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Quantifying the effects of non-tariff measures on African agri-food exporters

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ABSTRACT

Non-tariff measures (NTMs) such as technical barriers to trade (TBT) and sanitary and phytosanitary measures (SPMs) have become new trade barriers, which is contrary to these measures' original intention to correct market failure and adverse selection of free markets and to protect the people, animals, plants and the environment in importing countries. For different African agri-food exporters, the compliance with NTMs has varied impacts. For relatively comprehensive exporters, NTMs are helpful in upgrading their food production, increasing agricultural input and promoting sustainable development. For countries with relatively less diversified crops, however, such compliance has huge negative effects such as rise in trading costs and reduction in exporting profits. In an attempt to address the above-mentioned issue using the VARMA(X) model and intervention analysis, this paper first examines agri-food trade records between African countries and analyses NTMs, which reveals the mechanisms of NTMs. Second, defining impacts of NTMs as the difference between the estimated agri-food trades' volumes between African countries from 1996 to 2013 without NTMs and the actual volumes, the paper shows that NTMs have in fact led to a significant reduction in agri-food trade volume in Africa. Finally, based on these empirical econometrical results, the authors suggest possible solutions, including strengthening external assistance, improving trade liberalisation and accelerating economic integration.

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1. Introduction

Non-tariff measures (NTMs) refer to all barriers other than tariffs that are developed by a nation or a union to regulate, manage and control international trades in order to restrict imports to some degree so that the domestic industry can be protected. These measures can be divided into direct and indirect ones. Direct measures, such as permissions and quota systems, set limits on the numbers or sums of importing merchandise. Indirect measures, such as sanitary and phytosanitary measures (SPMs) and technical barriers to trade (TBT), are restrictive rules, principles and measures set by importing nations, and spill-over ones—policies that are not supposed to cope with trading issues but have some side effects on imports. Disdier and Marette (2010) pointed out that tariffs have been reduced because of the negotiations made in recent years so that NTMs are playing an increasingly important role in functioning as new barriers in international trade. The Organisation for Economic Co-operation and Development (OECD) also claims that NTMs are attracting attention

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all over the world because they can distort international trade from an economic viewpoint and become more harmful than tariffs. Herghelegiu (2017) reckoned that NTMs reflect protectionist forces, especially those that are concerned with the World Trade Organization (WTO). There is no evidence yet that protectionism is the driving force of the other measures, which indicates their determinants may be related to legitimate goals such as consumer health and safety. Although NTMs were developed with the original intention of protecting domestic industries and benefiting the process of sustainable development, they have also given rise to new trade barriers that have a negative impact on developing countries. Moreover, according to the *Oxford English Dictionary* (20 volume set), "measure" refers to "an official action that is done in order to achieve a particular aim", while "barrier" means "a problem, rule or situation that prevents one from doing something or that makes something impossible". The Organisation for Economic Cooperation and Development (2006), or OECD, defines non-tariff barriers as all measures other than normal tariffs which have the effect of restricting trade between nations, and claims that NTBs such as high *ad valorem* fees add heavy costs to low- and middle-income countries. In other words, the tax burden increases as the total trade volume increases, therefore deterring developing countries from exporting more products and affecting both South–South and North–South trade. Moreover, some NTMs such as SPMs and TBT set specific standards to hold importing goods and services from developing countries and thus have a negative influence on developing countries' exports. Clark and Bruce (2006) confirmed that barriers created by NTMs mainly target parties applying them, while Bratt (2017) uses the regression on the decomposed tariff levels to reveal the heterogeneous effects of NTMs on nations: nations with higher GDP are able to exert their influence via NTMs on the ones with lower GDP. The present study aims to explore the mechanism of how NTMs affect the trade of both developed and developing countries in Africa.

Studies on the negative effects of NTMs are abundant. Li and Beghin (2014) proposed aggregation indices of NTMs and conclude that the protectionism behind them varies from country to country. The study of Cadot and Gourdon (2016) suggests that deep-integration clauses can mitigate the price-raising effect of NTMs but the solutions remain largely unknown. Felbermayr and Jung (2011) agreed that although TBT liberalisation does facilitate the openness of industries, the incremental trade implicit costs increase as well. Despite these findings, however, existing literature usually focuses directly on the difference between trade volumes before and after NTM implementation to assess their influences and may have neglected the mechanism underlying NTMs. For example, Peterson *et al.* (2013) verified the negative impact of NTMs on the trade of fresh fruit and vegetable products and discovered that the experience of exporters can reduce the negative influence, without mentioning how NTMs affect the trade exactly. Wood *et al.* (2017) analysed TBT and SPMs associated with Korean exports to China using the gravity model, which also mainly focuses on whether the impacts on trades between two countries are positive or not. Sequentially, the potential solutions could not be evaluated quantitatively. On the other hand, the methodologies proposed in this study, using econometrical models (dynamical regression model, intervention model and exogenous variables in time series) to highlight the influencing mechanisms of NTMs and evaluate the proposed potential solutions, provide more convincing empirical results for both academic researchers and market regulators.

Because few studies focus on the issue of how NTMs can impact the trades among African countries and how the mechanism of NTMs implemented in Africa can be quantified, we made an attempt to look into it in the present study. We first classify African nations into developed and developing countries, using indicators such as agricultural science and technology indicators (which measure the input and capabilities of agricultural science and technology research in low- and middle-income countries), producer price index of agricultural products (which measures the cost of agricultural production in the region), and CO^2 emissions/output value of agricultural production (which measures the area's state of sustainable development). Then, the mechanisms of positive NTMs and those of adverse NTMs would be explored, respectively, using a dynamical regression model. Second, a vector autoregressive moving average (VARMA) model and an intervention model would be integrated to quantitatively study NTMs' effects on agri-food trading volumes from 1996 to 2013, which is defined as the difference between the actual trading volumes and the predicted ones by the models, under the assumption that there are no NTMs in effect for the same time period. Finally, using the coded potential solutions including external assistance, trade liberalization, and economic integration as exogenous variables, the vector autoregressive moving average with eXogenous variables (VARMA(X)) model would be proposed to evaluate possible combinations of solutions to alleviate the adverse effects of NTMs. Liu *et al*. (2015) discussed the advantages of VARMA(X) model, as it can build a dynamical framework for the issue that is worked on and take exogenous variables into consideration. The methodology introduced in this study can estimate the factors in linear time series model and help to identify the most effective out of the three solutions that we propose by testing the significance of their effects.

The rest of this paper is organised as follows. Section 2 reviews related works. Section 3 introduces the econometrical models, such as dynamical regression, VARMA(X), and intervention models. Section 4 presents the empirical results and Section 5 concludes the paper.

2. Literature review

2.1 Factors influencing trade among African nations

Plenty of scholars are keeping track of the agricultural trade in Africa. Weeks and Subasat (1998) proposed that increasing agricultural trade are feasible between eastern and southern African nations if the dissimilarities in their consumption and production structures could be appropriately addressed. Using a multi-sector equilibrium model of a small open economy calibrated to represent a "typical" African country Kose and Riezman (2001) put forth a theory that trade shocks contribute to half of the economic fluctuations in aggregated output in Africa. Otsuki (2001) and Otsuki *et al*. (2001) believed that new harmonised standard set by the EU negatively influences the export of cereals, dried fruits, and nuts from Africa. Using point and interval estimation Cashin *et al*. (2004) revealed that the effects of trade shocks on different African nations in different periods vary from one economy to another and result in the evident lack of similarities among them. Gebrehiwet *et al*. (2007) suggested that stringent phytosanitary standards (SPSs) have an evident constraint on South African food trades. Scheepers *et al*. (2007) also demonstrated that SPSs cut the revenue from exports by US$15.27million. Trade facilitation, among other standard factors, was analysed by Iwanow and Kirkpatrick (2009) to believe that advance in border policies yields a higher return in terms of increasing manufacturing export performance in African countries than in the rest of the world. Collier and Venables (2008) found that the recent implementation of the African Growth and Opportunity Act encourages large manufacturing export supply in Sub-Saharan Africa. By comparing the trade policies in the EU with NTMs with those in Africa, Kareem (2011) concluded that the latter affects exports from Africa more significantly. Again, using the gravity equation and monopolistic competition trade model, the study of Raimondi and Olper (2011) indicated that trade liberalisation will increase food exports from high-income countries and therefore decrease the ones from developing countries. Santeramo and Cioffi (2012) confirmed that the entry price scheme has made a difference in avoiding or deterring low priced imports from main EU partner countries, including major African agri-food exporters.

2.2 Previous studies on the impacts of NTMs

Thornsbury *et al*. (1997) claimed that the causes of TBT might have become non-transparent means of protection for domestic industries with growing demands in the developed world for enhanced food safety and for protection of Earth's resources. Disdier and Marette (2010) argued for the idea that a stricter standard of NTMs will lead to an increase in both domestic and international welfare based on the econometric gravity equations. On the other hand, Disdier *et al*. (2008) found that, also using the gravity model, the serious impact of TBT is not on the agricultural trades among African OECD countries but on the European imports from developing countries. Disdier *et al*. (2015) confirmed that the trade between southern and northern African countries expands at the cost of their reducing trade volume with their non-bloc southern partners. Dal Bianco *et al*. (2016) claimed that friction in the world wine trade remains unchanged during the past 15 years as the growing technical barrier always compensates the decreasing tariff. A cost function has been used by John *et al*. (2012) to confirm the complex relationship among trade, welfare, regulations, and NTMs. Tudelamarco *et al*. (2014) find growing interests in NTMs when agricultural tariffs shrink. Also in line with this research are Disdier and Marette (2010). Beckman and Arita (2017) claimed that NTMs, especially SPMs and tariff-rate quotas, are blocking agriculture trades and the interaction among them will restrict trade liberalisation. However, Peterson *et al*. (2013) held that although SPMs can reduce trades in most cases, the real restrictions will decrease dramatically as the experiences of exporters increase and will ultimately disappear when such experiences reach a given threshold. Wood *et al*. (2017) suggested in a research of trades between South Korea and China that the SPMs adopted by China, estimated by both the coverage ratio and the frequency index are positively related to agricultural exports of South Korea. However, Chinese TBT measures estimated by coverage ratios restrain Korean manufacturing exports and exports as a whole. Blignaut *et al*. (2009) claimed that conservation agriculture should be increasingly promoted in Africa, as most parts of Africa are made up of climate-sensitive areas (like South Africa), suffering a lot from the great uncertainty of output in total production.

NTMs work in a different way from tariffs in many cases. Bianco (2016) investigated the world wine trade and finds that SPMs measures do not seem to be obstacles for exports while technical barriers have a different impact on trades. The declining trend in tariffs is compensated for by more stringent technical barriers, which, on the whole, have not changed the frictions in the world wine trade over the past five years. According to Tudelamarco *et al*. (2014), there are also dynamical substitution statistical relationships between NTMs and tariffs, providing room for the ongoing harmonisation in agricultural trades.

The impacts of NTMs on African countries are summarised in Table 1.

Table 1. Impacts of NTMs on African countries.

Year	Nation/Region	Measure	Impact	Reference
1992–2012	ECOWAS	Regional trade arrangements (RYA)	Welfare-improving for the members as a group, for the majority of the individual member countries, and for some third countries	Deme, M. and Ndrianasy, E.R. (2017)
1995–1999	South Africa	SPMs	South Africa would have gained an estimated additional amount of US $69 million per year	Gebrehiwet, Y., Ngqangweni, S. and Kirsten, J.F. (2007)
	Africa	Non-tariff barriers from trade policies in EU	Export performance of African exports is hampered	Kareem, O.I. (2011)
	South Africa	Foreign technical requirements	Export delays associated with meeting foreign technical requirements	Koch, S.F. and Peet, M.A. (2007)
1989–1998	Chad, Egypt, the Gambia, Mali, Nigeria, Senegal, South Africa, Sudan, Zimbabwe	A new harmonised aflatoxin standard set by the EU	A negative impact on African exports of cereals, dried fruits and nuts to Europe – decrease these African exports by 64% or US$670 million	Otsuki, T., Wilson, J.S. and Sewadeh, M. (2001a)
1989–1998	Chad, Egypt, the Gambia, Mali, Nigeria, Senegal, South Africa, Sudan, Zimbabwe	A new harmonized aflatoxin standard set by the EU	1. A 10% tighter aflatoxin standard in European countries will reduce edible groundnut imports by 11% 2. A new European Union regulation on aflatoxins will result in a trade flow that is 63% lower than when the Codex Alimentarius international standards are followed	Otsuki, T., Wilson, J.S. and Sewadeh, M. (2001b)
1998–2007	Morocco (with Argentina, Turkey and China)	Entry price scheme (EPS) for fresh fruit and vegetables	Isolating European Market	Santeramo, F. G. and Cioffi, A. (2012)

2.3 Models applied in present literature and this paper

VARMA (X) has been introduced in this field by various literatures and proved correct for this paper's research target. Asche *et al*. (2017) demonstrated the mechanism by which environmental shocks during biological production can result in extreme price fluctuation. Ordinary least squares estimation and seawater temperature deviations are adopted to estimate the exogenous supply movements and the autoregressive moving average (ARMA*)* time series model is applied to evaluate real prices. Based on the stress test framework, Liu *et al*. (2015) used a non-stationary Markov chain model and a VARMA with exogenous variables coupled with a logistic function (VARMA(X)-L) to analyse and predict the stability of a retail mortgage portfolio. Näätänen (2015) applied VARMA(X) to a regression analysis and discovers that institutional stickiness has a more remarkable impact on social welfare than capital flow in most of the samples observed. Efromovich (2014) invented an adaptive estimation for a class of spectral densities which include classical causal autoregressive moving-average time series. The theory shows how missing mechanism can affect estimation and the penalty that it exerts on risk convergence. Thornton and Chambers (2017) studied the estimation and expression problem of mixed continuous time ARMA systems of orders *p*, *q*.

A diverse range of factors appear to help cope with studies on exporting. Gutierrez *et al*. (2015) added factors including the logarithm of export prices quoted in US dollars, the wheat stock-to-use ratio computed as the fraction of the stocks to total consumption, fertiliser price, the exchange rate and the index of consumer food prices into their study of wheat export price. The study of Götz *et al*. (2016) focuses on wheat export in Russia and Ukraine but aims to figure out the impact of domestic wheat price on wheat export controls. Sanjuán-López and Dawson (2015) applied GDP, agricultural and non-agricultural exports in constant local currency units to panel Z-LMC test to explore agricultural exports and economic growth in developing countries. Baiardi *et al*. (2014) considered the relevance of relative prices and world income as factors of food exports for the top trading countries over the period of 1992 to 2012. Newman *et al*. (2016) proposed that a different policy stance in Vietnam prompts its exporting and therefore leads to the rise in national economy. Vietnam's per capita income and structural characteristics resemble that of many African economies only 20 years ago. Xiong (2017) explored the relationship between regional trade agreements (the Trans-Pacific Partnership and the Regional Comprehensive Economic Partnership) and tea exports from Vietnam.

In this study, we adopt factors including PPI, ASTI, government investment and fertiliser use, which can evaluate exporting status of each nation from various dimensions and describe them in a more detailed way along with VARMA(X) model. Some other factors are also taken into consideration but are not significant in empirical results.

3. Methodology

In this section, the fundamentals of the quantitative methods would be presented. As a preliminary step, principal component analysis and clustering analysis are introduced to divide African countries into different groups. The influencing mechanisms of NTMs (which will be very similar in one group but very different between groups) are going to be studied later. Section 3.1 also introduces the dynamical autoregressive model for estimating a time serial of the parameter β_j, which would be used for selecting the most representative indicators and tracking the structure changes from NTMs' impacts. The statistical method for the significance test of the nulls hypothesis, the means of different groups, which is used for selection, will be briefly described in the Appendix. The mean of groups is the mean of the indicator values before/after the implementation of NTMs in all African countries. As a result, NTMs' heterogeneous mechanisms on developed and developing African countries could be ultimately understood. Section 3.2 provides the time serials models based on a vector autoregressive moving average (VARMA) model and an intervention model, in which the effects of NTMs are approximated as the differences between the predictions from the VARMA model (the model is estimated with the exporting values data before the implementation of NTMs for each country and therefore the prediction from the model could be deemed as the simulated trading values free of NTMs) and the predictions from the intervention model (the model is fed with the data with actual exporting value data) with NTMs' interference being considered. Furthermore, one extension of the VARMA model is VARMA with eXogenous variables model which is to evaluate the solutions, such as strengthening external assistance, improving trade liberalisation, and accelerating economic integration, with the solutions coded as exogenous variables.

3.1 Country clustering and dynamical autoregressive models

3.1.1 Country clustering

We obtained 55 years of data from 30 countries in Africa from the FAO database. These data are multi-dimensional panel data and the structure is complicated. There are 30 research samples (countries). Each sample has p indicators $\{X_1, X_2, \ldots, X_p\}$. The length of time is T, and $x_{ij}(t)$ indicates the value of the jth indicator of the ith sample (country) at time t.

Based on this data feature, we first performed a principal component-cluster analysis of all data in African countries. The method uses principal component analysis to construct an annual comprehensive index and then clusters the comprehensive indicators. Xiao *et al.* (2009) conducted principal component analysis on cross section data of multi-indicator panel data at time t, constructed a comprehensive index of multi-indicator panel data at time t–F_{nt}:

$$F_{nt} = \sum_{s=1}^{p} \alpha_t^s X_{nt}^s, \quad n = 1, 2, \ldots N \tag{1}$$

and obtained the comprehensive evaluation matrix.

After the dimensionality reduction above, cluster analysis of the panel data is made. According to data characteristics Q-type clustering is chosen. In the present study, we chose spatial distance[1] between samples to measure the "proximity" between them.

Based on the method proposed by Sahmer *et al.* (2006) and the connotation of the F matrix, the formula for determining the similarity of panel data is:

1. Absolute distance

$$d(F_i, F_j) = \sum_{t=1}^{T} |F_{it} - F_{jt}|, i, j = 1, 2 \ldots, N \tag{2}$$

2. Euclidean distance

$$d(F_i, F_j) = \sum_{t=1}^{T} (F_{it} - F_{jt})^2, i, j = 1, 2 \ldots, N \tag{3}$$

3. Mahalanobis distance

$$d(F_i, F_j) = \frac{(F_{it} - F_{jt})^2}{S}, i, j = 1, 2 \ldots N \tag{4}$$

Finally, the system clustering method is used to cluster the panel data. The specific steps are as follows:

1. Calculate the distance between the two samples in the F matrix.
2. Construct N classes, each class consisting of only one sample.
3. The two types of the closest combination are one class.

4. The two categories with the closest merge are a new class.
5. Calculate the distance between the new class and the current class, and return to Step 3 until the expected classification result is obtained.

3.1.2 Dynamical autoregressive models

Using quarterly exporting-related indicators data, the dynamical regress model estimates a serial of βs by literally feeding the model with data of three consecutive years and moving one quarter ahead starting from the first three years. The model is given as:

$$y_{it} = \beta_{it-1}y^i_{-1} + \beta_{it-2}y^i_{-2} + \beta_{it-3}y^i_{-3} + \varepsilon^i_t \tag{5}$$

Where y_{it} is the status indicator of ith developing country at the tth period, y^i_{-t}, $t = 1, 2, 3$ is the values with t lags for the indicator, and ε^i_t is residual assumed to be independent identically distributed (IID) at all iterations for the indicator. β is the parameter of interest since it bears most information on the transition between the current trading volume and the most recent one as first introduced by Yang and Chen (2010). Using β, instead of the original indicators, has at least three advantages. First, the serials of β are smooth, and the outliers and abnormalities in the original data have been removed by the autoregressive models. Second, unlike traditional methods that remove the outliers altogether and replace them with some superficial substitutes, which could introduce still another source of errors, the method proposed in this study uses the entire information contained in all of the data and thus keeps the information loss to a minimum. Finally, the parameter of the first order autoregressive model contains crucial and smooth information on structure changes in the time serial data of the indicators, which would be tested for comparison of means between the mean of indicators before and after the implementation of NTMs. Statistics for mean comparisons are to be introduced in Section 3.2.

3.2 VARMA (X) models and the intervention model

3.2.1 VARMA (X) models

The VARMA model, used to provide benchmarks of the African agri-food exporting values, is built on the data before the NTMs implementation. This model would be used to estimate the impacts of NTMs on exports when the results are analysed using the combination of results from the intervention model which is estimated with the NTMs effects. The general form of VARMA is given as:

$$Y_t = \sum_{k=1}^{p} \phi_k Y_{t-k} + \sum_{k=1}^{q} \theta_k \varepsilon_{t-k} \tag{6}$$

where Y_t is a vector of an agriculture product total export value for a selected African country, p and q are orders of the autoregressive and moving average parts of the model, respectively, and ϕ_k, θ_k are coefficient matrices, $\varepsilon_i \in IID(0, \sigma^2)$.

On the other hand, the VARMA(X) model is used to evaluate the potential solutions for adverse NTMs impacts. The model is given by:

$$Y_t = \sum_{k=1}^{p} \phi_k Y_{t-k} + \sum_{k=1}^{q} \theta_k \varepsilon_{t-k} + \sum_{k=0}^{s} \varphi_k X_{t-k} \tag{7}$$

where ϕ_k, θ_k, φ_k are coefficient matrices and X_{t-k} is a vector of the exogenous variable, defined in the empirical section as the potential solutions, and p, q, and s are orders of the autoregressive, moving average parts of the model, and exogenous variables, respectively.

The procedure for estimating the above models are standardized:

1. Time serials of exporting volumes of selected African countries are time-matched and consolidated before and after each country's implementation of NTMs (the time of each country's implementation of NTMs could be inconsistent).
2. Stationary tests are performed by ADF test for each time serial. ADF-GLS test, PP test and KPSS test are also used as supplementary methods to check the stationarity.
3. If the time series is not stationary, a logarithm will be used to smooth the series to eliminate the trend in samples. Zero-mean time serials are generated and applied instead in modelling.
4. The orders of models (p, q, s) are estimated using common methods such as autocorrelation function (ACF) and partial autocorrelation function (PACF).
5. The parameters of the model are estimated by maximum likelihood estimation. The procedure would be implemented in *Eviews* or *SAS*.

3.2.2 The intervention model

The intervention method was introduced into time series by Box and Tiao (1975), forming the intervention analysis model to quantify the impact of intervention events. Currently, this method is widely used to analyse the economic impact of political events, strikes or advertising promotions. Bausell *et al*. (2001) used this method to analyse the impact of removing the Alaskan crude oil export ban.

Let y_t be the time serials of the NTMs effect, which is the difference between actual export values and predicted export values generated by VARMA. N_t is the white noise to describe the intervention process, S_t is the intervention event that occurs at the pre-known time t, and the general form of intervention models is given by:

$$y_t = \frac{\omega(B)B^b}{\delta(B)} S_t + N_t \tag{8}$$

where B is backward shift operator and B^b means the intervention will delay b phases. ω, δ, and b are vectors of the parameters to be estimated. Intervention analysis is based on the assumption that intervention events happen at a pre-known time point t in time serials to see whether there are structural changes in y_t. Transfer functions are usually adopted to imitate the characteristics of intervention effect and estimate its magnitude. As a result, the intervention model given in transfer function's form is given by:

$$\begin{cases} (1-B)^d(1-B^s)^D y_t = \mu + \phi(B)^d(1-B^s)^D S_t + \dfrac{\theta(B)\theta_s(B^s)}{\phi(B)\phi_s(B^s)} N_t \\ \phi(B) = \dfrac{\omega_0 - \omega_1 B - \cdots - \omega_q B^q}{1 - \delta_1 B - \cdots - \delta_p B^p} \end{cases} \tag{9}$$

where $\theta(B)$ is the moving average operator, q, p, d, s are the orders of the transfer function.

There are two common assumptions of intervention effects. The first one is the constant intervention variable, which means once the intervention event occurs the intervention effect prevails to the end of the time span. This intervention function is given as:

$$S_t^T = \begin{cases} 0 \mathrm{t} < \mathrm{T} \\ 1 \mathrm{t} \geq \mathrm{T} \end{cases} \tag{10}$$

On the other hand, the intervention effect is assumed to be transient, which means the effect exists only at the moment the intervention occurs. As a result, its function is given as:

$$S_t^T = \{\, 1\ \mathrm{t} \} = \ \mathrm{T}\ 0\ \mathrm{t} \neq \mathrm{T}\,. \tag{11}$$

A 3-step procedure for estimating intervention model runs as follows:

1. On the basis of the predicted result produced by the VARMA model, white noise sequence N_t is determined. Therefore, the impact of NTMs could be approximated by subtracting the anticipated trading volumes from the ones that are actually observed.
2. Auto-regression is performed using intervention value to determine the optimal order of the model and the lasting orders of intervention.
3. The parameters of this intervention model are estimated by Equation (8).

4. Empirical results[2]

In this section, the mechanism of NTMs on agri-food trading among African nations would be analysed using the model presented in the previous section. This section is organised as follows. In Section 4.1, countries are divided into three groups based on the principal opponent analysis and clustering analysis. Then, significance tests results of β are presented, which are generated by dynamical regression to all indicators of three groups. Conclusions are then drawn with regard to the impact of the mechanism of NTMs on three groups, respectively. In Section 4.2, the VARMA model is used to forecast agricultural exporting values under the assumption of no NTMs, with detailed results of each step shown. The intervention model is also constructed in this section to evaluate the impact of NTMs. Section 4.3 evaluates the potential solutions by the VARMA (X) model.

4.1 Country clustering and mechanism research

Considering the integrity of data, indicators are selected for processing in all African countries. The selection of indicators that reflect 85 per cent of a country's agricultural situation suggests that the country's development and agricultural conditions can be represented by these indicators. The indicators used are summarised in Table 2.

Finally, according to the expression of the country's comprehensive indicator F for the current year, the value of the country's comprehensive principal component F is obtained.

Based on the results of principal component analysis, we performed cluster analysis on all countries. Using bottom-up hierarchical clustering, we obtained the results and summarised them in Table 3.

Table 2. Summary of indicators.

Indicators	Indicators explanations
Pesticide use	Including data on the use of major pesticide groups (insecticides, herbicides, fungicides, plant growth regulators and rodenticides) and of relevant chemical families
Agriculture gross product value annual growth rate	Generating from gross production values, in constant 2004–2006 1000 international US$
Emissions (Co^2eq)	Containing all the emissions produced in the different agricultural emissions sub-domains (enteric fermentation, manure management, rice cultivation, synthetic fertilisers, manure applied to soils, manure left on pastures, crop residues, cultivation of organic soils, burning of crop residues, burning of savanna, energy use)
Agriculture share of GDP in US$	Agriculture share of GDP in US$
Gross agricultural production value	
GDP deflator (value of local currency)	A figure expressing the change in prices over a period of time for a product or a basket of products by comparing a reference period to a base period
Developed Mar_Pre	Proportion of export value of developed countries to total export value
PPI	Producer price index of agricultural products. These are prices received by farmers for primary crops, live animals and livestock primary products as collected at the point of initial sale (prices paid at the farm-gate); measuring production costs
ASTI_Per	The number of scientific and technological personnel per one thousand farmers; measuring the level of science and technology
Export value for specified crops	For designated group, special representative crops export value
Government expenditures and public investment	Government expenditure and public investment
Fertilisers_Use (by product)	The fertilisers. Use by product contains all use of chemical and mineral fertilisers products like diammonium phosphate (DAP) and monoammonium phosphate (MAP).

Table 3. Classification results of 30 samples (countries).

GROUP 3		GROUP 1	
Country Code	Country	Country Code	Country
238	Ethiopia (Ethiopia PDR)	53	Benin
GROUP 2		59	Egypt
Country Code	Country	61	Equatorial Guinea
32	Cameroon	72	Djibouti
37	Central African Republic	74	Gabon
181	Zimbabwe	75	Gambia
251	Zambia	81	Ghana
GROUP 1		90	Guinea
Country Code	Country	107	Coate d'Ivoire
4	Algeria	114	Kenya
7	Angola	122	Lesotho
20	Botswana	123	Liberia
29	Burundi	124	Libya
35	Cabo Verde	129	Madagascar
39	Chad	130	Malawi
45	Comoros	133	Mali
46	Congo	136	Mauritania

Note: Ethiopia and the People's Democratic Republic of Ethiopia merge into one sample.

For each type of country, we perform a dynamical regression by pre-processing all of its indicators (weighted average of the indicators by export value). Starting from Q1 1998, the dynamical regression uses data of three consecutive years (a total of 12 quarterly data points) for each round and moves forward one quarter at each step to generate a serial of β values from each regression. The procedure is performed on all indicators of each group above. Then, the β values are tested for equality in means by the method presented in the Appendix before and after the implementation of NTMs. The most significant indicators (both positive and negative) or representative indicators for the testing in equality in means and directional comparison for means in all nations are selected and presented in Table 4.

The indicators selected above reflect most of the characteristics of these countries' exports. Developed Mar_Pre represents the proportion of exports to developed countries in total exports, which can portray the country's export structure. PPI can characterise changes in producer costs in the country. ASTI_Per represents the number of scientific and technical personnel per 10 000 farmers, through which the most direct technological level of agricultural production can be observed. Government expenditures and investment shows whether NTMs prompt the government to increase investment in agriculture. As shown in Table 4, major agricultural products and other factors are also taken into account. Based on the approximate changes in the selected parameters, the impact mechanisms of NTMs on the three groups are examined (Figures 1, 2 and 3).

From Figure 1, we can summarise the characteristics of the impact of NTMs on Group 3 countries:

1. The country's export crops are relatively single – oilseeds and coffee dominate. Their export value is highly correlated with the country's total agricultural exports, and NTMs for oilseeds and coffee will have a strong impact on the country's agricultural exports.
2. NTMs have made significant changes in the export target markets. After the release of NTMs, the Developed Mar_Per indicator of such countries has changed (decreased) significantly, but the total value of exports has remained stable or has continued to rise. This reflects the fact that such countries are more inclined to circumvent NTMs by changing targets and export to "easy markets" (countries with fewer NTMs). Our finding confirms the research result of Shafaeddin (2006).

Table 4. Statistical test results of β generated by dynamical regression.

Regression objects	Selected indicators	*P* value	Simultaneous upper confidence	Simultaneous lower confidence	Indicator explanation
Group 3	Developed Mar_Pre	**0.003 (***)**	**−0.02**	**0**	Exports value to the more developed market/gross export value
Ethiopia (Ethiopia PDR)	PPI	**0.002 (***)**	**0**	**0.07**	Producer price index
	ASTI_Per	**0.008 (***)**	**0**	**0.05**	Agricultural science and technology indicators
	Oilseeds and coffee export value	0.059	−0.03	0.01	Coffee: Including green, husks and skins, roasted or substitutes
Group 2	ASTI_Per	**0.008 (***)**	**0**	**0.05**	Agricultural science and technology indicators
Cameroon; Central African Republic; Zimbabwe; Zambia	Developed Mar_Pre	0.073	−0.04	0.06	Exports value to the more developed market/gross export value
	Government expenditures and investment	**0.017 (***)**	**0**	**0.12**	
	Cocoa and coffee export value	**0.009 (***)**	**−0.04**	**0**	Cocoa: Including beans, butter, paste, powder and cake
Group 1	PPI	**0.008 (***)**	**0.01**	**0.05**	Gross agricultural product export value
Algeria; Angola; Botswana; Burundi; Cabo Verde; Chad; Comoros …	ASTI_Per	0.080	−0.01	0.05	Agricultural science and technology indicators
	Government expenditures and investment	0.068	−0.05	0.01	
	Fertilisers_Use	**0.024 (***)**	**0**	**0.07**	Including tractors, harvesters and threshers, irrigation pumps, milking machines, hand tools and soil machines.

The entries in bold face and three asterisks mean this indicator is significant in dynamical regression under 5% significance level.

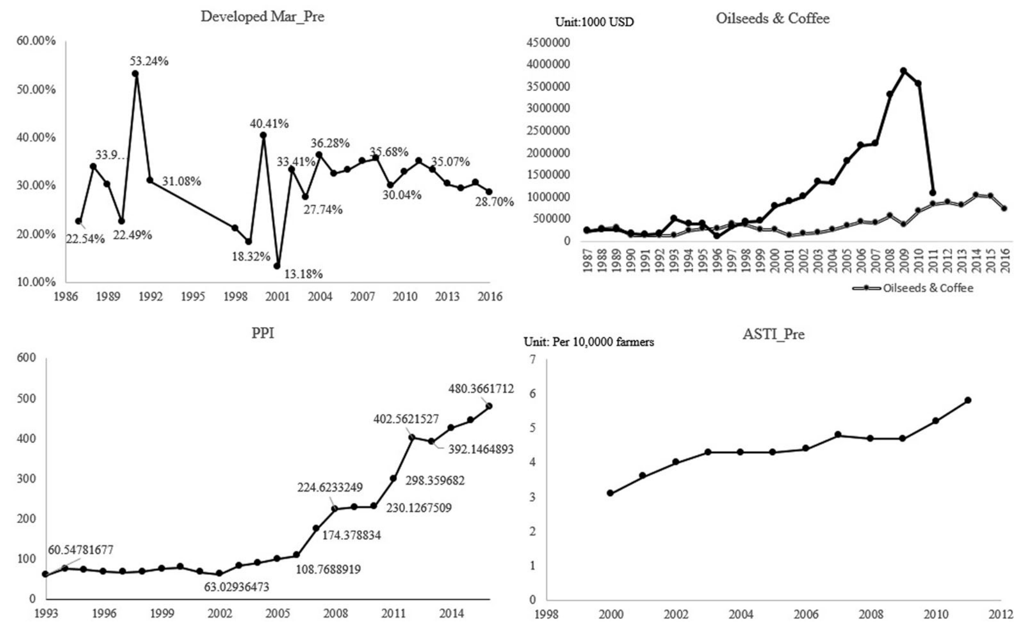

Figure 1. Significant indicators for Group 3 countries.

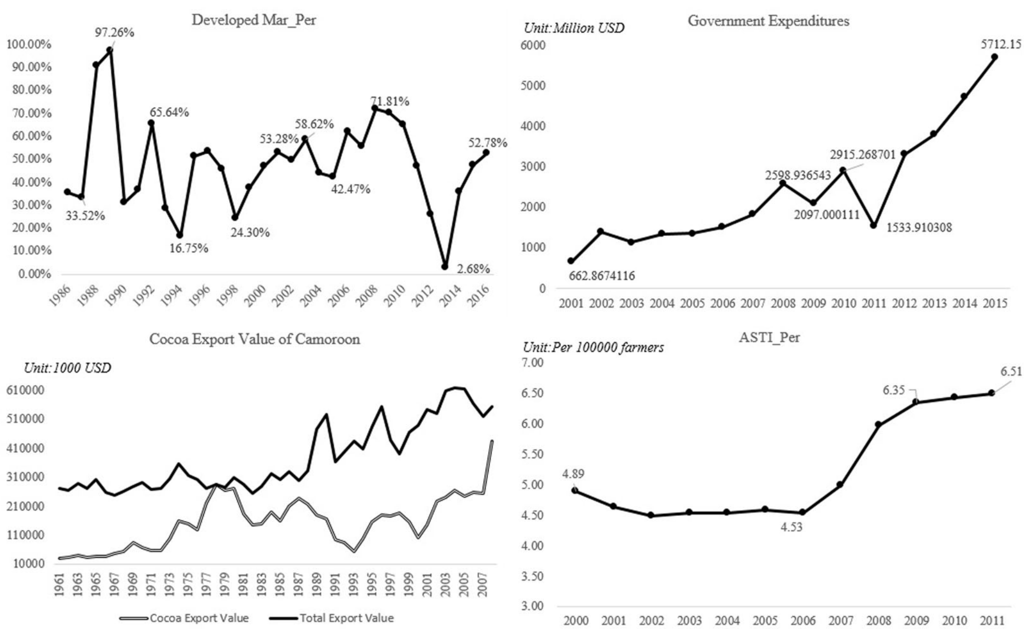

Figure 2. Significant indicators for Group 2 countries.

3. NTMs have a significant impact on the cost of this group. Several PPI bursts in this group are consistent with the timing of new NTMs.
4. There is little change in government investment (this indicator is not significant at the time of statistical testing) and its impact on the scientific and technological indicator ASTI needs further study.

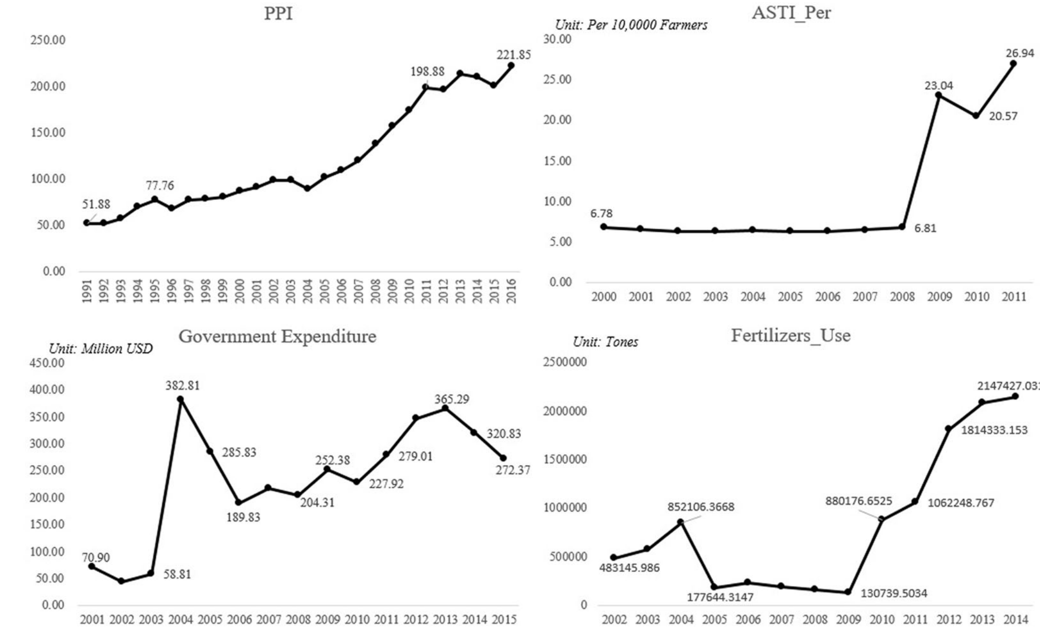

Figure 3. Significant indicators for Group 1 countries.

The NTMs impact mechanism of Group 2 countries is similar to that of Group 3:

1. Cocoa and coffee exports occupy a very important position in the entire agricultural export, and their export value is highly correlated with the total agricultural export value, especially for Cameroon. This is consistent with the research result of Gilbert *et al.* (2013).
2. NTMs also change the export target market of these countries significantly.
3. 3. Such national government investment indicators are significant and have brought about a significant increase in the overall level of technology.

Group 1 countries include many African countries with comprehensive agriculture, and their cost (PPI) has also increased significantly. Compared with Group 2, its government expenditure has not experienced large or long-term fluctuations and its technological level is also stable (ASTI explosiveness might be caused by changes in data collection objects and methods) indicating that the development of science and technology still requires long-term government investment. It is worth noting that the indicators of agrochemical use in these countries have improved significantly but remain low in other countries, indicating that NTMs have a certain role in promoting the agricultural modernization of these countries.

Based on the analysis above, we have the following three findings.

1. NTMs significantly increase the cost of agricultural products in most African countries.
2. For some countries (backward, with less diversified export crops or a lower technology level, such as Group 3: 2), when they are subject to NTMs, they are more inclined to change their export targets rather than improve the technology that hinders export. However, the countries included in Group 1 are different.
3. NTMs do promote the advancement and modernisation of agricultural science and technology in most African countries, but this requires long-term substantial investment and construction by local governments. For countries lacking in initiative and competence, the effect is not obvious over a short period of time.

4.2 VARMA forecasting and intervention analysis

Based on the analysis above, we intend to study the direct impact of NTMs on annual agricultural export value for different groups. For this purpose, the VARMA method is used to predict the export value without NTMs, followed by interventions to adjust the result and completed with a more accurate intervention model developed.

4.2.1 Pre-processing

First, the annual agricultural product export values of different groups are pre-processed. By comparing the results, we found that it is necessary to use the logarithmic method to smooth out series.

For Group 3, we first performed the stationary test, including ADF test, ADF-GLS test, PP test and KPSS test. All the results indicated that the original sequence was non-stationary, and the results after first-order difference were stationary.[3]

Group 2 countries include Cameroon, Central African Republic, Zimbabwe, and Zambia. After averaging the sequences of these four countries, results of the stationary test showed that the original sequence was non-stationary, and the results after the first-order difference were stationary.[4] For Group 1, we chose the three major countries of Ghana, Kenya, and Malawi as our research represents. Results of the unit root test show that the first-order difference sequences of the four countries are relatively stationary[5] with no obvious trend or breakout.[6]

An algorithm called simulated annealing (SA), which belongs to Travellers Optimisation (TO), is used to estimate the p and q orders for the model.[7] The SA algorithm is proposed by Kirkpatrick *et al*. (1983), which is based on Monte-Carlo iterative solution strategy and can opt out of the local optimal solution probabilistically and eventually tend to the global optimal solution.[8] In other words, the algorithm traverses a reasonable range of p and q combinations such that the best model is selected with the lowest AIC and BIC criteria. After finding the value of p and q, we will also put them into *Eviews* to verify the results with Correlogram.

According to the selected p, q values we generate the VARMA model for each group with the export data before NTMs are implemented and the resulting equalisations are as follows:

Group 3: Ethiopia; $p = 3$, $q = 3$

$$\begin{aligned} Y_3^t &= -0.37Y_3^{t-1} - 0.57Y_3^{t-2} - 0.61Y_3^{t-3} \\ &\quad -0.14\varepsilon_3^{t-1} + 0.25\varepsilon_3^{t-2} - 0.55\varepsilon_3^{t-3} \end{aligned} \tag{12}$$

Group 2: Zimbabwe and Cameroon; $p = 2$, $q = 2$

$$Y_2^t = -0.86Y_2^{t-1} - 0.57Y_2^{t-2} + 0.72\varepsilon_1^{t-1} + \varepsilon_2^{t-2} \tag{13}$$

Group 1: Madagascar, Ghana, Kenya and Malawi; $p = 4$, $q = 4$

$$\begin{aligned} Y_1^t &= -2.28Y_1^{t-1} - 1.87Y_1^{t-2} - 0.61Y_1^{t-3} - 0.08Y_1^{t-4} \\ &\quad +\varepsilon_1^{t-1} + 1.26\varepsilon_1^{t-2} - 0.50\varepsilon_1^{t-3} - 0.05\varepsilon_1^{t-4} \end{aligned} \tag{14}$$

Finally, the estimated VARMA presented in Equations (12) to (14) predicts exporting trading values. Because the VARMA model is estimated using data of the export values before NTMs implementation, the predicted export values by the model are thus assumed to be free of the NTMs impacts. Table 5 reports predicted export values and real export values for all three groups in Africa, respectively.

From Table 5, it is obvious that NTMs have a significant negative impact on less developed countries such as Group 3 and Group 2. However, the extent of the impact of NTMs on these countries is related to their export volume. Because of the small export value of Group 2 countries, the impact of NTMs on them is also weak. When exports volume grows, as is the case in Group 3, the impact of NTMs also increases. For most other countries in Africa represented by Group 1 the impact of NTMs is unstable, which may be due to the gap between these countries (developed countries benefit more

Table 5. Impact of NTMs on three groups (Unit: US$1000).[a]

Year	Real export value	Predicted export value	NTMs effect
Group 3: Ethiopia			
2006	895694	745216.04	150478.00
2007	1019368	1523354.57	−503986.60
2008	1350111	2252500.36	−902389.40
2009	1331694	1353102.97	−21408.98
2010	1818254	1840060.35	−21806.35
2011	2173498	2054127.98	119370
2012	2220327	2744642.37	−524315.40
2013	3307248	3705943.26	−398695.30
2014	3844828	11120299.98	−7275472
2015	3572078	2971500.57	600577.40
2016	1086869	1321439.06	−234570.10
Group 2: Zimbabwe; Cameroon			
1996	1197975	827958.71	370016.30
1997	1468509	2143169.36	−674660.40
1998	1623543	2934879.70	−1311337
1999	1108822	1167012.39	−58190.39
2000	1360094	928699.54	431394.50
2001	737603	2258215.61	−1520613
2002	713791	2622848.38	−1909057
2003	585778	1120083.66	−534305.70
2004	770228	1035945.37	−265717.40
2005	594315	2328498.06	−1734183
2006	580018	2360091.20	−1780073.00
2007	447330	1096695.19	−649365.20
2008	463687	1146421	−682734.00
2009	535293	2357540.38	−1822247.00
2010	516848	2142591	−1625743.00
2011	557671	1091756.63	−534085.60
2012	708725	1256527	−547802
2013	640169	2351501	−1711332
2014	702932	1965095	−1262163
2015	606358	1101477	−495119
2016	507503	1362626	−855123
Group 1: Ghana; Kenya; Malawi			
1996	867656.70	1205661	−338004
1997	611641.70	1154261	−542619
1998	684405.30	1145572	−461167
1999	611388.30	1200736	−589348
2000	601219.70	1118236	−517017
2001	639914	1214706	−574792
2002	672138.70	1116918	−444779
2003	974916	1205721	−230805
2004	1017105	1132746	−115641
2005	915621.70	1183660	−268039
2006	1045795	1156178	−110383
2007	1427943	1159991	267951.80
2008	1124231	1177123	−52892
2009	1022804	1143623	−120819
2010	1049524	1188399	−138875
2011	1455434	1138483	316951
2012	1020549	1188005	−167456
2013	1383828	1143639	240188.80
2014	1231537	1178864	52672.86
2015	1170877	1154849	16027.95
2016	1092794	1166485	−73690.50

Note: [a]NTMs effect = real export value-predicted export value.

and less developed countries suffer more). However, this also indicates that probabilities are high that agri-food exports will increase for developing countries in Africa if appropriate solutions would be applied to offset NTMs' negative effects. Potential solutions will be evaluated in Section 4.3.

4.2.2 Well-specified tests of model

For the above-selected parameters (such as lag orders) and the output results, we performed a normality test and a Goldfeld-Quandt heteroscedasticity test on the residuals. This method is applicable to an independent variable and requires that the perturbation terms of the observations of each sample group have the same variance (Gong, 2002). Results of the tests of heteroscedasticity are not significant, indicating that the residual distribution satisfies ARMA's model assumptions and that the model is relatively robust. The heteroscedasticity test results for all groups are presented in Table 6.

4.2.3 Intervention analysis

In this section, NTMs can be considered as sudden (Equation (10)) and continuous pulse (Equation (9)) interventions. Given that the NTMs impacts are assumed to be prolonged during the life of NTMs, the continuous pulse of Equation (9) would be used in the following analysis. An intervention model could also be represented in its autoregressive form as showed in Equation (8). By standard procedure for estimating an autoregressive model, the model is given as:

Group 3: Ethiopia

$$y_3^t = 1.18y_3^{t-1} - 0.73y_3^{t-2} \tag{14}$$

Table 6. Heteroscedasticity test results.

Group 3	Ethiopia	p	3	Q	3
Sample 1	12 (observations)	SSR1	1.28	F	1.28
Sample 2	12 (observations)	SSR2	1.64	$F_{0.05}$ (6,6)	4.21
Group 2	Cameroon; Zimbabwe	p	2	Q	2
Sample 1	34 (observations)	SSR1	2.93	F	0.22
Sample 2	21 (observations)	SSR2	0.66	$F_{0.05}$ (32,19)	
Group 1	Ghana; Kenya; Malawi	p	4	Q	4
Sample 1	34 (observations)	SSR1	0.64	F	0.45
Sample 2	21 (observations)	SSR2	0.29	$F_{0.05}$ (30,17)	0.50

Group 2: Zimbabwe and Cameroon

$$y_2^t = 0.01y_2^{t-1} - 0.98y_2^{t-2} - 0.94y_2^{t-3} + 1.19y_2^{t-4} \tag{15}$$

Group 1: Ghana, Kenya and Malawi

$$y_1^t = 1.15y_1^{t-1} - 0.15y_1^{t-2} - 0.60y_1^{t-3} \tag{16}$$

And the adjusted VARMA can be constructed as below, which can be used to predict expected export value:

Group 3:

$$\begin{aligned} Y_3^t &= -0.37Y_3^{t-1} - 0.57Y_3^{t-2} - 0.61Y_3^{t-3} \\ &\quad - 0.14\varepsilon_3^{t-1} + 0.25\varepsilon_3^{t-2} - 0.55\varepsilon_3^{t-3} + 1.18y_3^{t-1} - 0.73y_3^{t-2} \end{aligned} \tag{17}$$

Group 2:

$$\begin{aligned} Y_2^t &= -0.86Y_2^{t-1} - 0.57Y_2^{t-2} + 0.72\varepsilon_1^{t-1} + \varepsilon_2^{t-2} \\ &\quad + 0.01y_2^{t-1} - 0.98y_2^{t-2} - 0.94y_2^{t-3} + 1.19y_2^{t-4} \end{aligned} \tag{18}$$

Group 1:

$$\begin{aligned} Y_1^t &= -2.28Y_1^{t-1} - 1.87Y_1^{t-2} - 0.61Y_1^{t-3} - 0.08Y_1^{t-4} \\ &\quad + \varepsilon_1^{t-1} + 1.26\varepsilon_1^{t-2} - 0.50\varepsilon_1^{t-3} - 0.05\varepsilon_1^{t-4} + 1.15y_1^{t-1} - 0.15y_1^{t-2} - 0.60y_1^{t-3} \end{aligned} \tag{19}$$

Table 7 reveals several facts.

1. For all kinds of countries, NTMs have a certain impact on agricultural exports during the most recent years.
2. The impact is somehow unstable. The influence of NTMs is highly correlated with the actual export value of groups, which means that NTMs are only one reason among many other factors that affect African countries' export. They do have impact on the volatility of exporting volume. The trend, on the other hand, remains unchanged.
3. The impact of NTMs on Group 3, which mainly consists of countries with multiple sources of income, is on a continuous decline.

Other possible factors that have significant impacts on agricultural foods export will be examined in Section 4.3.

The predictions in Table 9 are derived from the adjusted VARMA model, Equations (18) to (20), which excludes fluctuations and anomalies in the actual data, making reasonable prediction and analysis on the impact of intervention.

Table 7. The impact of interventions on export value (Unit: US$1000).[a]

Group 3: Ethiopia							
Year	Real export value	Adjusted expected export value	Impact	Year	Real export value	Adjusted expected export value	Impact
2009	1331694	1346267	1.09%	2013	640169	1264835	97.58%
2010	1818254	1827385	0.50%	2014	702932	1816893	158.47%
2011	2173498	2180465	0.32%	2015	606358	1419135	134.04%
2012	2220327	2227469	0.32%	2016	507503	966139.4	90.37%
2013	3307248	3316230	0.27%	Group 1: Ghana; Kenya; Malawi			
2014	3844828	3856404	0.30%	1999	611388.3	1047649	71.36%
2015	3572078	3585282	0.37%	2000	601219.7	1033242	71.86%
2016	1086869	1099665	1.18%	2001	639914	1069248	67.09%
Group 2: Zimbabwe; Cameroon				2002	672138.7	1099030	63.51%
1999	1108822	1819212	64.07%	2003	974916	1399414	43.54%
2000	1360094	1778846	30.79%	2004	1017105	1439228	41.50%
2001	737603	1383707	87.60%	2005	915621.7	1335387	45.84%
2002	713791	1906432	167.09%	2006	1045795	1463215	39.91%
2003	585778	1372959	134.38%	2007	1427943	1843033	29.07%
2004	770228	1198959	55.66%	2008	1124231	1537005	36.72%
2005	594315	1232433	107.37%	2009	1022804	1433276	40.13%
2006	580018	1745203	200.89%	2010	1049524	1457707	38.89%
2007	447330	1243874	178.07%	2011	1455434	1861342	27.89%
2008	463687	902404.5	94.62%	2012	1020549	1424196	39.55%
2009	535293	1166288	117.88%	2013	1383828	1785228	29.01%
2010	516848	1655819	220.37%	2014	1231537	1630702	32.41%
2011	557671	1362739	144.36%	2015	1170877	1567821	33.90%
2012	708725	1157417	63.31%	2016	1092794	1487532	36.12%

Note: [a]Impact = (Adjusted expected export value − Real export value)/ Real export value*100%.

4.3 The evaluation of potential solutions based on the VARMA(X) model

As NTMs have significant negative impacts on the agri-food related export of developing countries in Africa, this section evaluates potential solutions to the adverse effects. Cadot and Gourdon (2016) propose that deep integration is an important way to make NTMs play a positive role and avoid trade protection. There are also other ways such as trade liberalisation and external aid. The solutions are coded and used as exogenous variables in the VARMA(X) model (Equation (7)). The exogenous test of the variable using the Granger Causality Test proposed by Engle 1983) and Liu *et al.* (2015) has adopted this method in the test of exogenous variables, which validates the method. Results of exogenous test of the variable are summarised in Table 8.

Among them, *Y* is the explanatory variable – export values X1, X2 and X3 represent exogenous variables, trade liberalisation, economic integration and external aid, respectively. The test results presented in Table 8 show that these variables are very exogenous.

Considering that the estimation of the VARMA(X) model is the same as the procedure presented in Section 4.2, we only report the statistics for each of the coded solution (Table 9).

From Table 9, it is obvious that solutions to trade liberalisation and external aid have significant influences on the export of agricultural products for developing countries in Africa. On the other

Table 8. Results of exogenous test.

Null hypothesis	*F*-statistics	Probability
Y does not Granger cause X1	1.10	0.36
X1 does not Granger cause *Y*	10.99	0.00
Y does not Granger cause X2	1.90	0.15
X2 does not Granger cause *Y*	2.78	0.04
Y does not Granger cause X3	1.83	0.24
X3 does not Granger cause *Y*	3.74	0.03

Note: Lag 5; significance level 5%.

Table 9. Statistics for coded solution based on the VARMA (X) model.

Parameters	*P* value	Simultaneous upper confidence	Simultaneous lower confidence
Trade liberalisation	0.008 (***)	0.01	0.05
Economic integration	0.011	0.00	0.03
External aid	0.008 (***)	0.00	0.02

hand, the integration process as a potential solution to improve the export for developing countries is not significant and its function as the facilitator for export is questionable, which could account for the fact that integration process will ultimately incur establishment of barriers between and among countries in different regions and thus weaken the NTMs' negative effects.

5. Conclusion

NTMs, a substitute for tariffs originally designed to reduce tariffs (Disdier and Marette, 2010), have attracted more attention all over the world for their ultimate negative effects of distorting international trade from an economic viewpoint and becoming even more harmful than tariffs (Herghelegiu, 2017). Although intensively studied, NTMs' heterogeneous effects on both developed and developing African countries that export agricultural food still need to be accurately quantified.

In the present study, mechanisms of both positive and adverse NTMs have been first studied by using the dynamical regression model to identify NTMs' heterogeneous effects on countries with various development levels classified by clustering analysis. Then, VARMA and intervention models have been applied to quantify the impacts of NTMs, defined as the difference between the estimated agri-food export values of African countries from 1996 to 2013 without NTMs and the actual values. This study has verified the substantial negative impact of these measures on African agri-food exporters despite the original intention of NTMs in dealing with market failure and accelerating sustainable development. Finally, possible solutions to enhance agricultural food trading among African nations, namely, strengthening external assistance (SEA), extending trade liberalisation (ETL) and accelerating economic integration (AEI), have been quantitatively evaluated by the VARMA(X) model.

Yet still, several issues with this study are worth considering. First, the impacts of NTMs are assumed to be the differences between the actual trading values and the predicted ones, the accuracy of which depends on the ability of the VARMA(X) models to describe the trading values' real evolving process. Second, in reality, some other factors, such as wars, weather, and regional macroeconomic situation, may all contribute to the differences in actual trading values and the expected ones after applying NTMs. Thus, tagging NTMs alone to the differences means exaggeration of their effects, and thus more comprehensive search for the "right" models is required. Finally, finding possible solutions to the current NTMs barriers requires a trial-and-error approach based on the precise simulation of the ultimate effects of any individual solution and their potential combinations. Despite the possibility for the authors to utilise more sophisticated models to capture NTMs' impacting dynamical, the simplified infrastructure of the current setup serves its purpose adequately in depicting a general picture of the NTMs effects while keeping the analytical process traceable.

Notes

1. Finally, this research uses Mahalanobis distance, which excludes the interference of correlation between variables and would not be affected by dimensions.
2. In this section, the data we use is all downloaded from the database of Food and Agriculture Organisation of the United Nations (http://www.fao.org/faostat/en/#data).
3. Under the 5% confidence interval, the original sequence is unstable. The t statistic of the first order difference sequence is −4.661781 ($p = 0.0059$), indicating the first order difference sequence is stationary.
4. Under the 5% confidence interval, the t statistic of the original sequence of Group 2 is −2.145791, and the t statistic of the first order difference sequence is −9.580032. The original sequence is unstable and the first order difference sequence is stationary.

5. To save space, the entire results for unit root tests would be available on request.
6. Under the 5% confidence interval, the original sequence t statistic of Group 1 is −1.903697, and the first-order difference sequence statistic is −4.231239. The original sequence is stationary enough.
7. To save space, the entire process for p and q selection would be available on request.
8. For more information on SA algorithm, readers can refer to Bertsimas, D. and Tsitsiklis, J. (1993). Simulated annealing. *Statistical Science* 8(1): 10–15.

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Appendix

Statistics for comparison of means

With a time serial of the estimated first order parameters β of autoregressive models, the general linear models (GLM) Procedure for testing the equality of the means of both groups (the means of the indicators before and after the implementation of NTMs) and Tukey's studentised range (HSD) test for directional testing would be employed to test (1) whether the means of the two groups are the same and (2) which one of the means is larger. While results of the first test indicate the presence or absence of a structure change because of NTMs, those of the second test reveal the directional mechanism of the NTMs' impacts.

Letting $\tau_i, i = 1, 2$ is the means of the two groups, $c_i\tau_i$ is the contract to test the equality $\sum c_i\tau_i \in \left(\sum c_i\bar{y}_i \pm t_{n-v,\alpha/2}\sqrt{msE\sum c_i^2/r_i}\right)$, and thus the Null-Hypothesis is H_0: $\sum c_i\tau_i = 0$, the null-hypothesis that the means are equal would be rejected with confidence level α if:

$$\left|\frac{\sum c_i\bar{y}_i}{\sqrt{msE\sum c_i^2/r_i}}\right| > t_{n-v,\alpha} = F_{1,n-v,\alpha} \tag{20}$$

where r_i are the lengths for each group, msE is the mean square error given by $msE(\bar{x}) = E(\bar{x} - x)^2$, $\bar{y}_i$ are the observations and $t_{n-v,\alpha/2}$ is the T distribution with parameters n (total numbers of the observations), $F_{1,n-v,\alpha}$ the F distribution with parameters n (total numbers of the observations), v (the degree of freedom) and α. Furthermore, the Tukey's studentised range (HSD) test for directional testing is given by the One-tail test H_0: $\sum c_i\tau_i < 0$. The Hull-Hypothesis would be rejected if:

$$\frac{\sum c_i\bar{y}_i}{\sqrt{msE\sum c_i^2/r_i}} < -t_{n-v,\alpha/2} \tag{21}$$

where the parameters are the same as the ones in Equation (20). Note also that the confidence level for Equality testing is α while that for directional testing is α/2.