null hypothesis of the likelihood ratio tests cannot be rejected. This confirms that for both RQs the respective parsimonious model is appropriate. The test statistic for the logit model is $\chi^2(8) = 3.51, p = 0.899$. The test statistic for the negative binomial model is $\chi^2(9) = 3.60, p = 0.936$. The results of the final unrestricted and final restricted model is

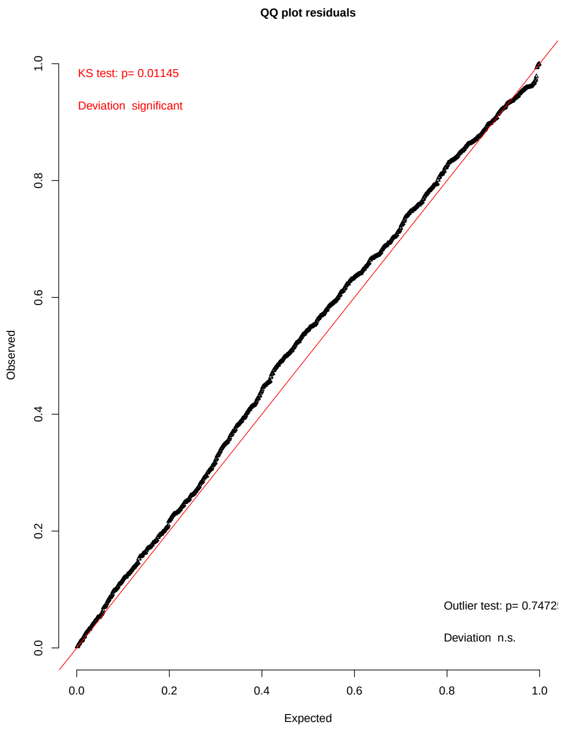
[25] Equivalently all other nested models were tested. Results can be obtained from authors upon request.



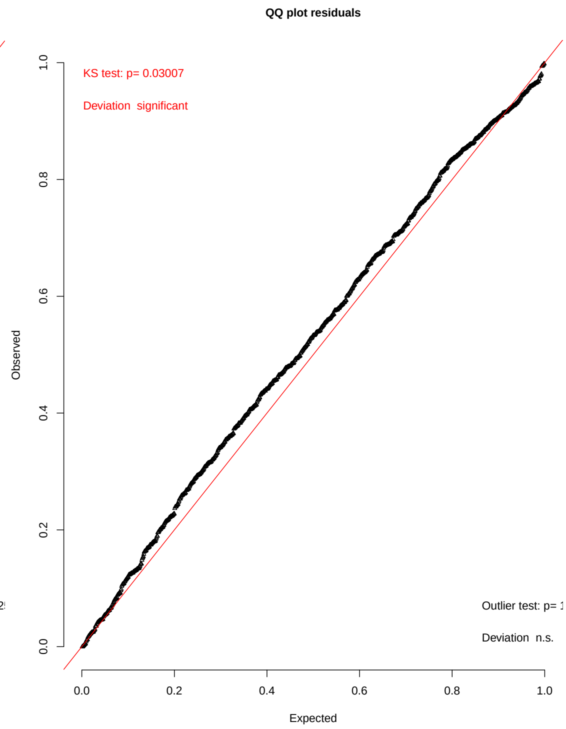

(a) Pooled Poisson




(b) Poisson random effects




(c) Negative binomial random effects




(d) Negative binomial random effects with AR(1)

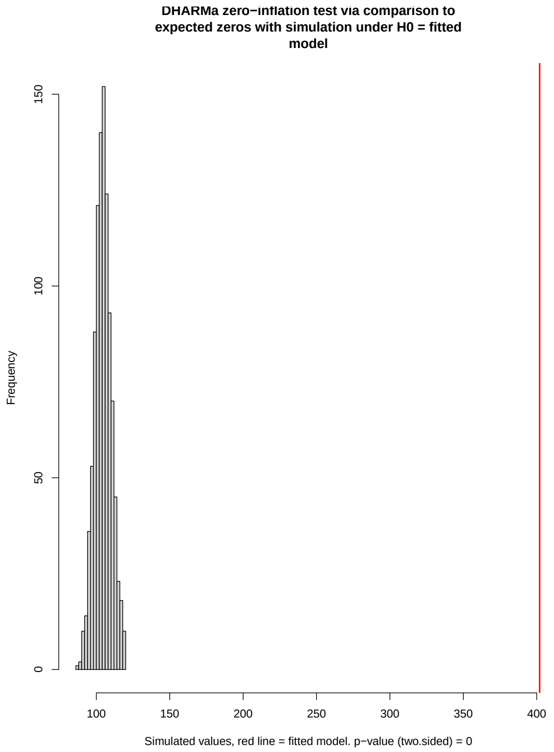
Figure D1: Specifcation test of overdispersion
Source: Own elaboration based on DHARMa package in R (Hartig, 2019).

presented in Table D2.

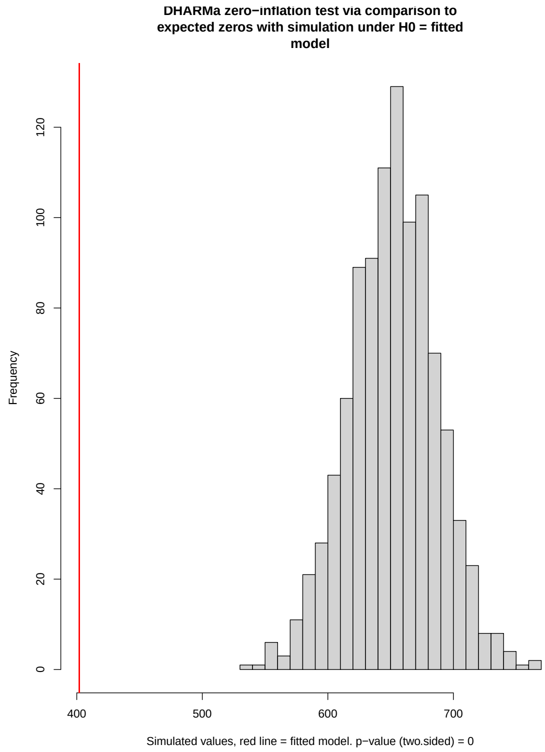
Table D2: Coefficient estimates of the final unrestricted and restricted model

| | Unrestricted model | | Restricted model | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| VARIABLES | RQ one, Logit | RQ two, NB | RQ one, Logit | RQ two, NB |
| GlobaGAP neighbouring countries (lag) | 2.314* | 0.177 | 2.200* | 0.126 |
| | (1.328) | (0.154) | (1.292) | (0.150) |
| Export Share to EU (lag) | 0.363 | 0.286* | | 0.254* |
| | (0.403) | (0.146) | | (0.143) |
| Fruits and vegetables area share (lag) | -1.075 | 0.06 | -1.234 | |
| | (0.779) | (0.279) | (0.764) | |
| Agricultural capital stock (lag) | -0.551 | -0.047 | | |
| | (0.696) | (0.205) | | |
| Crops export share (lag) | 0.806* | 0.381** | 0.755* | 0.372** |
| | (0.445) | (0.168) | (0.406) | (0.167) |
| Inflation rate | -0.249 | 0.021 | | |
| | (0.288) | (0.09) | | |
| Exchange rate | 0.185 | 0.077 | | |
| | (0.381) | (0.161) | | |
| Population | | 0.18 | | |
| | | (0.271) | | |
| Doing Business indicator | 1.163* | 0.796*** | 1.141* | 0.821*** |
| | (0.654) | (0.25) | (0.635) | (0.247) |
| Maximum Residue Limits | 2.526* | 0.041 | 2.412 | |
| | (1.416) | (0.108) | (1.543) | |
| Development flows to agriculture | -0.138 | -0.299*** | | -0.302*** |
| | (0.194) | (0.083) | | (0.082) |
| Conflict related deaths | -0.401 | 0.063 | | 0.062 |
| | (0.444) | (0.058) | | (0.057) |
| Urbanisation | 1.259* | 0.515 | 1.394* | 0.635* |
| | (0.718) | (0.405) | (0.735) | (0.357) |
| Road density | -0.307 | 0.952*** | | 1.005*** |
| | (0.643) | (0.329) | | (0.320) |
| Fixed broadband subscriptions | 2.502** | 0.519** | 2.572*** | 0.524*** |
| | (1.005) | (0.21) | (0.935) | (0.200) |
| GDP per capita | -2.141*** | 0.568 | -2.398*** | |
| | (0.758) | (0.67) | (0.712) | |
| GDP per capita | | -0.608 | | |
| | | (0.473) | | |
| Colonial history with EU6 (dummy) | 2.399* | 1.016 | 2.705* | 0.937 |
| | (1.302) | (0.672) | (1.470) | (0.660) |
| ISO membership (dummy) | 3.564*** | 0.398 | 3.485*** | 0.395 |
| | (1.005) | (0.278) | (1.065) | (0.276) |
| landlocked (dummy) | -0.190 | -0.233 | | |
| | (1.742) | (0.794) | | |
| Observations | 985 | 985 | 985 | 985 |
| Overdispersion parameter | | 6.23 | | 6.3 |
| $\rho$ | | 0.932*** | | 0.933*** |

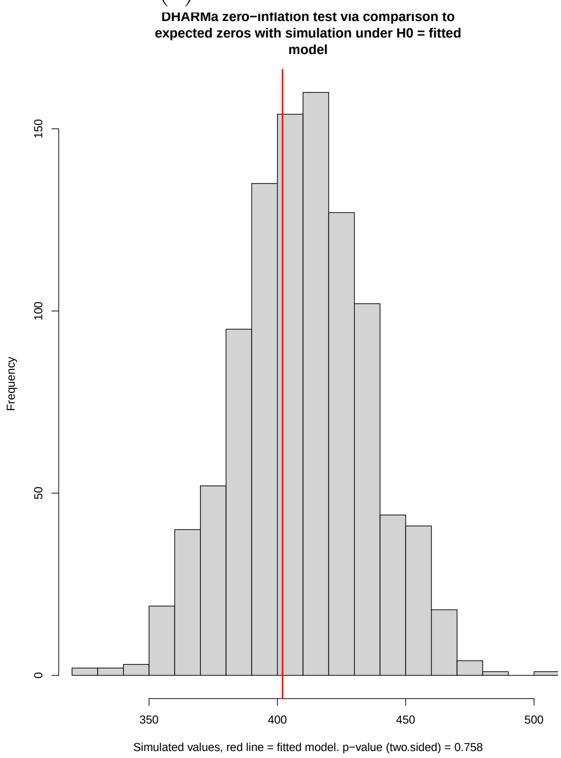
Note: *** p<0.01, ** p<0.05, * p<0.1; Standard errors given in parentheses; All models include random effects; RQ = Research question; All covariates are z-transformed for normalisation purposes; Restricted models omit those variables with z-values<1 in the corresponding unrestricted models; Logit model includes cropland as control variable; NB = negative binomial models include Cropland as an offset variable in logarithm, thus interpretation of results should be 'number of certified farmers per hectare'; population variable omitted in unrestricted logit model due to high collinearity with cropland control.



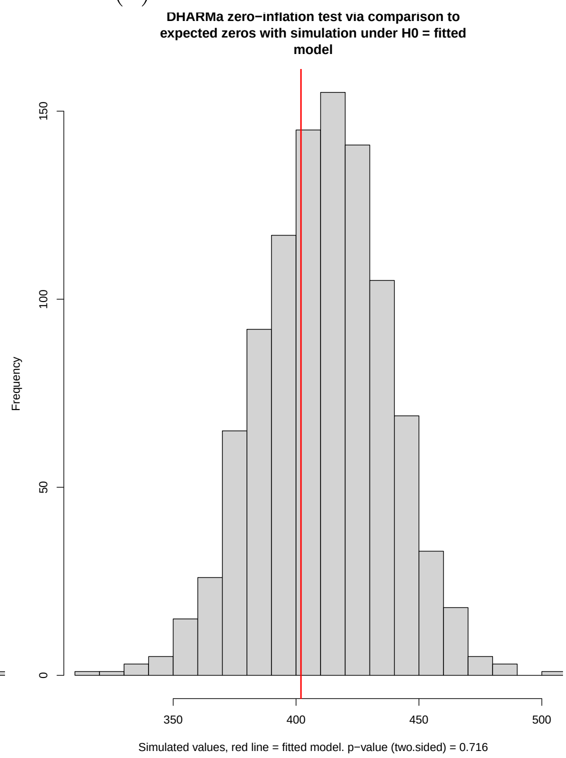

(a) Pooled Poisson




(b) Poisson random effects

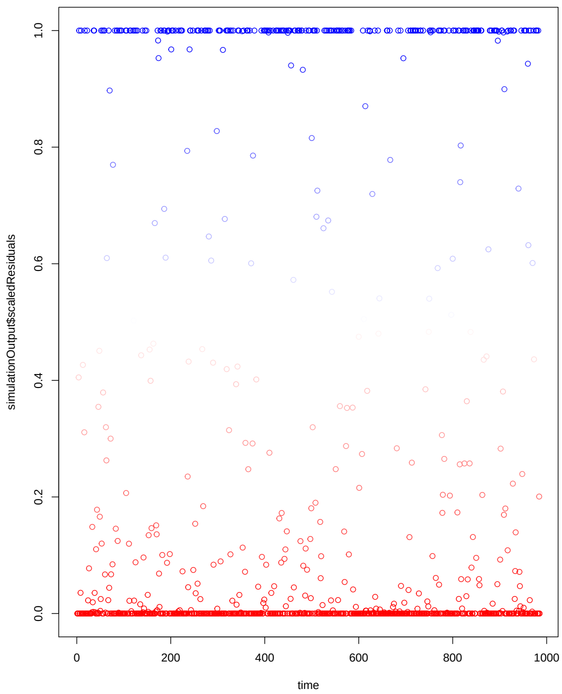



(c) Negative binomial random effects

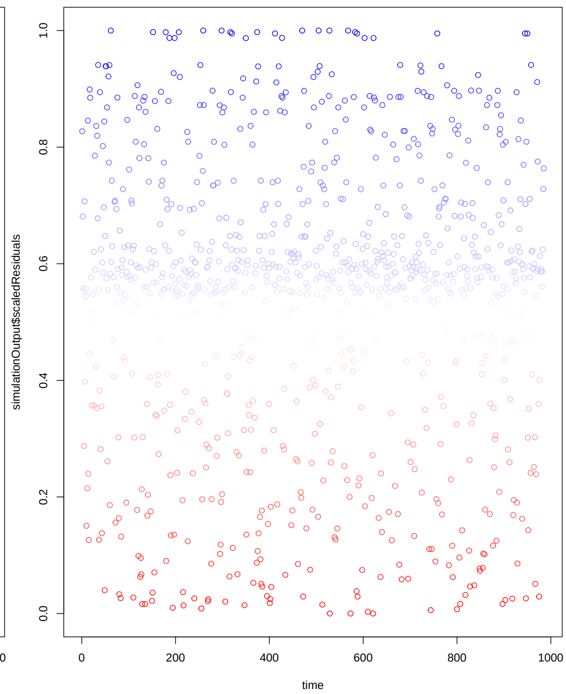



(d) Negative binomial random effects with AR(1)

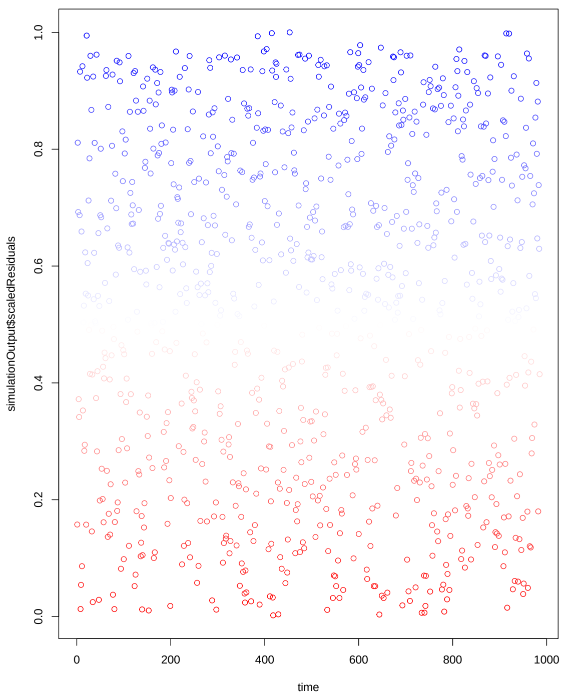
Figure D2: Specifcation test of zero-inflation
Source: Own elaboration based on DHARMa package in R (Hartig, 2019).



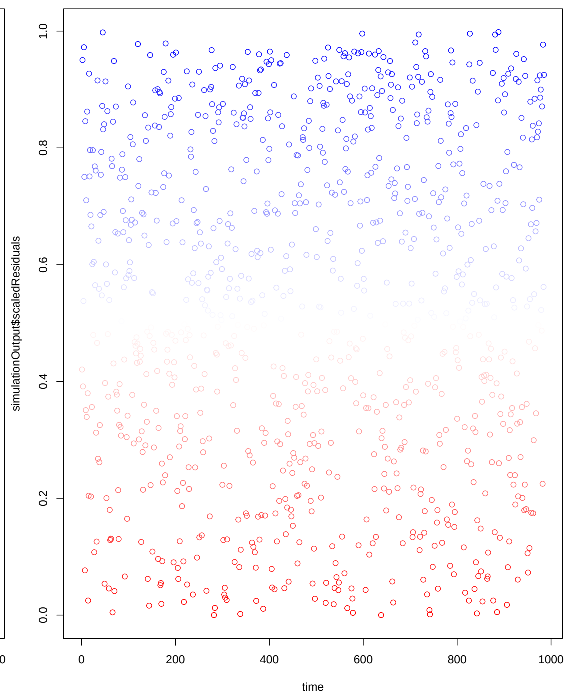

(a) Pooled Poisson




(b) Poisson random effects

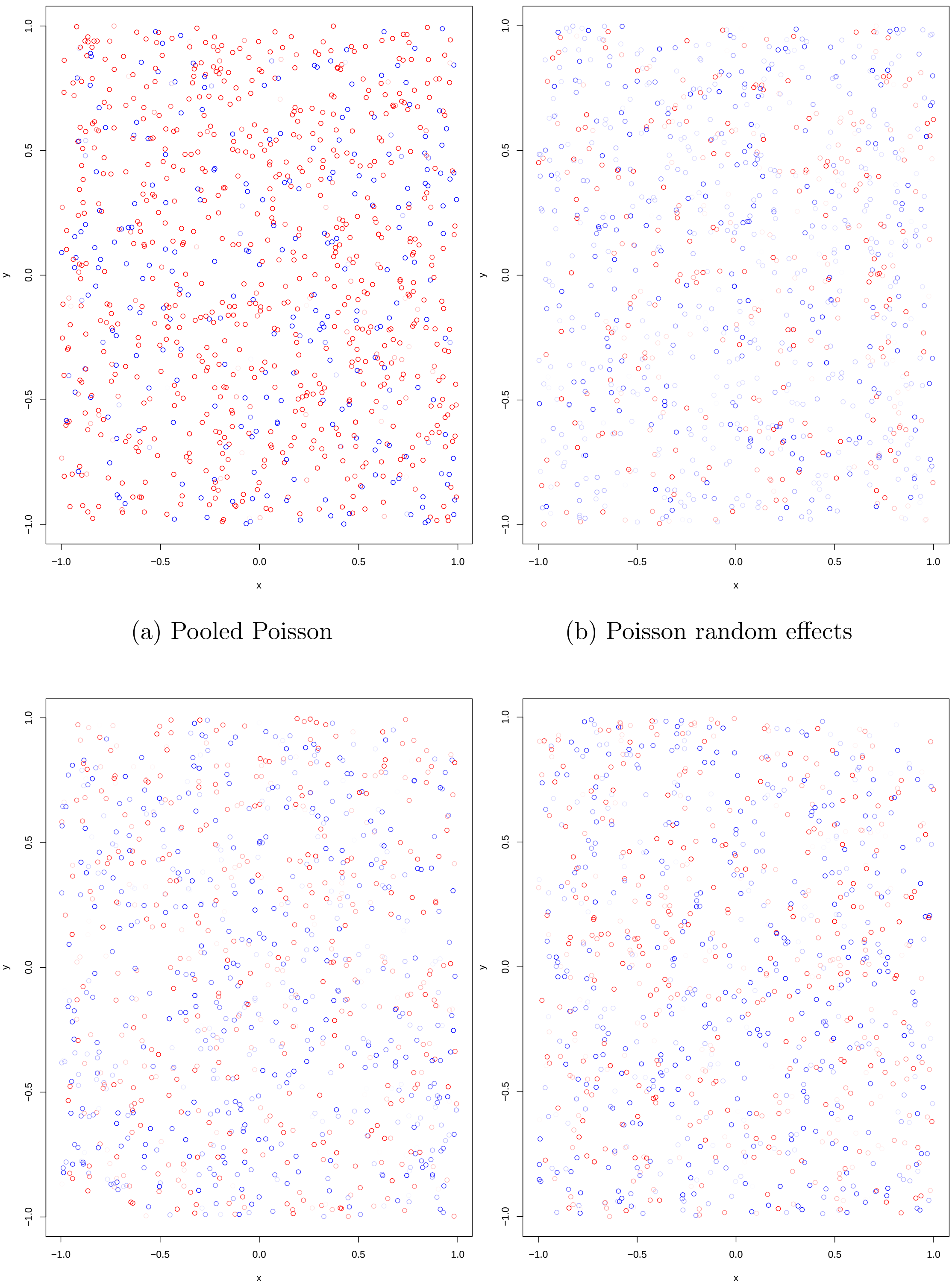



(c) Negative binomial random effects




(d) Negative binomial random effects with AR(1)

Figure D3: Specifcation test of temporal autocorrelation (Moran I test)
Source: Own elaboration based on DHARMa package in R (Hartig, 2019).




(a) Pooled Poisson

(b) Poisson random effects

(c) Negative binomial random effects

(d) Negative binomial random effects with AR(1)

Figure D4: Specifcation test of spatial autocorrelation
Source: Own elaboration based on DHARMa package in R (Hartig, 2019).

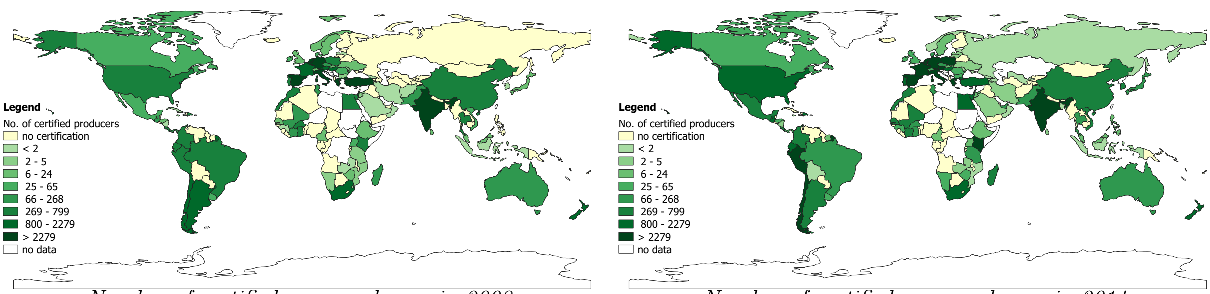
# E Countries

Table E1: List of countries included in analysis

| | | | |
|---|---|---|---|
| Afghanistan | Denmark | Kyrgyzstan | Saint Kitts and Nevis |
| Albania | Djibouti | Lao People's Dem. Rep. | Saint Lucia |
| Algeria | Dominica | Latvia | St. Vincent and the Grenadines |
| Angola | Dominican Republic | Lebanon | Samoa |
| Antigua and Barbuda | Ecuador | Lesotho | Sao Tome and Principe |
| Argentina | Egypt | Liberia | Saudi Arabia |
| Armenia | El Salvador | Lithuania | Senegal |
| Australia | Equatorial Guinea | Luxembourg | Seychelles |
| Austria | Estonia | Madagascar | Sierra Leone |
| Azerbaijan | Ethiopia | Malawi | Singapore |
| Bahamas | Fiji | Malaysia | Slovakia |
| Bahrain | Finland | Maldives | Solomon Islands |
| Bangladesh | France | Mali | South Africa |
| Barbados | Gabon | Malta | Spain |
| Belarus | Gambia | Mauritania | Sri Lanka |
| Belgium | Georgia | Mauritius | Suriname |
| Belize | Germany | Mexico | Swaziland |
| Benin | Ghana | Micronesia (Fed. States of) | Sweden |
| Bhutan | Greece | Moldova, Rep.of | Switzerland |
| Bolivia | Grenada | Mongolia | Tajikistan |
| Botswana | Guatemala | Morocco | Tanzania, United Rep. of |
| Brazil | Guinea | Mozambique | Thailand |
| Brunei Darussalam | Guinea-Bissau | Namibia | Togo |
| Bulgaria | Guyana | Nepal | Tonga |
| Burkina Faso | Haiti | Netherlands | Trinidad and Tobago |
| Burma | Honduras | New Zealand | Tunisia |
| Burundi | Hungary | Nicaragua | Turkey |
| Cambodia | Iceland | Nigeria | Turkmenistan |
| Cameroon | India | Norway | Uganda |
| Canada | Indonesia | Oman | Ukraine |
| Cape Verde | Iran | Pakistan | United Arab Emirates |
| Central African Republic | Iraq | Panama | United Kingdom |
| Chad | Ireland | Papua New Guinea | United States of America |
| Chile | Israel | Paraguay | Uruguay |
| China | Italy | Peru | Uzbekistan |
| Colombia | Ivory Coast | Philippines | Vanuatu |
| Comoros | Jamaica | Poland | Venezuela |
| Congo | Japan | Portugal | Viet Nam |
| Costa Rica | Jordan | Qatar | Yemen |
| Cuba | Kenya | Romania | Yugoslavia, former |
| Cyprus | Korea | Russian Federation | Zambia |
| Czech Republic | Kuwait | Rwanda | Zimbabwe |

# F Descriptives

Figure F1: Spread of GlobalGAP certified producers worldwide




*Number of certified crop producers in 2008* *Number of certified crop producers in 2014*

As already briefly discussed in section A, and shown in more detail in Figures F1 and F2, the speed and geographical spread of GlobalGAP certification rates varies vastly across the world. Europe is the continent where countries have highest certification rates in all periods. This is unsurprising, as GlobalGAP is a European retailer standard and most farmers predominantly supply European markets. With more than (17,500) 30,000 certified Spanish farmers and more than (7,000) 20,000 certified Italian farmers in (2008) 2014, these two countries increased their global certified market share from about 30% in 2008 to almost 38% in 2014. Most other European countries also show comparatively high GlobalGAP certification rates (above 1,000 certified farmers per country), but numbers grow at a slower pace. Figure F1 also shows that GlobalGAP plays an increasingly role outside of Europe. Some African or Latin American countries show comparatively high certification rates with a continuously increasing trend. For example, Kenya's number of certified farmers grew four-fold to reach about 2,400 by 2014 and Peru's numbers even increased 12-fold to reach more than 6,400 farms by 2014. Even the smaller and poorer country Senegal showed a remarkable increase in certification rates growing from only a handful in 2008 to reach 290 certified farmers in 2014. By contrast, large countries, like China or Russia show very low or literally no certification of GlobalGAP over the entire period of investigation. A reason may be that they are net food importers and are not dependent on delivering the core GlobalGAP markets. In the Pacific region, only New Zealand plays a major role in the GlobalGAP market, likely due to its high apple production for the European market. The following section disentangles the driving forces behind this uneven spread of GlobalGAP.

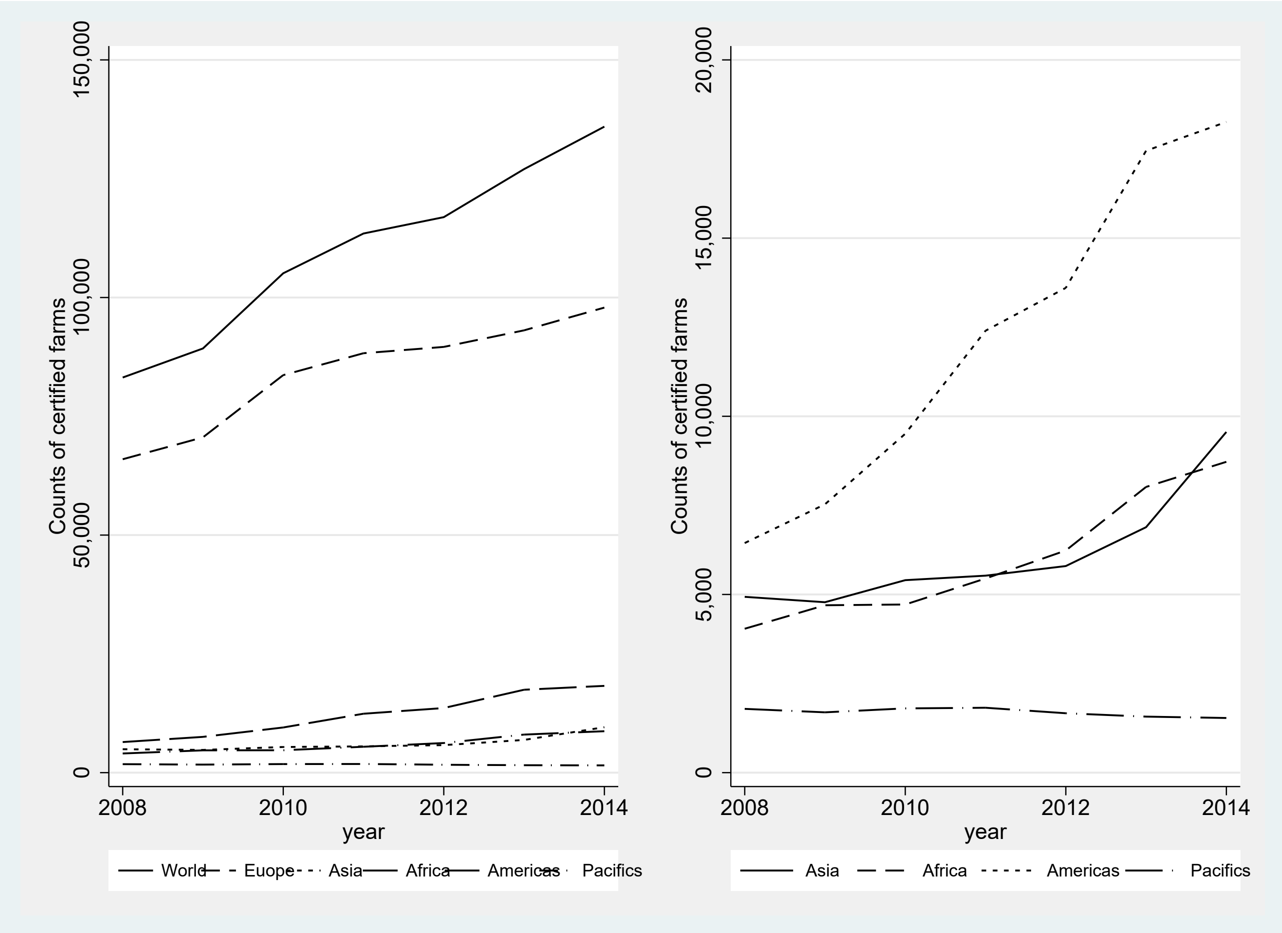



Figure F2: Trend in certification rates between 2008 and 2014 in different world regions. (Right panel without Europe and global total for better readability.)
Source: own elaboration based on data by GlobalGAP