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Three Essays on Technical Non-Tariff Measures in Developed Countries and African Countries' International Trade in Agricultural Products

Thèse

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Résumé

L'objectif de cette thèse est d'analyser les implications économiques des mesures techniques non tarifaires (MTNT) en vigueur dans les pays développés sur le commerce international de produits agroalimentaires des pays Africains. De façon plus spécifique, elle s'intéresse à trois questions principales. La première, qui est plus générale, est de savoir quel est et qu'est-ce qui détermine l'effet net de l'ensemble des mesures techniques non tarifaires en vigueur dans les pays de l'OCDE sur les exportations Africaines de produits végétaux. La deuxième question, plus spécifique, cherche à savoir quels sont les effets de la conformité aux mesures de limites maximales de résidus (LMR) de pesticides sur la production, l'offre d'exportation et la demande d'importation. Finalement, la troisième question consiste à déterminer quel est l'impact direct des rejets de produits à la frontière des pays Européens du système d'alerte rapide pour les denrées alimentaires et les aliments pour animaux (RASFF) sur les exportations Africaines de fruits et légumes comestibles. Nous traitons ces différentes questions à travers trois essais.

Dans le premier essai, nous analysons de façon théorique l'effet net des MTNT sur le commerce bilatéral et proposons une approche empirique robuste pour évaluer cet effet. Ensuite, nous évaluons les effets d'entrave et d'amélioration ainsi que l'effet net des MTNT en vigueur dans les pays de l'OCDE sur les exportations africaines de produits végétaux. Nos résultats théoriques montrent que l'effet net des MTNT sur le commerce bilatéral agrégé dépend non seulement de l'élasticité de substitution et de l'élasticité du coût marginal par rapport aux MTNT, mais aussi du paramètre de forme de la distribution des coûts marginaux qui dépend de la technologie. En plus, nous constatons que pour une élasticité de substitution donnée, seules les entreprises ou les pays caractérisés par un coût marginal inférieur à un coût marginal seuil et une productivité supérieure à un niveau de productivité seuil connaîtront un effet net positif du commerce vers une destination donnée. Pour nos investigations empiriques, nous estimons une équation de gravité sectorielle en utilisant la base de données des MTNT publiée par la CNUCED et le WITS, combinée aux données commerciales transversales pour 2017 de UN COMTRADE/WITS. Les données couvrent 53 pays africains exportant 40 produits végétaux à 4 chiffres du Système harmonisé (SH) vers 35 pays membres de l'OCDE. Nos résultats empiriques montrent à la fois des effets d'entrave (diminution de 3,099%) et d'amélioration (augmentation de 2,056%) des MNT en vigueur dans les pays de l'OCDE sur les exportations africaines de produits végétaux. Ensemble, ces effets produisent un effet net négatif et significatif, ce qui indique que les MNT en vigueur dans les pays membres de l'OCDE constituent des obstacles pour les exportateurs

Africains de produits végétaux.

Dans le second essai, nous démêlons théoriquement et empiriquement les effets des LMR pour les pesticides sur la production, l'offre d'exportation et la demande d'importation. Nous adoptons une approche de modélisation basée sur les coûts et les bénéfices associés aux normes de sécurité sanitaire des aliments et utilisons notre cadre théorique pour évaluer les effets empiriques nets des LMR de pesticides sur la production de mangues en Afrique et le commerce avec les pays membres de l'OCDE. Théoriquement, nous montrons que les effets des LMR sur la production sont négatifs tandis que leurs effets nets sur le commerce bilatéral peuvent être positifs, nuls ou négatifs selon que l'effet de la qualité perçue par les consommateurs sur la demande d'importation est supérieur, égal ou inférieur à l'effet du coût de mise en conformité sur l'offre d'exportation. Nous utilisons des données transversales pour 12 pays africains qui ont produit et exporté des mangues conformes aux LMR vers 31 pays de l'OCDE en 2016, et nous constatons que, d'une part, les effets nets des LMR de pesticides sur la production de mangues sûres sont négatifs. D'autre part, ils sont positifs sur le commerce des mangues entre les pays africains et les pays membres de l'OCDE. Nos résultats impliquent que le renforcement ou l'imposition de LMR strictes pour les pesticides dans les pays développés peut favoriser les échanges commerciaux alors qu'ils entravent fortement la production dans les pays africains.

Dans le dernier essai, nous évaluons l'effet des refus d'importation des pays Européens sur les exportations Africaines de fruits et légumes comestibles, au cours de la période 2008 à 2018. De façon plus spécifique, nous estimons l'effet moyen des rejets aux frontières des pays du réseau RASFF sur les marges extensive et intensive de commerce de fruits et légumes comestibles pour 45 pays africains. Nous utilisons les données sur les rejets aux frontières issues de la base de données en ligne du RASFF avec les données sur les exportations Africaines provenant de la base de données de WITS des Nations Unies. Nous estimons la version canonique de l'équation de gravité sectorielle d'Anderson et al. (2004) en utilisant l'estimateur du Pseudo poisson maximum de vraisemblance (PPML) de Silva et al.(2006) en combinaison avec l'approche robuste d'estimation à deux étapes avec inclusion de résidus (2SRI) de Terza et al.(2008). Nous constatons qu'une augmentation du nombre de refus d'importation par un pays du RASFF une fois dans l'année en cours entraîne une diminution du nombre de partenaires commerciaux en Europe pour les pays africains de 0,018% pour les légumes comestibles et de 0,143 % pour les fruits comestibles. En outre, nos résultats montrent qu'un refus d'importation supplémentaire diminue la valeur des exportations de légumes comestibles des pays africains de 0,045%. Cependant, nous constatons que les refus d'importation des pays du RASFF une fois dans l'année en cours entraînent une augmentation de la valeur des exportations de fruits comestibles des pays africains de 0,126%. Par ailleurs, nos résultats valident explicitement l'hypothèse d'endogénéité du nombre de refus d'importation et mettent en évidence les effets directs et les effets de contagion des rejets aux frontières. Ce dernier résultat signifie qu'une augmentation du nombre de rejets à la frontière d'un produit donné (par exemple un fruit frais) au cours d'une année précédente entraîne une augmentation du nombre de rejets à la frontière pour ce produit et les produits voisins (par exemple un légume frais) au cours de l'année suivante.

Abstract

The objective of this thesis is to analysis the economic implications of technical non-tariff measures (TNTMs) in force in developed countries on the international trade of agricultural and agri-food products of African countries. More specifically, we focus on three main issues. The first more general question is: what is and what determines the net effect of the set of TNTMs in OECD countries on African exports of plant products ? The second, more specific, question is: what are the effects of compliance with maximum residue limit (MRL) for pesticide on production, export supply and import demand ? Finally, the third question is to determine: what is the direct impact of product rejections at the border of European countries of the Rapid Alert System for Food and Feed (RASFF) on African exports of plant products ? We address these different questions through three essays.

In the first essay, we theoretically analyze the net effect of technical non-tariff measures (TNTMs) on bilateral trade and suggest a robust empirical approach to evaluate this effect. We assess the impediment, enhancement and net effects of the TNTMs in force in OECD countries on African exports of plant products. Our theoretical findings highlight that the net effect of the TNTMs on aggregate bilateral trade depends not only on the elasticity of substitution and the elasticity of marginal cost with respect to the TNTMs but also the shape parameter of the distribution of marginal costs which depends on the technology. In addition, we find that for a given elasticity of substitution, only firms or countries characterized by a lower marginal cost than a cutoff marginal cost and higher productivity than a threshold productivity level will experience a positive net effect of trade to a given destination. For our empirical investigation, we estimate a sectoral gravity equation using the non-tariff measures (NTMs) database released by UNCTAD and WITS combined with cross-sectional trade data for 2017 from the UN COMTRADE/WITS database. The data cover 53 African countries exporting 40 Harmonized System (HS) 4-digit plant products to 35 OECD member countries. Our empirical results show both impediment (decrease of 3.099%) and enhancement (increase of 2.056%) effects of the TNTMs in force in OECD countries on African exports of plant products. Together, these effects yield a negative and significant net effect, which indicates that the TNTMs in force in OECD member countries are obstacles for African exporters of plant products.

In the second essay, we disentangle theoretically and empirically the effects of the MRLs for pesticides on the production, export supply and import demand. We adopt a modelling approach based on the costs and benefits associated with food safety standards and use our theoretical framework to as-

sess the empirical net effects of the MRLs for pesticides on African mango production and trade with OECD member countries. Theoretically, we show that the production effects of MRLs are negative while their net effects on bilateral trade can be positive, zero or negative depending on whether the consumers' perceived quality effect on import demand is greater than, equal to or less than the compliance cost effect on export supply through the unconditional expected standard-compliant production. We use a cross-sectional data set for 12 African countries that produced and exported MRL-compliant mangoes to 31 OECD countries in 2016, and find that, on the one hand, the net effects of MRLs on the production of safe mangoes are negative. On the other hand, they are positive on mango trade between African and OECD member countries. Our results highlight that the tightening or imposition of strict MRLs for pesticides in developed countries may be trade promoting while they severely impede production in African countries.

In the last essay, we assess the effects of European countries' import refusals on African exports of edible vegetables and fruits from 2008 to 2018. We specifically estimate the average effects of the RASFF countries' border rejections on the extensive and intensive margins of African countries exports of edible vegetables and fruits. We use the border rejections data from the RASFF online database and export data on 45 African countries from the UN WITS database. We estimate the canonical version of the sectoral gravity equation of Anderson and al. (2004) using the Poisson pseudo maximum likelihood (PPML) estimator of Silva and al. (2006) in association with the robust two-stage residual inclusion (2SRI) approach of Terza and al. (2008). We find that a single increase in the number of import refusals by a RASFF country in the current year leads to a decrease in the number of trade partners in Europe for African countries by 0.018 percent for edible vegetables and 0.143 percent for edible fruits. In addition, our results show that one additional import refusal decreases the export value of African countries' edible vegetables by 0.045 percent. However, we find that RASFF countries' refusal to import once in the current year leads to an increase in the export value of African countries' edible fruit by 0.126 percent. Furthermore, our results explicitly validate the hypothesis of the endogeneity of the number of import refusals and highlight both the direct and spillover effects of border rejections. The latter result means that an increase in the number of border rejections for a given product (for instance, a fresh fruit) in a given year leads to an increase in the number of border rejections for a product and its neighboring products (for instance, a fresh vegetable) in the next year.

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Dedicaded to my mother Fanta Dembélé, my grand-mother Mousssokoura Dembélé, my sweet wife Naren Keita and Projet de formation agricole pour la securité alimentaire au Mali (FASAM)

La seule manière de sortir de la violence consisterait à prendre conscience des mécanismes de répulsion, d'exclusion, de haine ou encore de mépris afin de les réduire à néant grâce à une éducation de l'enfant relayée par tous.

Françoise Héritier

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Avant-propos

This thesis is separated into three articles that are submitted or in preparation for submission for publication in peer-reviewed scientific journals. The first two articles were written jointly with my thesis supervisor Prof. Lota D. Tamini, full professor at the Department of Agri-Food Economics and Consumer Sciences at Laval University. The third article is written with Dr. Karine Latouche, Researcher at French National Institute of Research for Agriculture (UMR SMART-LERECO/INRA) and Prof. Lota D. Tamini. I thank Ms. Cécile Le-Roy, data manager officer at INRA in Nantes, for her helpful contributions in this latter article. She helped me to elaborate a replicable program on the Stata Software that allows us to treat and match the RASFF data with the UN WITS HS 6-digit trade data.

I am the principal author of the three essays presented in this thesis. The first essay entitled **"The Net Effect of Technical Non-Tariff Measures in OECD Countries on African Exports of Plant Products"** are in preparation to be submitted in a peer-reviewed scientific journal and the second essay entitled **"African Trade of Mangoes to OECD Countries : Disentangle the effects of compliance to Maximum Residue Limits on Production, Export supply and Import Demand"** has been submitted for publication in the *European Review of Agricultural Economics*. The third essay entitled **"European's RASFF Border Rejections, African Countries's Reputation and Exports of Fruit and Vegetable Products"** are in preparation to be submitted in a peer-reviewed scientific journal.

Introduction

Durant ces dernières années, l'utilisation des mesures non tarifaires (MNT) de plus en plus strictes s'est accrue dans les pays développés (Beghin et al., 2015b; Maertens and Swinnen, 2015; Swinnen et al., 2015a; Swinnen, 2016; WTO, 2012). Ces mesures représentent toutes les mesures de politique commerciale autres que les droits de douane ordinaires (qui ont, eux, considérablement baissé). Elles sont susceptibles d'avoir un effet économique sur les échanges internationaux de biens en modifiant les quantités échangées et/ou les prix (UNCTAD (2013, 2012) et UNCTAD (2008)). Parmi les MNT, ce sont les mesures techniques [1], notamment les mesures sanitaires et phytosanitaires (SPS), les obstacles techniques au commerce (OTC) et les mesures de vérification de la conformité avant expédition, qui sont les plus fréquemment utilisées. Selon WTO (2012), les mesures techniques représentaient 59% de toutes les MNT en vigueur en 2012. En outre, Swinnen (2016) et Swinnen et al. (2015a) indiquent que le nombre de notifications de mesures SPS et celui des OTC soumis à l'organisation mondiale du commerce (OMC) sont passés chacun, de quelques centaines dans les années 1990 à plus de 17 000 en 2014. Les pays réputés comme ayant des réglementations plus nombreuses et des normes plus strictes que celles recommandées dans les cadres internationaux (par exemple, le CODEX Alimentarius ou Code alimentaire [2]) sont les pays membres de l'organisation de coopération et de développement économique (OCDE). Au-delà de leur nombre, ces mesures techniques s'intéressent à différentes préoccupations (qualité et sécurité sanitaire des aliments, protection environnementale et éthique) liées à la production et aux échanges internationaux des biens (Maertens and Swinnen, 2015; Swinnen, 2016). Elles sont omniprésentes dans les chaînes de valeur des produits agroalimentaires et, elles concernent plus particulièrement les produits des secteurs de fruits et légumes, céréales, oléagineux et animaux (Smith, 2009; Maertens and Swinnen, 2015; Swinnen, 2016).

L'objectif de cette thèse est d'analyser les implications économiques des MTNT en vigueur dans les

1. Les mesures techniques non tarifaires correspondent aux mesures définies dans les chapitres A, B et C du système de classification international des MNT de la Conférence des Nations Unies sur le Commerce et le Développement (CNUCED). La classification des mesures non tarifaires est disponible sur le site web de la CNUCED https://unctad.org/en/Pages/DITC/Trade-Analysis/Non-Tariff-Measures/NTMs-Classification.aspx

2. Le code alimentaire, initié par la FAO et l'OMS en 1963, définit au niveau international un ensemble de normes harmonisées, de lignes directrices et de codes d'usage destinées à protéger la santé des consommateurs et de promouvoir des pratiques loyales en matière de commerce de denrées alimentaires. L'utilisation des normes du CODEX est encouragée dans le cadre des accords de l'OMC sur les mesures SPS (voir https://www.wto.org/french/docs_f/legal_f/15sps_02_f.htm#annA) et OTC (voir https://www.wto.org/french/docs_f/legal_f/17-tbt_f.htm#ann1. Elles impliquent 188 pays. Les informations sur le CODEX sont disponible sur le site web http://www.fao.org/fao-who-codexalimentarius/home/fr/. Sites consulté le 14 août 2017.

pays développés sur le commerce international de produits agroalimentaires des pays Africains. En effet, la prolifération des MTNT coïncidant avec la baisse substantielle des tarifs douaniers et leurs éloignements aux normes définies dans les cadres internationaux soulèvent des interrogations sur leurs motivations. Par exemple, la majorité des plaintes portant sur ces mesures, surtout d'origine Étatique, les dénoncent comme obstacles aux échanges ou mesures protectionnistes déguisées (WTO, 2012). Concernant les motivations, plusieurs raisons sont évoquées dans la littérature pour justifier la prolifération des normes dans les secteurs agricole et agroalimentaire. Celles-ci se rapportent essentiellement à des considérations d'ordre politico-économique, social, environnemental et sanitaire (qualité et sécurité sanitaire des aliments). Pour la dimension politico-économique, certains auteurs (Li et al., 2017; Orefice, 2017; Disdier, 2009; Tamini et al., 2014; Beghin et al., 2015b) s'accordent pour dire que la prolifération des mesures non tarifaires est liée à la suppression ou à la réduction progressive des mesures ordinaires (tarifs douaniers, quotas d'importation, subventions, etc.) permises par les accords de libre-échange bilatéraux, régionaux ou multilatéraux. De plus, Li et al. (2017) ajoutent que ces mesures peuvent être souvent utilisées pour répondre aux pressions des lobbies des producteurs nationaux et créer des avantages compétitifs au détriment des entreprises étrangères. Quant à la dimension environnementale et sociale, Tamini et al. (2014) indiquent que les MNT sont utilisées respectivement pour encourager les pratiques pro-environnementales (pratiques agricoles durables) et pour établir la justice sociale (commerce équitable, droit de travail ou travail des enfants). La quatrième dimension évoquée se rapporte à la défaillance des marchés à corriger les problèmes telles que les externalités de production ou de consommation et l'imperfection ou l'asymétrie de l'information (Swinnen et al., 2015b; Beghin et al., 2015a, 2012). En présence d'asymétrie ou d'imperfection de l'information, les décisions des agents ne sont pas efficaces et donc, l'allocation des ressources n'est pas optimale. Par exemple, sur des marchés agricoles où l'information est imparfaite ou asymétrique, plusieurs produits sont définis comme des biens d'expérience ou de confiance (Nelson, 1970; Darby and Karni, 1973). Alors que, pour les biens d'expérience, certaines caractéristiques qualitatives et quantitatives sont observées au moment de la consommation, elles ne sont pas identifiables à priori pour les biens de confiance par les mécanismes habituels du marché. Lorsque les caractéristiques des biens de production ou de consommation ne sont pas observables, cela peut impliquer des différences entre les coûts privés et les coûts sociaux (incluant les problèmes de santé publique). Dès lors, les normes publiques ou privées s'imposent pour garantir et/ou informer les acteurs sur les attributs (qualité, sécurité sanitaire, nutriments, etc.) désirés ou l'innocuité des biens de production ou de consommation. Les normes utilisées à cette fin sont les MTNT notamment les normes SPS et OTC. Elles font partie d'une panoplie de mesures identifiées et classifiées en 2008 et mises à jour en 2012 par la CNUCED et une équipe d'experts issus de huit organisations du système des nations unies, dénommée MAST [3] (« Multi-Agency Support Team »). L'objectif affiché des mesures techniques est de corriger les défaillances des marchés en vue de garantir aux consommateurs des aliments sains et de bonne qualité, qu'ils soient locaux ou importés. Toutefois, ces mesures sont souvent utilisées par les pays dévelop-

3. Les experts du groupe MAST proviennent de la FAO, du FMI, du CIT, de l'OCDE, de la CNUCED, de l'ONUDI, de la Banque Mondiale et de l'OMC)

pés et vont souvent au delà des normes définies au niveau international et de ce fait, elles peuvent protéger leurs entreprises locales et constituer des obstacles aux firmes des pays en développement. À titre d'exemple, les LMR de pesticides ou de médicaments vétérinaires en vigueur dans plusieurs pays de l'OCDE sont inférieures à celles du CODEX (Li et al., 2017) et celles-ci représentent des obstacles aux exportations des pays à faible revenu avec des infrastructures déficientes et de capacités techniques insuffisantes (Xiong and Beghin, 2014).

Plusieurs études ont analysé de façon théorique ou empirique avec différentes stratégies les effets des MTNT sur les échanges bilatéraux. Il ressort de cette littérature que les implications économiques des différences de MTNT entre les pays sur le commerce international sont contrastées. En effet, les impacts des normes sur le commerce varient selon les pays, les produits, les acteurs et les caractéristiques des normes. Certains auteurs estiment que l'application des normes hétérogènes ou leur harmonisation n'ont aucun impact sur les échanges (Czubala et al., 2009; Fontagné et al., 2005; Xiong and Beghin, 2011) ou à la limite elles en favorisent (Chevassus-Lozza et al., 2008; De Frahan and Vancauteren, 2006). Par contre, plusieurs autres études (Anders and Caswell, 2009; Burnquist et al., 2011; Hoekman and Nicita, 2011; Otsuki et al., 2001; Swinnen, 2016; Tran et al., 2012; Van Tongeren et al., 2010) indiquent que les normes constituent des barrières au commerce et au développement des pays à revenu moyen et faible avec des capacités techniques insuffisantes. Par exemple, Smith (2009) trouve qu'elles réduisent plus les exportations des petites et moyennes entreprises agricoles et agroalimentaires des pays en développement et affectent négativement leurs gains du commerce. Korinek et al. (2008) et Maskus et al. (2013) montrent que les normes réglementaires peuvent engendrer une augmentation des coûts de production et des coûts au commerce chez les entreprises. Il s'agit notamment des coûts d'adaptation (nouvelles pratiques), d'établissement de la conformité et ceux associés à la certification et aux inspections. Pour Otsuki et al. (2001) et Xiong and Beghin (2014), les mesures SPS telles que les mesures de limite maximales de résidus (LMR) de pesticide peuvent constituer des obstacles aux exportations. Par exemple, Otsuki et al. (2001) estiment à 670 millions de dollars américains, la perte pour les exportateurs africains de céréales, fruits et noix, qui serait attribuée à l'harmonisation des LMR d'aflatoxine dans les pays membres de l'UE en 2002. Par ailleurs, Xiong and Beghin (2014) et Disdier and Marette (2010) ajoutent que ces mesures techniques peuvent en même temps stimuler la demande d'importation.

La majorité de ces études ont modélisé les coûts des normes dans les coûts au commerce chez les exportateurs. Cependant, aucune d'entre elle n'a considéré explicitement les coûts supportés par les producteurs en amont. Or, ces coûts peuvent être prohibitifs pour les producteurs de fruits et légumes dans la majorité des pays Africains (Kareem and Martinez-Zarzoso, 2020) et compromettre leurs exportations vers des pays avec des normes strictes. En plus, à notre connaissance, il n'y a pas d'étude dans la littérature qui s'est intéressée aux effets de l'ensemble des MTNT en vigueur dans les pays de l'OCDE sur les exportations de produits agricoles des pays Africains (Santeramo and Lamonaca, 2019). Pourtant, les exportations de produits végétaux de ces derniers dépendent fortement des pays de l'OCDE qui ont de nombreuses réglementations et des normes plus strictes. En plus, les exportations de produits végétaux représentent une part importante des revenus d'exportation de produits agricoles pour plusieurs pays Africains. Enfin, les études ayant examiné les effets économiques *de facto* (détention, destruction ou rejet d'exportations) des réglementations strictes de l'Union européennes (UE) en matière de qualité et de sécurité sanitaire des aliments sur les exportations des pays Africains, ne se sont intéressées qu'aux produits de poissons et de fruit de mer (Baylis et al., 2010) et qu'à quelques fruits et légumes (Kareem et al., 2017). En plus, ces études ne tiennent pas suffisamment compte des effets de contagion des rejets de produits reliés ; elles ne traitent pas de façon explicite et robuste le problème d'endogéneité des rejets et des flux de commerce nuls. Cette thèse vise donc à combler ces vides dans les littératures théorique, méthodologique et empirique sur les implications des mesures techniques non tarifaires sur les échanges bilatéraux de produits agroalimentaires. Elle s'intéresse plus particulièrement à trois questions principales relatives aux effets *de jure et de facto* des MTNT en vigueur dans les pays développés sur le commerce international de produits agricole et agroalimentaire des pays Africains :

- Quel est et qu'est-ce qui détermine l'effet net de l'ensemble des mesures techniques non tarifaires en vigueur dans les pays de l'OCDE sur les exportations Africaines de produits végétaux ?
- Quels sont les effets de la conformité aux mesures de limites maximales de résidus de pesticides sur la production, l'offre d'exportation et la demande d'importation ?
- Quel est l'impact direct des rejets de produits à la frontière des pays Européens du système d'alerte rapide pour les denrées alimentaires et les aliments pour animaux (RASFF) sur les exportations Africaines de produits végétaux ?

Nous abordons ces questions à travers trois essais. Dans le premier essai, nous analysons de façon théorique l'effet net des MTNT sur le commerce bilatéral et proposons une approche empirique robuste pour évaluer cet effet. Ensuite, nous évaluons les effets d'entrave et d'amélioration ainsi que l'effet net des MTNT en vigueur dans les pays de l'OCDE sur les exportations africaines de produits végétaux. Nos résultats théoriques montrent que l'effet net des MTNT sur le commerce bilatéral agrégé dépend non seulement de l'élasticité de substitution et de l'élasticité du coût marginal par rapport aux MTNT, mais aussi du paramètre de forme de la distribution des coûts marginaux qui dépend de la technologie. En plus, nous constatons que pour une élasticité de substitution donnée, seuls les pays caractérisés par un coût marginal inférieur à un coût marginal seuil et une productivité supérieure à un niveau de productivité seuil connaîtront un effet net positif du commerce vers une destination donnée. Dans le second essai, nous démêlons théoriquement et empiriquement les effets des LMR pour les pesticides sur la production, l'offre d'exportation et la demande d'importation pour un produit particulier, la mangue. Nous adoptons une approche de modélisation basée sur les coûts et les bénéfices associés aux normes de sécurité sanitaire des aliments et utilisons notre cadre théorique pour évaluer les effets empiriques nets des LMR de pesticides sur la production de mangues en Afrique et le commerce avec les pays membres de l'OCDE. Nous montrons que les effets des LMR sur la production sont négatifs tandis que leurs effets nets sur le commerce bilatéral peuvent être positifs, nuls ou négatifs selon que l'effet de la qualité perçue par les consommateurs sur la demande d'importation est supérieur, égal ou inférieur à l'effet du coût de mise en conformité sur l'offre d'exportation. Ce qui signifie que le renforcement ou l'imposition de LMR strictes pour les pesticides dans les pays développés peut favoriser les échanges commerciaux alors qu'ils entravent fortement la production dans les pays africains. Dans le dernier essai, nous estimons l'effet moyen des rejets aux frontières des pays du réseau RASFF sur les marges extensive et intensive de commerce de fruits et légumes comestibles pour 45 pays africains durant la période 2008 à 2018. Nous estimons la version canonique de l'équation de gravité sectorielle d'Anderson et al. (2004) en utilisant l'estimateur du Pseudo poisson maximum de vraisemblance (PPML) de Silva et al. (2006) en combinaison avec l'approche robuste d'estimation à deux étapes avec inclusion de résidus (2SRI) de Terza et al. (2008). Nous constatons qu'une augmentation du nombre de refus d'importation par un pays du RASFF une fois dans l'année en cours entraîne une diminution du nombre de partenaires commerciaux en Europe pour les pays africains. En outre, nos résultats montrent qu'un refus d'importation supplémentaire diminue la valeur des exportations de légumes comestibles des pays africains. Cependant, nous constatons que les refus d'importation des pays du RASFF une fois dans l'année en cours entraînent une augmentation de la valeur des exportations de fruits comestibles des pays africains. Par ailleurs, nos résultats valident explicitement l'hypothèse d'endogénéité du nombre de refus d'importation et mettent en évidence les effets directs et les effets de contagion des rejets aux frontières.

La suite de cette thèse est composée de trois grandes parties. Dans la première partie, nous analysons l'effet net des MTNT en vigueur dans les pays de l'OCDE sur les exportations africaines de produits végétaux. Dans la seconde partie, nous démêlons les effets de la conformité aux mesures de limites maximales de résidus de pesticides sur la production, l'offre d'exportation et la demande d'importation. Dans la dernière partie, nous évaluons l'effet des rejets de produits à la frontière des pays européens du RASFF sur les exportations africaines de produits végétaux.

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Chapitre 1

The Net Effect of Technical Non-Tariff Measures in OECD Countries on African Exports of Plant Products

1.1 Résumé

Dans cet article, nous analysons de façon théorique l'effet net des mesures techniques non tarifaires (MTNT) sur le commerce bilatéral et proposons une approche empirique robuste pour évaluer cet effet. Ensuite, nous évaluons les effets d'entrave et d'amélioration ainsi que l'effet net des MTNT en vigueur dans les pays de l'OCDE sur les exportations africaines de produits végétaux. Nos résultats théoriques montrent que l'effet net des MTNT sur le commerce bilatéral agrégé dépend non seulement de l'élasticité de substitution et de l'élasticité du coût marginal par rapport aux MTNT, mais aussi du paramètre de forme de la distribution des coûts marginaux qui dépend de la technologie. En plus, nous constatons que pour une élasticité de substitution donnée, seules les entreprises ou les pays caractérisés par un coût marginal inférieur à un coût marginal seuil et une productivité supérieure à un niveau de productivité seuil connaîtront un effet net positif du commerce vers une destination donnée. Pour nos investigations empiriques, nous estimons une équation de gravité sectorielle en utilisant la base de données des MTNT publiée par la CNUCED et le WITS, combinée aux données commerciales transversales pour 2017 de la base de données de UN COMTRADE/WITS. Les données couvrent 53 pays africains exportant 40 produits végétaux à 4 chiffres du Système harmonisé (SH) vers 35 pays membres de l'OCDE. Nos résultats empiriques montrent à la fois des effets d'entrave (diminution de 3,099%) et d'amélioration (augmentation de 2,056%) des MNT en vigueur dans les pays de l'OCDE sur les exportations africaines de produits végétaux. Ensemble, ces effets produisent un effet net négatif et significatif, ce qui indique que les MNT en vigueur dans les pays membres de l'OCDE constituent des obstacles pour les exportateurs africains de produits végétaux.
Mots-clés : Mesures techniques non tarifaires, Produits vegetaux, Commerce, Afrique, OCDE.
Codes JEL : Q17, Q18, F13, F14

1.2 Abstract

In this paper, we theoretically analyze the net effect of technical non-tariff measures (TNTMs) on bilateral trade and suggest a robust empirical approach to evaluate this effect. We assess the impediment, enhancement and net effects of the TNTMs in force in OECD countries on African exports of plant products. Our theoretical findings highlight that the net effect of the TNTMs on aggregate bilateral trade depends not only on the elasticity of substitution and the elasticity of marginal cost with respect to the TNTMs but also the shape parameter of the distribution of marginal costs which depends on the technology. In addition, we find that for a given elasticity of substitution, only firms or countries characterized by a lower marginal cost than a cutoff marginal cost and higher productivity than a threshold productivity level will experience a positive net effect of trade to a given destination. For our empirical investigation, we estimate a sectoral gravity equation using the non-tariff measures (NTMs) database released by UNCTAD and WITS combined with cross-sectional trade data for 2017 from the UN COMTRADE/WITS database. The data cover 53 African countries exporting 40 Harmonized System (HS) 4-digit plant products to 35 OECD member countries. Our empirical results show both impediment (decrease of 3.099%) and enhancement (increase of 2.056%) effects of the TNTMs in force in OECD countries on African exports of plant products. Together, these effects yield a negative and significant net effect, which indicates that the TNTMs in force in OECD member countries are obstacles for African exporters of plant products.

Keywords : Technical Non-Tariff Measures ; Plant Products ; Trade ; Africa ; OECD.
JEL codes : F13, F14, Q17, Q18.

1.3 Introduction

Trade in plant products between Africa and the member countries of the Organisation for Economic Co-operation and Development (OECD) has played a significant role in the export earnings and economic growth for many African countries during recent years. For instance, in 2017, the major trade partners of African countries in plant products were OECD member countries, with shares exceeding 30% in each of the five plant product groups presented in table 1.1. However, even if numerous bilateral, regional and multilateral trade agreements have contributed to this trade growth by eliminating customs duties and quantitative restrictions, noncompliance with technical non-tariff measures (TNTMs) [1] remains a substantial barrier to many African countries accessing OECD countries' markets. Indeed, during recent decades, the use by OECD countries of TNTMs such as measures related to sanitary and phytosanitary standards (SPSs) and technical barriers to trade (TBTs) has increased in the agri-food and agricultural sectors to reduce uncertainty over product quality and safety (MAST/UNCTAD, 2013; WTO, 2012). These stringent technical standards appear to limit African countries' access to OECD countries' markets, even if many of the latter have considerably lowered their tariff rates for the former. Indeed, during recent years, while ordinary customs tariffs have been considerably reduced, the non-tariff measures (NTMs) have proliferated (Beghin and Xiong, 2016; WTO, 2012). The NTMs are defined as *"policy measures other than ordinary customs tariffs that can potentially have an economic effect on international trade in goods, changing quantities traded, or price or both"* (MAST/UNCTAD, 2013). Among NTMs, TNTMs are the most frequently used (WTO, 2012; UNCTAD, 2017) ; they affect plant products more than other traded goods and have been seen to be more trade-impeding for African countries (Santeramo and Lamonaca, 2019). For instance, according to data from the International Trade Center (ITC Map) [2], the export potential of African countries for most plant products is still highly untapped [3]. This may be due not only to the financial, institutional and political constraints of African exporter countries but also to administrative formalities and technical difficulties that African exporter countries may face for accessing the markets of their actual and potential trade partners, among those there are OECD member countries. The latter countries have the highest number of regulations, and the measures are stricter than those recommended in the Codex [4] (Li et al., 2017). At the same time, most African countries have the lowest number of regulations and less restrictive measures. As a result, the more stringent and numerous regulations in force in OECD countries might represent substantial barriers to African exports, especially in sectors with high export potential, such as the plant products sector.

However, in the literature, there is no consensus on the trade effect of TNTMs. On the one hand, seve-

1. TNTMs refer to import measures classified in the first three chapters of the international classification of NTMs (2012 version). The first chapter (A) is composed of sanitary and phytosanitary standards (SPSs) ; the second (B) is related to technical barriers to trade (TBTs) ; and the third chapter (C) concerns preshipment inspection requirements and other formalities.

2. http://exportpotential.intracen.org

3. See figures 1.3, 1.5, 1.7, 1.9 and 1.11 in appendix A

4. The Codex Alimentarius is the international framework for food standards involving the WHO and FAO : http://www.fao.org/fao-who-codexalimentarius/home/en/.

ral previous studies (Disdier et al., 2008; Hoekman and Nicita, 2011; Otsuki et al., 2001) indicate that TNTMs are substantial barriers to trade. These studies offer evidence that compliance with a stricter TNTM may increase both the fixed and variable costs of production and the distribution costs for suppliers in countries where standards are less stringent. Fixed costs may include, for example, the upgrade of practice codes and facilities, the acquisition of certificates and compliance with marketing requirements. In addition, some other costs may come from the prolonged delivery time due to inspection and testing procedures at customs points, the rejection of certain shipments, or even denial of entry. More specifically, for suppliers of fresh plant products (e.g., fruits and vegetables) to comply with some specific TNTMs, they need to invest in better storage facilities, mandatory labeling and training of labor (Disdier et al., 2008). Given that African countries face more constraints in meeting stricter standards (Henson and Jaffee, 2004; Kareem et al., 2017; Martin, 2018), TNTMs can reduce supply from these countries or even exclude less productive suppliers from destination markets where standards are more stringent. Most African countries face deficient infrastructures and insufficient technical and storage capacities (Beestermöller et al., 2018), and they often have limited access to certification bodies (Essaji, 2008). Other studies (Medin, 2019; Santeramo and Lamonaca, 2019; Xiong and Beghin, 2014) show that TNTMs may enhance import demand through their product quality and information improvement effects. Indeed, TNTMs such as SPS measures can increase trade by mitigating phytosanitary risks associated with agrifood consumption. In the same vein, TBTs may enhance consumer trust, reduce transaction costs and increase consumer demand by addressing market failures such as imperfect or asymmetric information between consumers and suppliers with respect to quality, safety and any product characteristics other than price (Crampes and Hollander, 1995; Leland, 1979; Ronnen, 1991; Xiong and Beghin, 2014). For example, when information is asymmetric, the introduction of TNTMs can force suppliers to improve the quality and safety of their products and provide reliable information to consumers about product attributes beyond prices. Therefore, among consumers who value such characteristics, which may be tangible (e.g., size and color) or intangible (e.g. reputation and safety), TNTMs might help to increase demand for these products. This is especially the case for consumers in developed countries such as OECD member countries. According to Okello et al. (2007), increased demand for higher-quality and safer products in developed countries is correlated with the proliferation of TNTMs in agricultural and agrifood sectors. However, Santeramo and Lamonaca (2019) highlighted that the effects of the proliferation of NTMs on international trade depend on the type of NTM, the countries in partnership and the type of commodity.

In this paper, we focus on the technical NTMs in force in the OECD member countries and the impacts of the measures on African exports of plant products. First, we theoretically analyze the net effect of technical non-tariff measures (TNTMs) on bilateral trade. In complement to previous studies, we show that the net effect of TNTMs on aggregate bilateral trade depends not only on the elasticity of substitution between varieties of products and the elasticity of marginal cost with respect to the TNTMs but also the shape parameter of the distribution of marginal costs which depends on the technology. In addition, our theoretical findings highlight that for a given elasticity of substitution, stringent TNTMs reduce the exports of firms or countries that exhibit higher marginal cost of compliance with TNTMs and lower productivity. In contrast, firms or countries that face fewer constraints in complying with TNTMs and have higher productivity may generate a positive net trade effect. Second, we suggest a robust empirical approach to evaluate the effects of the TNTMs on bilateral trade and following this proposed empirical strategy we assess the impediment, enhancement and net effects of the TNTMs in force in OECD countries on African exports of plant products. For our empirical investigations, we estimate a sectoral gravity equation using cross-sectional data for 2017. These data cover 53 African countries exporting 40 Harmonized System (HS) 4-digit plant products to 35 OECD member countries. The trade database for 2017 is then merged with data on the TNTMs in force in OECD member countries on May 9, 2019 [5]. Our empirical results support both the trade-impeding (decrease of 3.099%) and trade-enhancing (increase of 2.056%) effects of the TNTMs in force in OECD countries on African exports of plant products. Together, these effects yield a negative and significant net trade effect associated with TNTMs, which indicates that the TNTMs in force in OECD member countries are obstacles for African exporters of plant products. To the best of our knowledge, no study in the literature has analyzed the net effect of all TNTMs in force in OECD countries on African exports of plant products, although these stringent-TNTM countries represent the main destination markets for African exports of these products. Most of the empirical studies (Anders and Caswell, 2009; Henson et al., 2000; Otsuki et al., 2001; Santeramo and Lamonaca, 2019; Shepherd and Wilson, 2013; Wilson and Otsuki, 2004; Xiong and Beghin, 2011) that investigated the effect of NTMs on African trade only focused on a single TNTM, considering whether this measure is a trade barrier or trade catalyst, but seldom examined whether TNTMs are both at the same time. One of the rarely studies that has clearly investigated the net effect of a TNTM on trade is Xiong and Beghin (2014), who disentangled the dual effects of maximum residue levels (MRLs) for pesticide, a particular type of TNTM, on OECD countries' imports of plant products from developed and developing countries. Unlike previous studies (Xiong and Beghin, 2014; Medin, 2019), we appropriately measure both separately and simultaneously *"the perceived quality and the costs associated with TNTMs"* from consumer demand and exporter prices.

The remainder of this article is organized as follows. In section 1.4, we highlight some empirical evidence on African exports of plant products and related NTMs in force in OECD countries. In section 1.5, we provide a theoretical gravity model from which we derive the net effect of TNTMs on the bilateral equilibrium trade. In section 1.6, we describe our empirical strategy. In section 1.7, we present and discuss the empirical results. In the last section, we draw conclusions.

5. The NTM database is a cross-sectional data set. Since we compiled our data in 2019, we used more comprehensive cross-sectional trade data for 2017 and assumed that the stock of TNTMs in 2019 was not significantly different from that in 2017. In fact, new NTMs reported to the WTO are often updates of existing ones, so the stock of NTMs does not change significantly over short periods (Disdier et al., 2018).

1.4 Some empirical evidence on African exports of plant products and related NTMs in force in OECD countries

Table 1.1 shows the destinations of African exports of plant products in 2017 and the shares of each destination market. We find that OECD member countries represent the main destination market (with shares representing more than 30%) for all plant product groups except for cereal products (Harmonized System Chapter 10, HS10), for which the share of intra-Africa trade is 73%. The shares of OECD member countries in African exports of products classified in Harmonized System Chapters 7 (HS07) and 9 (HS09), approximately 40% and 44%, respectively, are greater than those for the other product groups. These groups are followed by the product groups HS08 and HS12, both with 35%. These findings indicate that African exports depend strongly on OECD member countries. Hence, a change in OECD market access regulations, such as the number or stringency of technical non-tariff measures, may affect the exports of African countries for these plant products. On the other hand, we find that the untapped export potential is very high for all African exporters in each plant products group [6]. In addition, we observe that African countries with a higher share of untapped export potential are those, in most cases, with fewer technical non-tariff measures [7], which indicates that the TNTMs in force in African exporter countries favor exports to OECD member countries. However, TNTMs in force in OECD countries may represent an obstacle. Therefore, we analyze the number of OECD trade partners in Africa with respect to their market access regulations in terms of the number of TNTMs.

TABLE 1.1 – Direction of African exports and shares of import from Africa, Year 2017

Exporter	**Importer**	**hs07**	**hs08**	**hs09**	**hs10**	**hs12**
		Share (in %)				
Africa	World	100	100	100	100	100
Africa	Africa	7.04	2.47	11.44	72.89	8.05
Africa	*OECD*	*39.89*	*35.18*	*44.13*	*17.66*	*34.84*
Africa	Rest of the World	53.07	62.35	44.43	9.45	57.11

Source : Authors calculation based on data from UN/COMTRADE/WITS, 2017

hs07 : Edible vegetables

hs08 : Edible fruits and nut ; peel of citrus fruit or melon

hs09 : Coffee, tea, mate and spice

hs10 : Cereals

hs12 : Oil seed, oleagi fruits ; miscall grain, seed

For each of the five product groups (HS07, HS08, HS09, HS10 and HS12), we observe that the lowest number of TNTMs in force in OECD countries is almost equal to the highest number of TNTMs in force in African exporter countries. In addition, figures 1.13, 1.15, 1.17, 1.19 and 1.21 in appendix A show that OECD countries with a lower number of partners in Africa are among those with a higher number of technical NTMs. Moreover, from figures 1.14, 1.16, 1.18, 1.20 and 1.22 in appendix A, the greater the number of technical NTMs in force is, the lower the number of trade partners in Africa for

6. See figures 1.3, 1.5, 1.7, 1.9 and 1.11 in appendix A
7. See figures 1.4, 1.6, 1.8, 1.10 and 1.12 in appendix A

each of the five plant product groups is. For instance, for the product group HS07, the OECD member countries with a high number of partners in Africa (more than 25) are the Netherlands, France, Switzerland and the United Kingdom. All of these countries have less than 50 measures imposed on edible vegetables (HS07) compared to more than 200 measures in force in Chile and New Zealand, which both have fewer than 10 partners in Africa. This indicates, as we already mentioned above, that the technical NTMs in force in OECD member countries potentially represent obstacles to African exports. However, some countries that have a high number of partners in Africa also have a high number of technical NTMs. For instance, the United States have the highest number of TNTMs imposed on edible vegetables (HS07), but they also have a high number of partners in Africa. This may be due to some market access facilities, such as the African Growth and Opportunity Act (AGOA), which the USA passed in 2000 with reference to certain African countries (sub-Saharan African, SSA).

1.5 The Theoretical Model

This section presents our modeling approach to analyzing the net effect of TNTMs on bilateral trade. Given that the number of TNTMs is lowest in African countries and the measures are less restrictive, and assuming that the TNTMs in force in OECD countries mitigate sanitary risk and reduce information asymmetry between consumers and suppliers related to product quality and safety attributes, we adopt a cost-benefit approach to evaluate the perceived quality effect of TNTMs on import demand and their cost effect on export supply.

1.5.1 Preferences and demand

Following Curzi and Pacca (2015); Hallak and Sivadasan (2013) and Xiong and Beghin (2014), we assume a representative consumer in each importer country j with preferences characterized by a constant elasticity of substitution (CES) utility function. Due to the set of TNTMs in force in each importing country j, the representative consumer is assumed to be perfectly informed about all of the attributes of plant product k exported by each exporting country i. She/he vertically differentiates the varieties by origin due to the reputation of each exporting country in terms of the quality and safety attributes of its products. The representative consumer maximizes the following CES utility function subject to her/his budget constraint :

$$U_j = \left[\sum_i \sum_{\Omega_{ij}^k} \left[\theta_{ij}^k(\nu) q_{ij}^k(\nu) \right]^{\frac{\sigma^k - 1}{\sigma^k}} d\nu \right]^{\frac{\sigma^k}{\sigma^k - 1}} \tag{1.1}$$

where ν indexes the varieties (origin) of plant product k; $q_{ij}^k(\nu)$ is the consumer's quantity demanded for variety ν of good k produced in country i; $\sigma^k > 1$ is a parameter capturing the elasticity of substitution between varieties of plant product k; and $\theta_{ij}^k(\nu)$ is the representative consumer's perceived quality of variety ν of plant product k imported from country i. *Perceived quality is defined as any* *tangible or intangible attributes other than price that the representative consumer values* (Hallak and Sivadasan, 2013; Kugler and Verhoogen, 2011; Piveteau and Smagghue, 2019).

The consumer's quantity demanded of variety v of good k imported from country i is obtained by maximizing the utility function (equation (1.1)) under the budget constraint :

$$q_{ij}^k = (\theta_{ij}^k)^{\sigma^k - 1}(P_{ij}^k)^{-\sigma^k} E_j^k (P_j^k)^{\sigma^k - 1} \tag{1.2}$$

where P_{ij}^k is the consumer price of plant product k imported from country i and sold in country j; E_j^k is the amount of income allocated to product k in country j; and P_j^k is the consumer price index of good k in country j.

Consistent with prior research (Xiong and Beghin, 2014) and with our definition of perceived quality, we assume that the information disclosed by the TNTMs, among other factors, influences consumer preferences for plant products. Thus, we parameterize θ_{ij}^k as follows :

$$\theta_{ij}^k = \delta_0^k \exp\left(\beta ln(tntm_j^k)\right) \tag{1.3}$$

where δ_0^k is the consumer's quality perception for good k in the absence of a TNTM regulation and $ln(tntm_j^k)$ is the logarithm of the number of TNTMs applied to good k by importing country j. β is a parameter to be estimated that captures the extent to which the TNTMs affect the consumer's quality perception of good k.

1.5.2 Technology, market structure and marginal cost

We assume that there are n_i^k potential firms in each exporting country i and sector k. These firms produce under monopolistic competition with a technology characterized by a Cobb-Douglas function. Each firm is negligible for a given destination market, such that the firm sets its price while accurately treating the market aggregates as given. As highlighted in section 1.3, we assume that to serve destination market j, each exporting firm has to pay a bilateral iceberg trade costs ($\tau_{ij}^k \geq 1$) and a unit cost of compliance ($\xi_{ij}^k \geq 1$) with TNTMs in force in destination market. Next, let ω_i be the price of the production factors in origin country i and ϕ_i^k the productivity of a given firm in sector k; then following (Feenstra, 2016, p.157) we can write the marginal cost of supply one unit of a variety of product k to a given destination country j as follow :

$$c_{ij}^k = \frac{\omega_i}{\phi_i^k} \tau_{ij}^k (\xi_{ij}^k)^{\alpha^k} \tag{1.4}$$

Furthermore, we assume that the unit cost of compliance ($\xi_{ij}^k \geq 1$) is increasing in the number of TNMTs in force in importing country j affecting product k. The unit cost of compliance with TNTMs is assumed to be identical to the consumer's quality perception (θ_{ij}^k) in importing country j (see Feenstra et al. (2018) and Feenstra and Romalis (2014)). Following the latter authors, we assume that the consumer' perceived quality (demand shifter) and the unit cost of compliance with TNTMs (supply shifter) are unobserved factors that influence identically, without loss of generality, the demand and supply. Therefore, to account for these unobserved factors we explicitly model the perceived quality and the corresponding cost in the demand and supply equations such that :

$$\xi_{ij}^{k} \equiv \theta_{ij}^{k} = h(tntm_{j}^{k}) \tag{1.5}$$

where the function $h(tntm_j^k)$ is defined by equation (1.3). Identity (1.5) signifies that the passthrough of the TNTMs in force in an importing country to perceived quality is identical to the passthrough of the TNTMs of that importing country to the unit cost of compliance in an exporting country. Intuitively, this implies that an exporter would comply with the TNMTs in force in a given importing country if and only if the unit cost it has to pay to comply with the TNTMs of that importing country is equal to the perceived value generated by the TNTMs that consumers are willing to pay.

1.5.3 Market Equilibrium and the Net Effect of TNTMs

Given the assumptions on the market structure (monopolistic competition), production technology form (Cobb-Douglas function) and characterization of representative consumer preferences (CES utility function), the market clearing condition yields the following equilibrium price (P_{ij}^k) and trade value (X_{ij}^k) :

Equilibrium price

$$P_{ij}^{k} = \frac{\sigma^{k}}{\sigma^{k}-1} c_{ij}^{k} = \frac{\sigma^{k}}{\sigma^{k}-1} \frac{\omega_i}{\phi_i^{k}} \tau_{ij}^{k} (\xi_{ij}^{k})^{\alpha^{k}} \tag{1.6}$$

where P_{ij}^k is the equilibrium price that equalizes producer supply and consumer demand in the monopolistic market. α^k is a parameter that measures the passthrough of the unit cost of compliance with TNTMs (ξ_{ij}^k) to consumer price (P_{ij}^k). Under monopolistic competition with a constant markup, there is a perfect passthrough (e.g., $\alpha^k = 1$). However, several previous studies found an imperfect passthrough. For example, Piveteau and Smagghue (2019) found a passthrough of 25 percent of import exchange rates to export prices of French firms. Then we assume that α^k is equal or less than one ($\alpha^k \leq 1$). Now, plugging equation (1.6) into the consumer's quantity demand equation (1.2), we obtain the bilateral equilibrium trade as a function of the consumer's perceived quality (θ_{ij}^k) and the unit cost (ξ_{ij}^k) of compliance with TNTMs, which enables us to derive the *net effect* of the TNTMs on bilateral trade.

Equilibrium trade

$$X_{ij}^{k} = \left(\frac{\sigma^{k}}{\sigma^{k}-1}\right)^{-\sigma^{k}} \left(\xi_{ij}^{k}\right)^{-\alpha^{k}\sigma^{k}} \left(\theta_{ij}^{k}\right)^{\sigma^{k}-1} (\omega_i)^{-\sigma^{k}} \left(\phi_i^{k}\right)^{\sigma^{k}} \left(\tau_{ij}^{k}\right)^{-\sigma^{k}} \left(P_j^{k}\right)^{\sigma^{k}-1} E_j^{k} \tag{1.7}$$

with X_{ij}^k being the volume of equilibrium trade for a variety of product k produced in country i and exported to country j. Equation (1.7) suggests that bilateral equilibrium trade is increasing in the *consumer's perceived quality (θ_{ij}^k)* of product k produced in country i, the productivity of firms producing a variety of product k (ϕ_i^k), the consumer price index of product k (P_j^k) and the income (E_j^k) allocated to this product in country of destination j. On the other hand, equation (1.7) shows that trade is decreasing in *the unit cost (ξ_{ij}^k)* of complying with the TNTMs, the price (ω_i) of production factors in country i and the iceberg trade cost (τ_{ij}^k).

Net effect of the TNTMs on bilateral equilibrium trade

We derive the *net effect* of the TNTMs on bilateral trade from equation (1.7) for equilibrium trade, equation (1.3) for consumer's perceived quality, and identity (1.5) as follow :

$$\frac{\partial ln(X_{ij}^k)}{\partial ln(tntm_j^k)} = \beta \left[\sigma^k(1-\alpha^k)-1\right] \begin{cases} =0 & \text{if} \quad \alpha^k = \frac{\sigma^k-1}{\sigma^k} \\ >0 & \text{if} \quad \alpha^k < \frac{\sigma^k-1}{\sigma^k} \\ <0 & \text{if} \quad \alpha^k > \frac{\sigma^k-1}{\sigma^k} \end{cases} \tag{1.8}$$

where $\frac{\partial ln(\xi_{ij}^k)}{\partial ln(tntm_j^k)} \equiv \frac{\partial ln(\theta_{ij}^k)}{\partial ln(tntm_j^k)} = \beta$ (see equation (1.3) and identity (1.5)). Equation (1.8) shows that the net trade effect of the TNTMs is positive or zero if and only if the elasticity (α^k) of marginal cost with respect to the TNTMs is less than or equal to the inverse of the producer markup, which is equal to the ratio between the marginal cost (c_{ij}^k) and the producer price (P_{ij}^k), $\frac{\sigma^k-1}{\sigma^k} = \frac{c_{ij}^k}{P_{ij}^k}$. However, if the elasticity of the marginal cost with respect to the TNTMs is greater than the inverse of the producer markup, then the net effect of the TNTMs on equilibrium trade will be negative. Now let us relate the elasticity of the marginal cost with respect to the TNTMs (α^k) to the firm's marginal cost (c_{ij}^k) and productivity (ϕ_i^k) through the following expression : $\alpha^k = \frac{\sigma^k-1}{\sigma^k} = \frac{c_{ij}^k}{P_{ij}^k}$, where c_{ij}^k is defined by equation (1.4). Given that $\alpha^k = \frac{c_{ij}^k}{P_{ij}^k}$ and that the marginal cost (c_{ij}^k) is decreasing in firm productivity (ϕ_i^k), the elasticity (α^k) of the marginal cost with respect to the TNTMs will also decrease with firm productivity. Figure 1.1 presents the relationship between the elasticity of the marginal cost and firm productivity and characterizes which firms are more or less likely to experience a positive net trade effect from the TNTMs of a given market.

From equation (1.8) and figure 1.1, we draw the following results :

— **Result 1 :** *For a given elasticity of substitution σ^k with a corresponding inverse markup $\tilde{\alpha}^k = \frac{\sigma^k-1}{\sigma^k}$, only firms characterized by a lower marginal cost than a cutoff marginal cost $\tilde{c}_{ij}^k = \frac{\sigma^k-1}{\sigma^k}P_{ij}^k$ and higher productivity than a threshold productivity level $\tilde{\phi}_i^k = \frac{\omega_i \tau_{ij}^k (\xi_{ij}^k)^{\tilde{\alpha}^k}}{\tilde{\alpha}^k P_{ij}^k}$ will experience a positive net trade effect with a given destination. However, firms with a higher marginal cost than the cutoff marginal cost and lower productivity than the threshold productivity level will generate* *a negative net trade effect. Finally, firms that have a marginal cost equal to the cutoff marginal cost and productivity equal to the threshold productivity level will see a net trade effect of zero.*

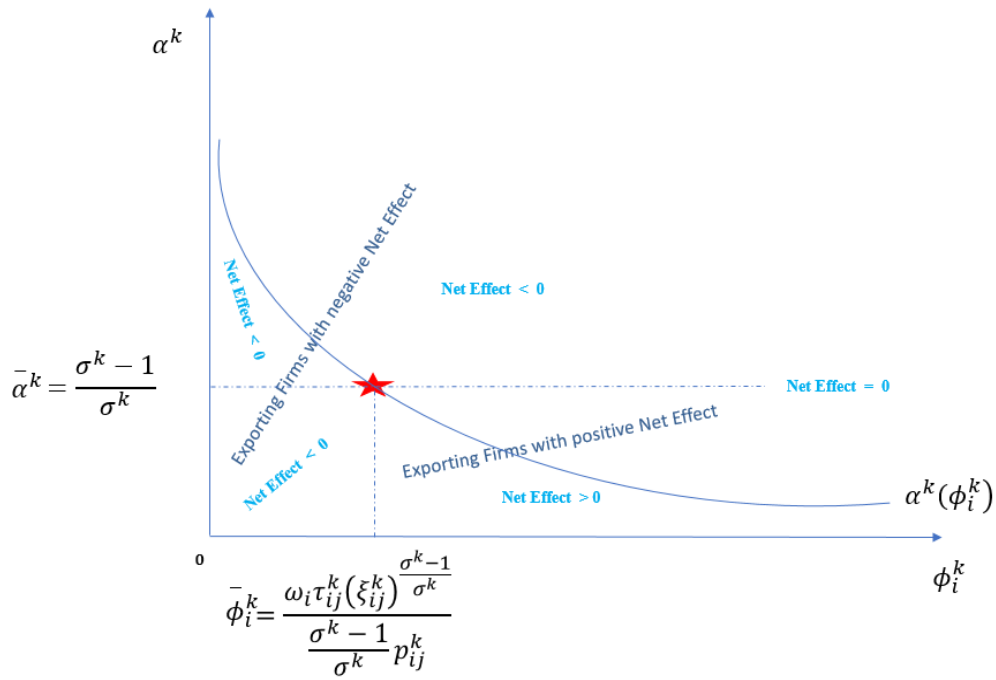

FIGURE 1.1 – Changes in Net Effect in the dimension of Marginal Cost and Productivity

— **Result 2 :** *Stringent TNTMs reduce the exports of firms characterized by higher marginal cost of compliance with TNTMs (greater than the cutoff marginal cost $\tilde{c}_i^k$) and lower productivity (less than the productivity $\tilde{\phi}_i^k$ required to obtain a positive net effect). In contrast, firms that face fewer constraints in complying with TNTMs and have higher productivity may generate a positive net trade effect.*

1.5.4 Aggregating Exports and Averaging Price over Firms by Origin-Destination-Product

In this subsection, we provide the aggregated trade and average price by sector. To obtain the aggregate bilateral trade within a given sector k, we sum the exports values of individual firms, which is defined as the product of the quantity of consumer demand (q_{ij}^k) for a variety (firm) of product k (equation (1.2)) and the exporter price (P_{ij}^k) given by equation (1.6). Next, let us assume that there is a constant number (n_i^k) of potential exporting firms in sector k and origin country i. Moreover, following (Fally, 2019, p.10), let assume that the marginal costs, c_{ij}^k, of supply of firms operating in sector k are Pareto-distributed with cumulative density function (cdf) $G_i^k(c_{ij}^k) = b_i^k (c_{ij}^k)^{\eta^k}$ and probability density function (pdf) $g_i^k(c_{ij}^k) = \eta^k b_i^k (c_{ij}^k)^{\eta^k - 1}$, where $\eta^k > 1$ is a shape parameter that measures the amount of variation within the distribution of marginal costs in sector k, with a bigger η^k implies less variability in marginal costs between firms operating in sector k. $b_i^k > 0$ describes the average productivity or level of technology in sector k of country i. Given the number (n_i^k) of potential exporting firms, the distribution assumption on marginal costs within sector k and the threshold marginal cost ($\tilde{c}_{ij}^k$) defined by equation (1.4), it is straightforward to define the total exports value (V_{ij}^k) by :

$$\begin{aligned} V_{ij}^k = & \; n_i^k \int_{c=0}^{\tilde{c}_{ij}^k} P_{ij}^k(c) q_{ij}^k(c) g_i^k(c) dc \\ & = A_0^k A_i^k \left(\xi_{ij}^k\right)^{\alpha^k(\eta^k - \sigma^k + 1)} \left(\theta_{ij}^k\right)^{\sigma_k - 1} \left(\tau_{ij}^k\right)^{\eta^k - \sigma^k + 1} \left(P_j^k\right)^{\sigma_k - 1} E_j^k \end{aligned} \tag{1.9}$$

where $\eta^k \in (1, \sigma^k - 1)$. $P_{ij}^k(c)$ is the exporter price defined by equation (1.6), and $q_{ij}^k(c)$ the quantity of consumer demand for a variety of product k given by equation (1.2).
$A_0^k = \frac{\eta^k}{\eta^k - \sigma^k + 1} \left(\frac{\sigma^k}{\sigma - 1}\right)^{1-\sigma^k}$ is a constant term, and $A_i^k = n_i^k b_i^k \left(\frac{\omega_i}{\phi_i^k}\right)^{\eta^k - \sigma^k + 1}$ is a factor that embodies all of the information related to sector k in origin country i, which includes the number (n_i^k) of potential exporting firms in the sector, the average productivity or level of technology (b_i^k), the production factor prices (ω_i) in origin country i and the productivity (ϕ_i^k) of individual firms in sector k. ξ_{ij}^k is the unit cost of compliance with TNTMs, and θ_{ij}^k indicates the consumer's perceived quality of product k produced in country i. τ_{ij}^k the bilateral iceberg trade cost, P_j^k is the consumer price index of product k, and E_j^k is the income allocated to the consumption of product k in destination country j.

As in equation (1.7), equation (1.9) shows that the aggregate bilateral trade is increasing in the *consumer's perceived quality (θ_{ij}^k)* of product k produced in country i, the consumer price index (P_j^k) of product k and the income (E_j^k) allocated to this product in country of destination j. On the other hand, equation (1.9) suggests that the aggregate bilateral trade is decreasing in *the unit cost (ξ_{ij}^k)* of complying with the TNTMs and the iceberg bilateral trade cost (τ_{ij}^k). From equation (1.9), we can derive the *net effect* of the TNTMs on aggregate bilateral trade as follow :

$$\frac{\partial ln(V_{ij}^k)}{\partial ln(tntm_j^k)} = \beta \left[\alpha^k \left(\eta^k - \sigma^k + 1\right) + (\sigma^k - 1)\right] \begin{cases} = 0 & \text{if} \quad \alpha^k = \frac{\sigma^k - 1}{\sigma^k - 1 - \eta^k} \\ > 0 & \text{if} \quad \alpha^k < \frac{\sigma^k - 1}{\sigma^k - 1 - \eta^k} \\ < 0 & \text{if} \quad \alpha^k > \frac{\sigma^k - 1}{\sigma^k - 1 - \eta^k} \end{cases} \tag{1.10}$$

where $\frac{\partial ln(\xi_{ij}^k)}{\partial ln(tntm_j^k)} \equiv \frac{\partial ln(\theta_{ij}^k)}{\partial ln(tntm_j^k)} = \beta$ (see equation (1.3) and identity (1.5)). Equation (1.10) indicates that the net effect of the TNTMs on aggregate bilateral trade is a function not only of the elasticity of substitution (σ^k) and the elasticity (α^k) of marginal cost with respect to the TNTMs but also the shape parameter (η^k). This equation implies thus that, for a given elasticity of substitution (σ^k) and a shape parameter (η^k), the net effect of the TNTMs on aggregate bilateral trade is positive or zero if and only if the elasticity (α^k) of marginal cost with respect to the TNTMs is less than or equal to a cutoff value of $\frac{\sigma^k-1}{\sigma^k-1-\eta^k}$. However, if this elasticity is greater than the cutoff value of $\frac{\sigma^k-1}{\sigma^k-1-\eta^k}$, then the net effect of the TNTMs on aggregate bilateral trade will be negative.

— **Result 3 :** *Stringent TNTMs reduce the exports of countries characterized by higher elasticity ($\alpha^k > \frac{\sigma^k-1}{\sigma^k-1-\eta^k}$) of marginal cost with respect to TNTMs in force in the importing country. In contrast, countries that face fewer constraints (lower value for elasticity, $\alpha^k \leq \frac{\sigma^k-1}{\sigma^k-1-\eta^k}$) in complying with TNTMs will potentially generate a positive or zero net trade effect.*

Next, we test these theoretical results for African exporters in our empirical investigation. Given that African exporters face more constraints in complying with TNTMs (higher marginal cost) and have potentially lower productivity than exporters in other countries, one may predict that a negative net trade effect is more likely to be observed for them. In contrast, exporters that face fewer constraints in complying with TNTMs (low marginal cost) and have higher productivity may generate a positive net trade effect.

We can now define the average bilateral price ($\bar{P}_{ij}^k$) of product k as the export unit value by using the total exports value (V_{ij}^k) in equation (1.9) and the quantity of consumer demand for product k given in equation (1.2). The export unit value is equal to the ratio between the total exports value (V_{ij}^k) and the total quantity of consumer demand for product k. This is a traditional practice in international trade analysis when computing exporter prices since the latter are rarely observed. Finally, we define the average bilateral export unit value ($\bar{P}_{ij}^k$) as follow :

$$\begin{aligned}\bar{P}_{ij}^k = & \frac{n_i^k \int_0^{\tilde{c}_i^k} P_{ij}^k(c) q_{ij}^k(c) g_i^k(c) dc}{n_i^k \int_0^{\tilde{c}_i^k} q_{ij}^k(c) g_i^k(c) dc} \\ & = \frac{\eta^k-\sigma^k}{\eta^k-\sigma^k+1} \left(\frac{\sigma^k}{\sigma^k-1}\right) \frac{\omega_i}{\phi_i^k} \tau_{ij} (\xi_{ij}^k)^{\alpha^k}\end{aligned} \tag{1.11}$$

1.6 The Empirical Strategy

In this section, we describe, first, how we measure the consumers' perceived quality for a variety of products imported from a given country and, second, our strategy to measure the unit cost of compliance with the TNTMs in force in a given importing country. Then, we present the equation to be estimated to evaluate the empirical effects of the TNTMs in force in OECD member countries on African exports of plant products. Finally, we describe the data used for our empirical investigation.

1.6.1 Evaluating Consumers' Perceived Quality

Let us assume that the use of stringent technical NTMs by importing countries allows us to perfectly reveal to consumers all of the information about the quality and safety attributes of products exported by each country. We follow Khandelwal et al. (2013) and use demand equation (1.2) to derive the representative consumer's perceived quality of a plant product imported from each country (θ_{ij}^k). This method to infer product quality differs from traditional methods that use price or unit value to measure quality. Indeed, using price to measure quality suffers from some limitations because a higher price does not necessarily reflect higher product quality. In many contexts, higher prices may be due to higher product differentiation (lower elasticity of substitution), lower productivity (this may be the case for African countries) and higher production and transportation costs (this is the case for African countries). Hence, we cannot use price (unit value) to measure the quality of a product in a given importing country. To empirically estimate quality, we follow (Khandelwal et al., 2013, pp.2187) and (Curzi and Pacca, 2015, pp.150), who used a CES demand function to infer product quality. According to these authors, quality is estimated by taking the residual from the CES demand function and dividing it by the destination market-specific elasticity of substitution minus one. Similar to (Curzi and Pacca, 2015, pp.150), we infer the quality of a given product from the consumer demand equation, defined by equation (1.2), by following a two-step procedure :

— 1^{st} *step :* Regress the logarithm of equation (1.2) for the consumer's CES demand

$$lnq_{ij}^k + \sigma^k lnP_{ij}^k = \gamma_i^k + \gamma_j^k + e_{ij}^k \tag{1.12}$$

where q_{ij}^k indicates consumer demand for product k imported by country i into country j and P_{ij}^k is the consumer price (unit value) for plant product k imported from country i and sold in country j. γ_i^k and γ_j^k account for exporter product- and importer product-specific fixed effects, respectively. e_{ij}^k is the standard error term.

— 2^{nd} *step :* Infer the quality from the residual of the estimated demand in equation (2.32)
Now, the quality is estimated by taking the residual $(\widehat{e_{ij}^k})$ from equation (2.32) and dividing it by the destination market-specific elasticity of substitution minus 1, so the quality of product k is $\theta_{ij}^k \equiv \frac{\widehat{e_{ij}^k}}{\sigma^k - 1}$. We measure the quality for $\sigma \approx 3$, which is close to the mean value of 3.28 for vegetable products estimated by (Piveteau and Smagghue, 2019, p.20) and to the median value of the micro-Armington elasticity of 3.22 estimated by (Feenstra et al., 2018, p.144) over a sample of 98 ten-digit import goods into the United States. This value of σ is also close to the median estimate of 3.10 from (Broda and Weinstein, 2006, p.568) computed over some 10 000 HS import product categories.

1.6.2 Evaluating the Unit Cost of Compliance with TNTMs

Our strategy is similar to that used by (Disdier et al., 2018, pp.23-25) to compute the additional unit cost of compliance with TNTMs. We infer the unit cost of compliance with the TNTMs in force in a given importing country by using the logarithm of the average exporter price given in equation (1.11) as follows :

$$ln\bar{P}_{ij}^k = m_0 + ln(\omega_i) - ln(\phi_i^k) + ln(\tau_{ij}^k) + \alpha^k ln(\xi_{ij}^k) + \varepsilon_{ij}^k \tag{1.13}$$

with $m_0 = ln\left(\frac{\eta^k - \sigma^k}{\eta^k - \sigma^k + 1}\left(\frac{\sigma^k}{\sigma^k - 1}\right)\right)$ is a constant, ω_i the price of production factors in country i, ϕ_i^k the productivity of a given firm in sector k and country i, and τ_{ij}^k the iceberg bilateral trade cost between exporting country i and importing country j. The variable ξ_{ij}^k measures the unit cost of compliance with the TNTMs in force in destination market j affecting product k imported from country i. Equation (1.13) defines the price as a function of exporter-specific characteristics, exporter-product pair-specific characteristics and importer-product pair-specific characteristics as well as the bilateral trade cost variables. Exporter-specific characteristics include the price of production factors (ω_i), and the exporter-product pair-specific characteristic is the productivity (ϕ_i^k) of a given firm in each considered product sector k. The importer-product pair-specific characteristic is the markup of exporters selling a given product k in the importing country. Finally, the empirical specification of unit price equation (1.13) can be rewritten as follows :

$$ln\bar{P}_{ij}^k = fe_i^k + fe_j^k + ln(\tau_{ij}^k) + \alpha^k ln(\xi_{ij}^k) + \varepsilon_{ij}^k \tag{1.14}$$

where the fixed effects fe_i^k and fe_j^k control for exporter-product pair-specific characteristics and importer-product pair-specific characteristics, respectively. The fixed effects fe_i^k control for the price of production factors in exporting country i and the productivity of firms in sector k. The fixed effects fe_j^k control for the markup of exporters selling product k in importing country j.

Given that the unit cost (ξ_{ij}^k) of compliance with TNTMs in equation (1.14) is unobservable, we follow Disdier et al. (2018) by using the ordinary least squares (OLS) method to estimate this equation without the cost variable $\ln(\xi_{ij}^k)$ and then use the residuals as the measure of the unit cost of compliance with TNTMs. Consistent with equation (1.6), the estimated $\ln(\widehat{\xi_{ij}^k})$ from (1.14) is equal to the log of the unit cost of compliance with the TNTMs in force in an importing country j affecting product k of an exporting country i, so the *unit cost of compliance* is $\ln(\xi_{ij}^k) \equiv \ln(\widehat{\varepsilon_{ij}^k})$, where α^k is set to one. One limitation of using price residuals as a measure of the unit cost of compliance with TNTMs is that the residuals may potentially include other unobservable factors such as supply or demand shocks. However, since we control for exporter-product pair-specific characteristics and importer-product pair-specific characteristics as well as traditional bilateral trade costs, the price residual may be considered as an appropriate measure of the unit cost of compliance with TNTMs.

1.6.3 Estimating the Effects of Technical NTMs on African Exports

We can now evaluate the effects of the universe of technical NTMs in force in OECD member countries on aggregate bilateral exports value of African plant products by exploiting the estimated measures of consumer perceived quality (equation (2.32)) and unit cost of compliance with TNTMs (equation (1.14)). The theoretical model characterized by the aggregate bilateral export value (equation (1.9)) provides a basis for our empirical investigation. We thus use the logarithm of this equation to assess the effects of the technical NTMs in force in OECD member countries on the total exports value of African plant products as follow :

$$
\begin{aligned}
ln(V_{ij}^k) &= a_0^k + a_i^k + \alpha^k(\eta^k - \sigma^k + 1)ln\left(\xi_{ij}^k\right) + (\sigma^k - 1)ln\left(\theta_{ij}^k\right) \\
&+ (\eta^k - \sigma^k + 1)ln\left(\tau_{ij}^k\right) + ln\left(E_j^k\right) + (\sigma^k - 1)ln\left(P_j^k\right) + \mu_{ij}^k
\end{aligned}
\tag{1.15}
$$

where $a_0^k = ln(A_0^k) = ln\left(\frac{\eta^k}{\eta^k-\sigma^k+1}\left(\frac{\sigma^k}{\sigma-1}\right)^{1-\sigma^k}\right)$ and $a_i^k = ln\left(A_i^k\right) = ln\left(n_i^k b_i^k \left(\frac{\omega_i}{\phi_i^k}\right)^{\eta^k-\sigma^k+1}\right)$ is a factor that embodies all of the information related to sector k in origin country i, which includes the number (n_i^k) of potential exporting firms in the sector, the average productivity or level of technology (b_i^k), the production factor prices (ω_i) in origin country i and the productivity (ϕ_i^k) of individual firms in sector k.

To estimate this equation, we face two issues : first, how to measure the unobservable consumer price index (P_j^k) and factor (a_i^k) and, second, how to accommodate zero trade flows in our database. For the former, because we use cross-sectional data, we follow Feenstra (2016), who suggests using importer- and exporter- fixed effects to control for importer-and exporter- specific characteristics such as the effects of the price index (P_j^k) and the factor (a_i^k) in a cross-sectional analysis. Instead, we include importer HS 4-digit product (fe_j^k) and exporter HS 4-digit product (fe_i^k) fixed effects in our empirical specification of equation (1.15). By including these fixed effects, we control for all of the characteristics that are specific to origin-product pairs and destination-product pairs. As a consequence, the effect of variables such as the consumer price index (P_j^k) of product k in destination country j, the income (E_j^k) allocated to the consumption of product k in destination country j, the number (n_i^k) of potential exporting firms in the sector, the average productivity or level of technology (b_i^k), the production factor prices (ω_i) in origin country i and the productivity (ϕ_i^k) of individual firms in sector k and are entirely absorbed by the importer HS 4-digit product and exporter HS 4-digit product fixed effects.

Next, to accommodate the zero trade flows that represent approximately 95% of our data set, we use the pseudo-Poisson maximum likelihood (PPML) method suggested by Silva and Tenreyro (2006) to estimate equation (1.15). This method has the advantage of estimating equation (1.15) under its multiplicative form (equation (1.9)). In addition, the PPML estimator corrects for potential heteroscedasticity. The final econometric specification to estimate the effects of all technical NTMs in force in OECD member countries on the total exports value of African plant products is given as follow :

$$
V_{ij}^k = \exp\left(\beta_0 + \beta_1 ln(\xi_{ij}^k) + \beta_2 ln(\theta_{ij}^k) + \beta_3 ln(\tau_{ij}^k) + fe_i^k + fe_j^k\right) + \mu_{ij}^k \tag{1.16}
$$

where $\beta_0 = a_0^k$, $\beta_1 = \alpha^k(\eta^k - \sigma^k + 1)$, $\beta_2 = \sigma^k - 1$, and $\beta_3 = \eta^k - \sigma^k + 1$ are parameters to be estimated. The variable V_{ij}^k is the total exports value of product k from country i to country j. ξ_{ij}^k is the unit cost of compliance with TNTMs in force in destination country j, with its impact on total exports value being $\beta_1 \leq 0$. θ_{ij}^k is the representative consumer's perceived quality of plant product k exported by country i into country j, with $\beta_2 \geq 0$ capturing the effect of the consumer's perceived quality on the total exports value. *The net effect of the TNTMs on the total bilateral exports value is defined as β_1 + β_2, which can be negative, zero or positive depending on whether β_1 is greater than, equal to or* *less than* β_2. τ_{ij}^k is the iceberg bilateral trade cost. Following the literature on international trade, we specify the iceberg bilateral trade costs as $\tau_{ij}^k = \exp\Big(\gamma_d ln(dist_{ij}) + \gamma_l Col45_{ij} + \gamma_c lang_{ij}\Big)$, where $dist_{ij}$ is the geographical distance between exporting and importing countries, $Col45_{ij}$ is a binary variable taking the value of 1 if there was a colonial relationship between the exporting and importing countries, and $lang_{ij}$ is a common language variable taking the value of 1 if the exporting and importing countries share a common official language and zero otherwise. fe_j^k and fe_i^k indicate importer HS 4-digit product and exporter HS 4-digit product fixed effects, respectively. μ_{ij}^k is a random error term.

1.6.4 Data

In this section, we both describe the data we use and provide in table 1.2 the descriptive statistics of the variables used for our empirical investigation of the effects of the TNTMs in force in OECD countries on African exports of plant products. We exploit different types of data from several sources. First, we use cross-sectional trade data downloaded from the UN COMTRADE/WITS database for 2017. These data cover 53 African countries exporting 40 HS 4-digit plant products to 35 OECD member countries [8]. The average bilateral trade value is evaluated at 0.847 million US dollars, with the mean value of consumers' perceived quality estimated to be 859.476 US dollars [9]. The unit cif [10] trade value is equal to 5835.428 US dollars per ton, for which exporters face, on average, an estimated 1.064 US dollars per ton (with a standard deviation equal to 0.635) as an additional unit cost of compliance with TNTMs. The 40 HS 4-digit products [11] used are classified in HS Chapters 7 (edible vegetables), 8 (edible fruits and nuts ; peels of citrus fruit), 9 (coffee, tea, mate and spices), 10 (cereals) and 12 (oil seed, oleagic fruits, and misc.). The choice of these products and the OECD member countries as the destination markets is motivated by three main considerations. First, African countries have comparative advantages in the production of plant products, and many TNTMs are imposed on these products by developed countries. Second, African exports for these products strongly depend on OECD member countries, which represent more than 30% of the export share in these markets (see table 1.1). Finally, African countries still have high untapped export potential for plant products that can be exported to OECD member countries. Hence, it is relevant to know to what extent the recent proliferation of technical NTMs in OECD member countries affects African exports for these plant products.

We merged the trade database for 2017 with the database of TNTMs in force in OECD member countries on May 9, 2019 [12]. The data on TNTMs are downloaded from the NTM database released by

8. See the list of exporting and importing countries in table 3.4 in appendix B.
9. Consumers' perceived quality is estimated using the median value of the elasticity of substitution of agricultural products calculated in (Broda and Weinstein, 2006, p.568)
10. The cif variable refers to the cost of transportation, insurance and freight associated with the export of a product.
11. See the detailed list of products in tables 1.5 and 1.6 in appendix B.
12. The NTM database is a cross-sectional data set. Since we compiled our data in 2019, we used more comprehensive cross-sectional trade data for 2017 and assumed that the stock of TNTMs in 2019 was not significantly different from that in 2017. In fact, new NTMs reported to the WTO are often updates of existing ones, so the stock of NTMs does not change significantly during short periods (Disdier et al., 2018).

TABLE 1.2 – Descriptive statistics of variables

Continuous variables	Count	Mean	St.Dev	Min	Max
Trade value (1000 USD)	616	847.144	6883.628	.001	138000
Estimated perceived quality, (USD, $\sigma = 3$)	74200	859.476	155000	0	4.06e+07
Unit value of import, CIF (USD/Ton)	74200	5835.428	18099.55	6.758	1990000
Estimated unit cost with compliance to TNTMs (USD/Ton)	74200	1.064	.635	.003	50.018
Population weighted distance between African and OECD countries (Km)	74200	7197.894	3414.077	425.177	19327.38
Number of TNTMs in force in OECD	74200	121.496	337.469	4	3831
Number of TNTMs in force in Africa	74200	78.369	300.953	0	4844
Binary variables		Percent (%)			
Binary trade variable	0		99.17		
	1		0.83		
Pair in colonial relationship post 1945	0		97.41		
	1		2.59		
Common official or primary language	0		84.37		
	1		15.63		

UNCTAD [13] and WITS [14] and made publicly available through the web applications TRAINS [15] and WITS [16]. These portals provide information on the measures by country, product and type of policy instruments. The data cover all of the NTMs classified into 16 chapters (from A to P) by UNCTAD and the multiagency group MAST [17]. The first fifteen chapters (from A to O) include technical (SPS, TBT, preshipment inspection) and nontechnical measures that a country applies to its imports, while the last chapter (P) encompasses measures that a country imposes on its exports. In our study, we only focus on the technical non-tariff measures (SPSs, TBTs, preshipment inspection requirements) in force in OECD member countries that are set to avert sanitary and phytosanitary risks. However, even without trade objectives, these measures may be obstacles to African exports due to the financial and technical constraints that African countries might face in complying with them. For example, table 2.2 shows that on average, the number of TNTMs in force in OECD countries (mean=121 and standard deviation=337) is largely greater than that in force in African countries (mean=78 and standard deviation=301). In addition, we find that the number of TNTMs in force in the destination markets, which we consider a proxy for restrictiveness (Disdier et al., 2018), is negatively correlated with the number of trading partners in Africa [18]. In the same vein, we also find that the share of untapped export potential is higher for African countries that have fewer TNTMs in force [19].

Finally, we use traditional gravity variables from the CEPII database [20] as control variables for the other trade costs. These variables include the population weighted distance between exporting and importing countries, a dummy variable indicating a colonial relationship between exporting and im-

13. UNCTAD is the United Nations Conference on Trade and Development.
14. WITS is the World Integrated Trade System.
15. TRAINS stands for Trade Analysis Information System, and its web application is https://trains.unctad.org/Forms/Analysis.aspx.
16. https://wits.worldbank.org
17. MAST is a multiagency group involving several international organizations such as the FAO, IMF, ITC, OECD, UNCTAD, UNIDO, World Bank and WTO.
18. See figures 1.14, 1.16, 1.18, 1.20 and 1.22 in appendix A
19. See figures 1.4, 1.6, 1.8, 1.10 and 1.12 in appendix A
20. CEPII is the Centre d'Etudes Prospectives et d'Informations Internationales. The CEPII database is available at http://www.cepii.fr.

porting countries and a binary variable that indicates if the exporting and importing countries share a common official or primary language. The weighted distance between African and OECD countries is, on average, 7198 km. The pairs of countries that share a common official or primary language represent 15.63%, and 2.59% of pair countries had a colonial relationship post-1945.

1.7 Results and Discussion

Table 1.3 presents the results of the effects of the TNTMs in force in OECD countries on the African exports of plant products. This table includes the effect of the unit cost of compliance and the quality improvement effect as well as the net effect. Our results highlight both the trade-impeding and trade-enhancing effects of the TNTMs in force in OECD countries for African exports of plant products. Indeed, the results presented in table 1.3 show a negative and significant effect associated with the unit cost of compliance variable ($\ln\xi_{ij}^{k}$) and a significant positive effect associated with the perceived quality variable ($\ln\theta_{ij}^{k}$). The trade effect of the unit cost of compliance with TNTMs is evaluated at -3.099 with $p < 0.01$. This result implies that a 1% increase in the unit cost of compliance with TNTMs leads to an average decrease in the value of African exports of more than 3%. The trade effect of consumers' perceived quality induced by the presence of TNTMs is 2.056. This result means that a 1% increase in consumers' perceived quality induced by the TNTMs in force in OECD countries leads to an average increase in the value of African exports of slightly more than 2%. Now, when we compute the net effect of the universe of TNTMs in force in OECD countries on the export value of African plant products, we find a negative and significant effect (-1.043% and $p < 0.01$). This result indicates that when we take into account both the cost effect on export supply and quality effect on import demand, the net effect of all of the TNTMs in force in OECD countries leads to an average net decrease in the value of African exports of slightly more than 1%. Our results are in line with those of previous studies that highlighted both the trade-impeding and trade-enhancing effects of TNTMs. In addition, our findings corroborate our theoretical result that stringent TNTMs reduce the exports of exporters characterized by a higher marginal cost of compliance with TNTMs and lower productivity. Therefore, the estimated negative net effect of the TNTMs in force in OECD countries on the value of African exports may be due not only to the constraints that African countries face in complying with these measures and the low productivity of their exporters but also to the administrative formalities and the technical difficulties they face in accessing the markets of OECD member countries and selling high product volumes. Indeed, most African countries have fewer and less restrictive regulations than OECD countries. At the same time, the latter have the highest number of regulations among all countries, with more stringent measures than those recommended in the Codex framework (Li et al., 2017), and they also have stricter border control.

For the control variables, we find an expected negative and significant effect (-0.053%, $p < 0.01$) associated with the geographical distance variable ($lndist_{ij}$) and expected positive effects (1.480, $p < 0.01$ and 0.009, $p = 0.548$) for the colonial relationship variable ($Col45_{ij}$) and common language variable ($Lang_{ij}$). African countries and OECD members that were in a colonial relationship trade approxima-

TABLE 1.3 – Effects of TNTMs in force in OECD countries on African exports of plant products, Year 2017

	PPML
	Exports value (equation (1.16))
Log of unit cost of compliance with TNTMS ($\ln\xi_{ij}^{k}$)	-3.099***
	(0.021)
Log of consumer' perceived quality ($\ln\theta_{ij}^{k}$)	2.056***
	(0.011)
Log of distance ($lndist_{ij}$)	-0.053***
	(0.020)
Common language ($Lang_{ij}$)	0.009
	(0.016)
Pair in colonial relationship post 1945 ($Col45_{ij}$)	1.480***
	(0.566)
Constant	1.069***
	(0.189)
H_0 : $\beta_1+\beta_2$ = 0, the Net Effect of TNTMs in force in OECD countries on African exports is zero	-1.043
Statistic for the test	6665.70
p value	0.000
Observations	1140
R-squared	0.999
Fixed effects :	
Exporter-product	YES
Importer-product	YES

Standard errors in parentheses : * p<.10 ; ** p<.05 ; *** p<.01

tely 1.5 times more than partner countries that had no such relationship.

1.8 Robustness Check

For a robustness check of our estimation approach and results, we conduct an alternative estimation. We evaluate the consumer's perceived quality and unit cost of compliance by estimating simultaneously equation (2.32) for consumer demand and equation (1.14) for exporter prices. We fit both equations simultaneously using the seemingly unrelated regression (SURE) routine. As the residuals of the two equations measure, respectively, the consumer's perceived quality and unit cost of compliance with TNTMs and they are functions of random parameters, we follow the procedure of Krinsky and Robb (1986) and Krinsky and Robb (1990) to compute them. Thus, we replicate 1 000 observations of parameters of the demand and price equations to compute multiple vectors of the residual in each equation. We draw the parameters from a multivariate normal distribution with mean and variance-covariance equal to the estimated vector of coefficients in the demand and price equations and the corresponding estimated variance-covariance matrix. For each new vector of parameters drawn, we compute new residual vectors of demand and price. Finally, for each residual vectors computed, we use equation (1.16) to re-estimate the *impediment, enhancement and net effects* of the TNTMs in force on bilateral trade. Figure 1.2 presents the distribution of the *net* trade effect of TNTMs. We find that our estimated mean net trade effect (-1.044 with p-value<0.01) over all African countries, presented in table 1.3, is less than the 10th percentile (0.330) of the distribution of the net trade effect displayed in figure 1.2. The mean and median values of this distribution are 1.334 and 1.206 respectively (with standard deviation equal to 0.650). These results imply that African exporters are among the 10 percent of exporters that have the smallest gain from trade in the presence of TNTMs. Hence, these results support our theoretical findings that the stringent TNTMs reduce the exports of firms or countries characterized by higher marginal cost of compliance with TNTMs and lower productivity. In contrast, firms or countries that face fewer constraints in complying with TNTMs and have higher productivity may generate a positive net trade effect.

Therefore, this alternative estimation approach supports our theoretical findings and the robustness of our empirical strategy in assessing the net effects of TNTMs in force in importing countries on bilateral trade. Hence, our theoretical and empirical results are robust.

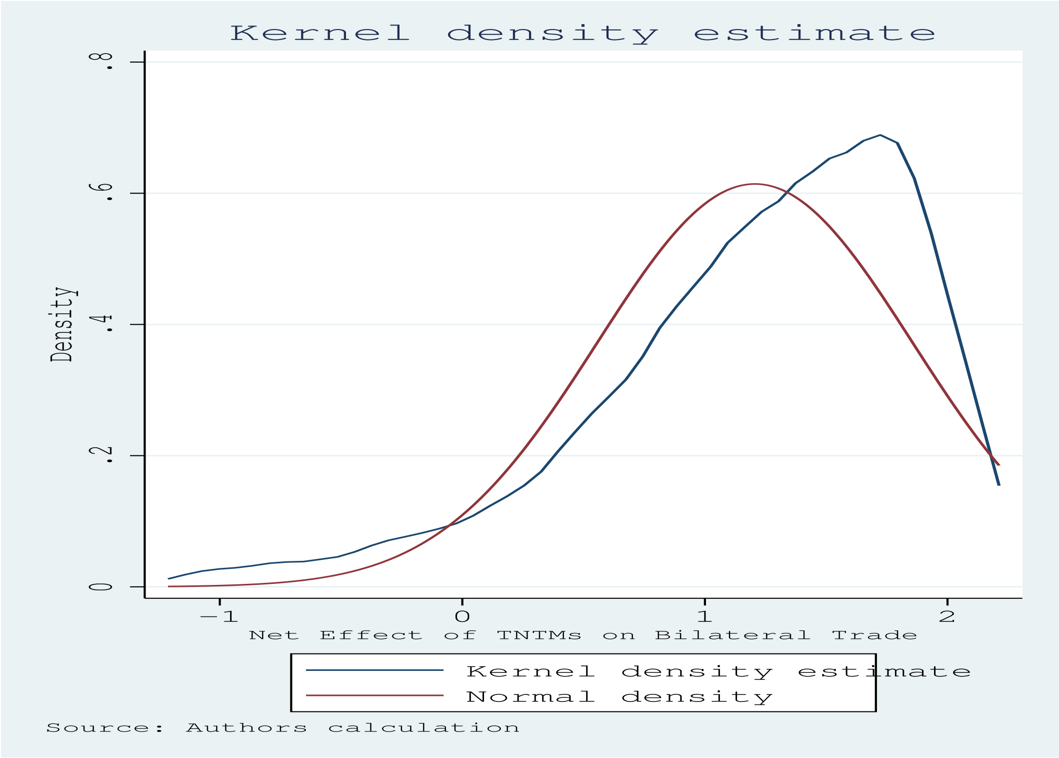

FIGURE 1.2 – Distribution of the Net effect of TNTMs on Bilateral Trade

1.9 Conclusion

This paper focuses on the TNTMs in force in OECD member countries and the impacts of the measures on the African exports of plant products. During the last decades, the use of stringent NTMs by developed countries has grown in the agricultural and agrifood sectors. Among these NTMs, TNTMs are the most frequently used and, for African countries, affect plant products more than other traded goods. While the TNTMs in force in developed countries may represent substantial barriers to African exports, no study in the literature has investigated the effects of all TNTMs in force in these countries on African exports. Our paper fills this gap by theoretically and empirically analyzing the underlying net effect of all of the technical NTMs in force in OECD countries on African exports of plant products. In contrast to previous studies, we adopt a cost-benefit approach and appropriately measure both the perceived quality and the unit cost of compliance with TNTMs. Then, we use these measures in our empirical investigations to estimate the effects of all of the technical non-tariff measures (not just a single measure) in force in OECD member countries on the African trade of plant products. Our theoretical findings highlight that for a given elasticity of substitution, only firms or countries characterized by a lower marginal cost than a cutoff marginal cost and productivity higher than a threshold productivity level will experience a positive net trade effect with a given destination. Firms or countries with a higher marginal cost than the cutoff marginal cost and lower productivity than the threshold productivity level will see a negative net trade effect. Finally, firms or countries that have a marginal cost equal to the cutoff marginal cost and productivity equal to the threshold productivity level will display a net trade effect of zero. Hence, stringent TNTMs reduce the exports of firms or countries characterized by higher marginal costs of compliance with TNTMs and lower productivity. In contrast, firms or countries that face fewer constraints in complying with TNTMs and have higher productivity will potentially generate a positive net trade effect. Our empirical results show that the trade-impeding effect of the TNTMs in force in OECD member countries on the African trade of plant products is slightly greater than the measures' trade-enhancing effect. As a consequence, we find a negative and significant net effect associated with TNTMs, which indicates that the TNTMs in force in OECD member countries are obstacles for African exporters of plant products.

The main implication of this paper is that our theoretical framework and proposed empirical strategy are useful for both policy analysts and policy makers in assessing or simulating the trade effects of TNTMs using existing information on the price elasticity of consumer demand and the characteristics of firms in terms of their marginal cost and productivity. More specifically, our theoretical and empirical approach will allow policy analysts and policy makers to respond to the following question : given the price elasticity of consumer demand for a given product and market, which firms or countries are likely to reach a positive, zero or negative net trade effect of TNTMs ?

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Appendix

Appendix A : Additional figures

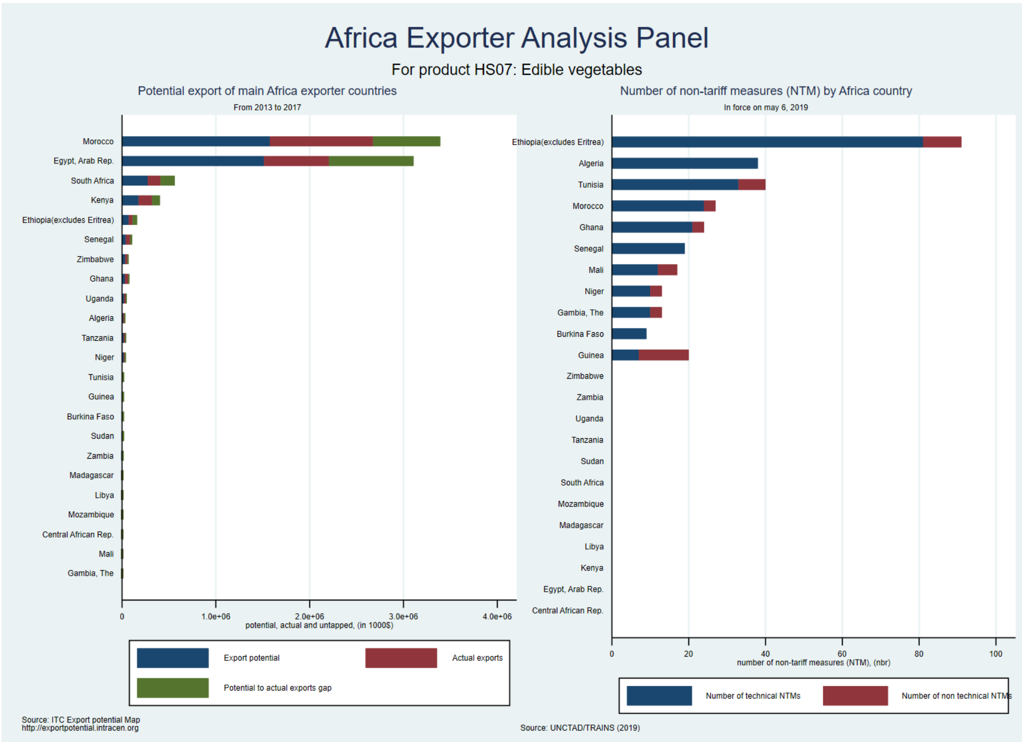

FIGURE 1.3 – Africa export potential panel for product HS07 : Edible vegetables

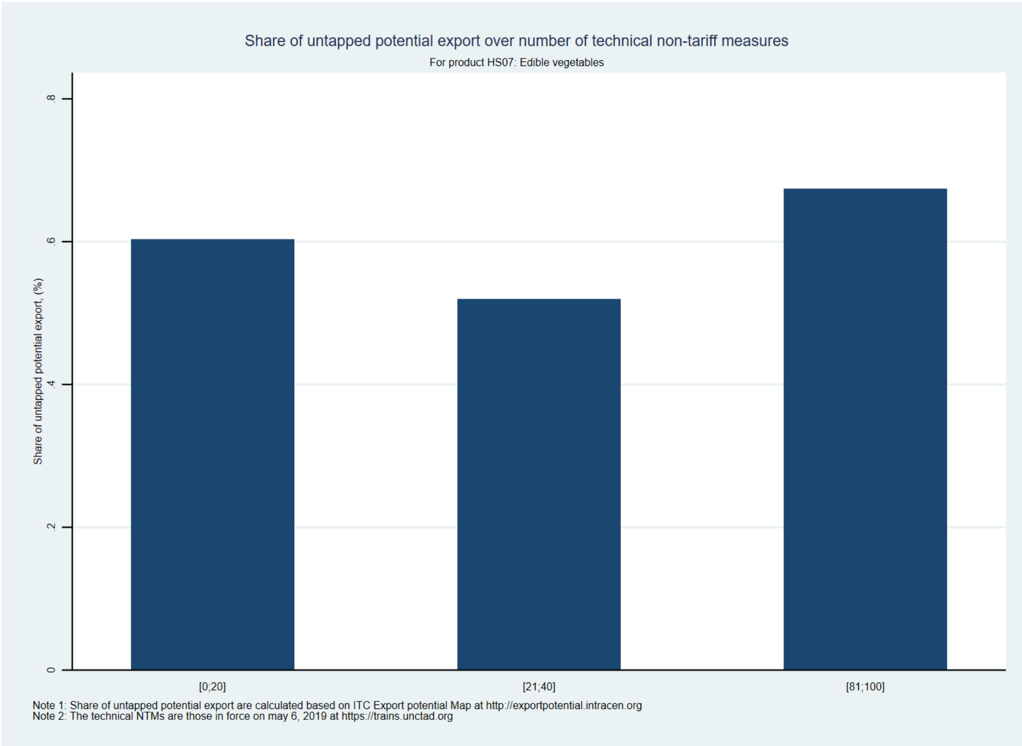

FIGURE 1.4 – Share of untapped export potential for product HS07 : Edible vegetables

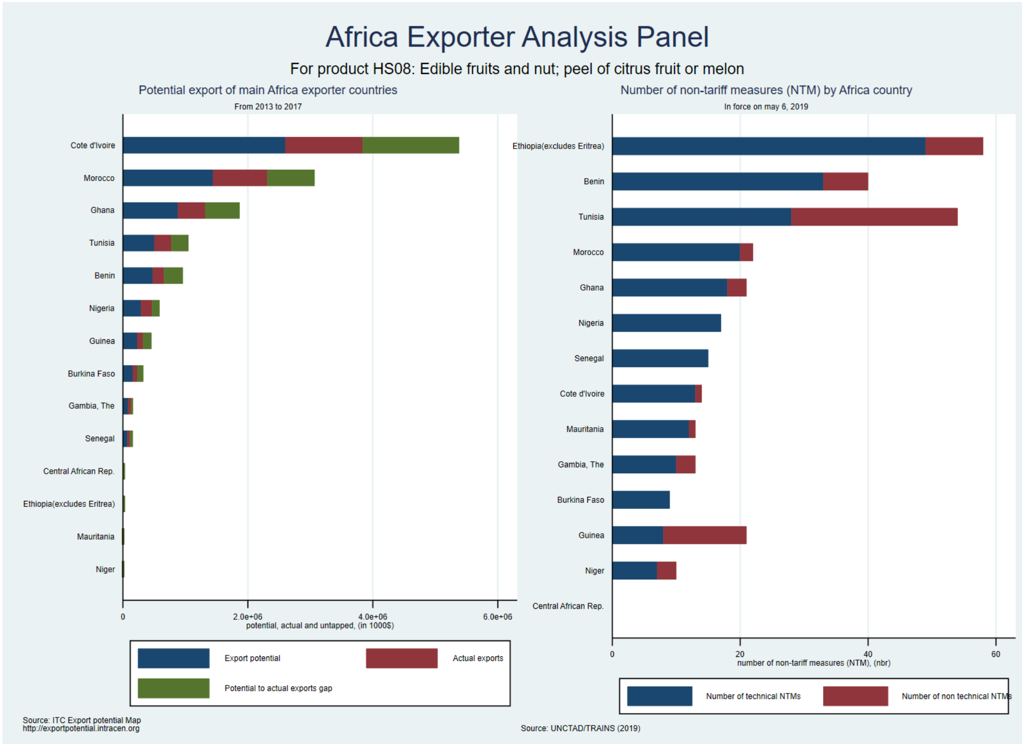

FIGURE 1.5 – Africa export potential panel for product HS08 : Edible fruits and nut ; peel of citrus fruit

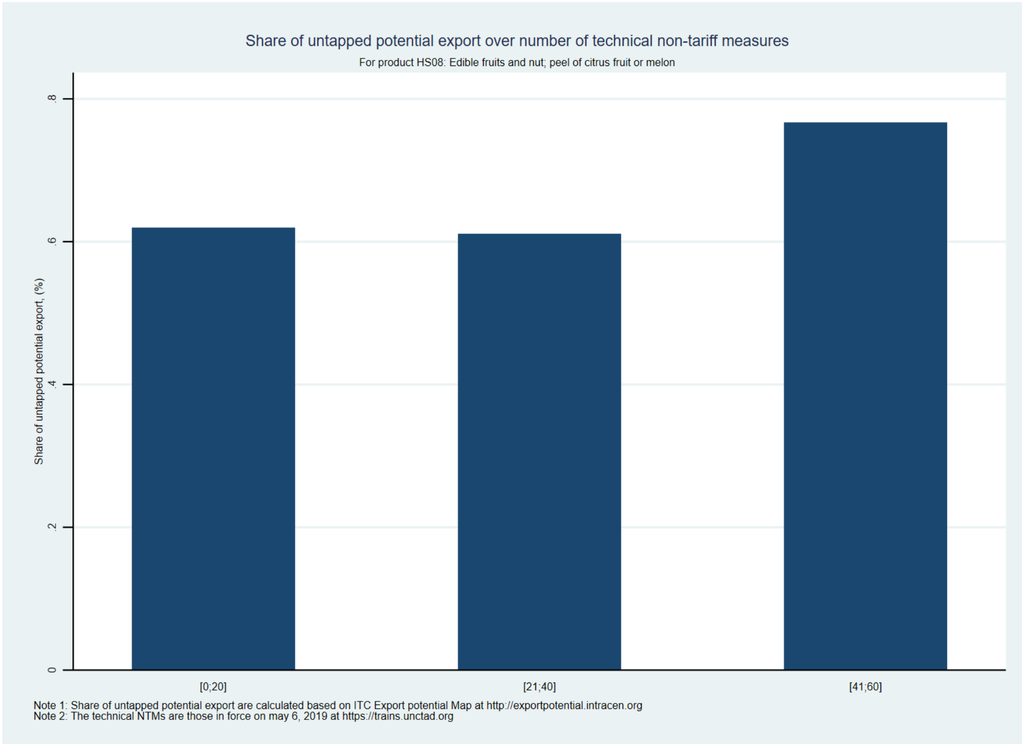

FIGURE 1.6 – Share of untapped export potential for product HS08 : Edible fruits and nut ; peel of citrus fruit or melon

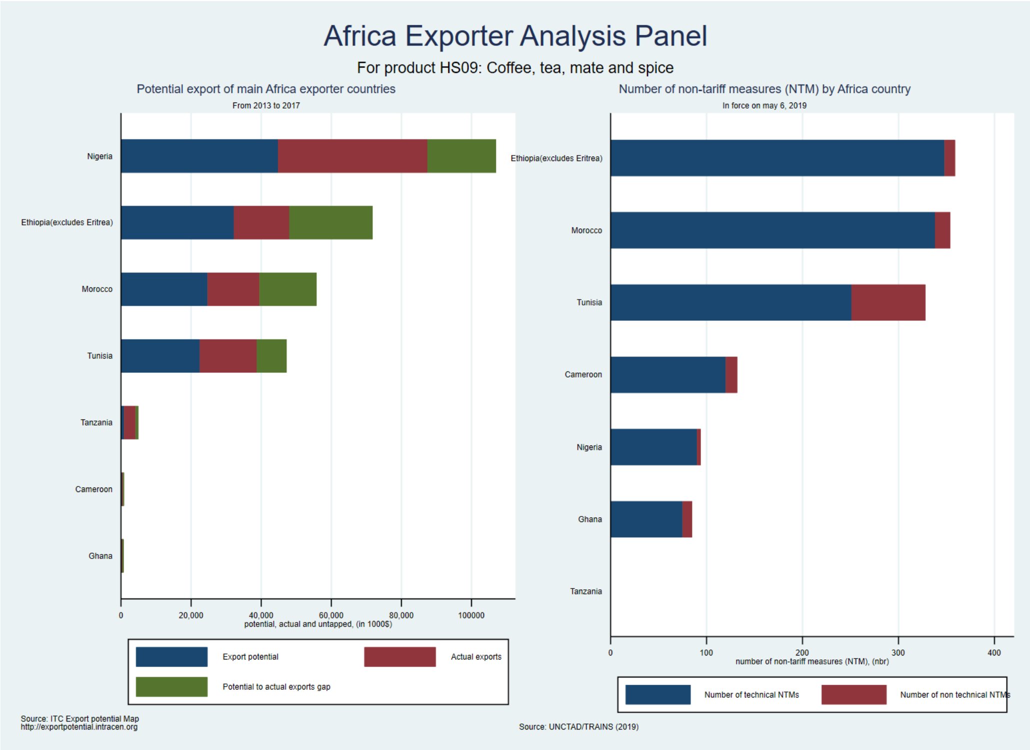

FIGURE 1.7 – Africa export potential panel for product HS09 : Coffee, tea, mate and spice

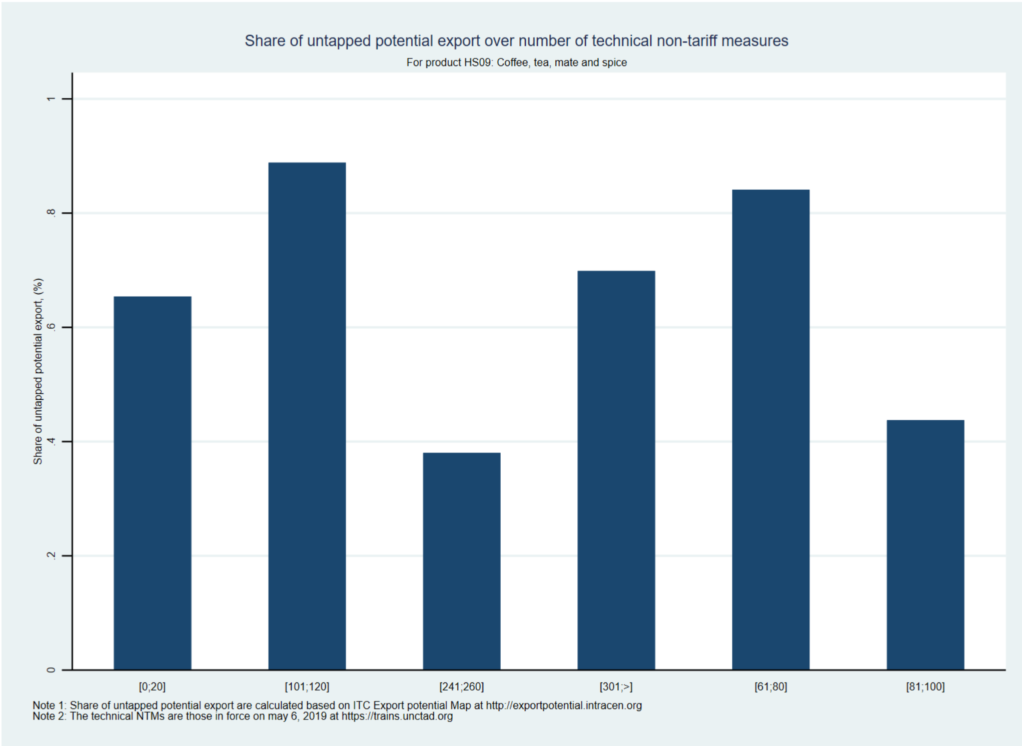

FIGURE 1.8 – Share of untapped export potential for product HS09 : Coffee, tea, mate and spice

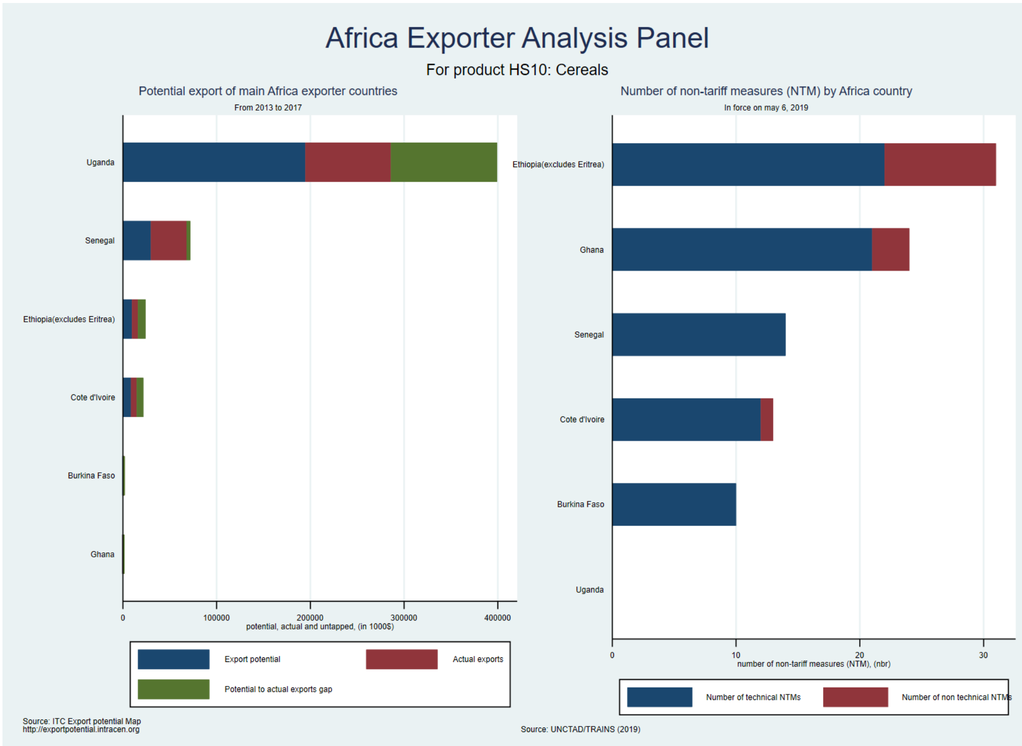

FIGURE 1.9 – Africa export potential panel for product HS10 : Cereals

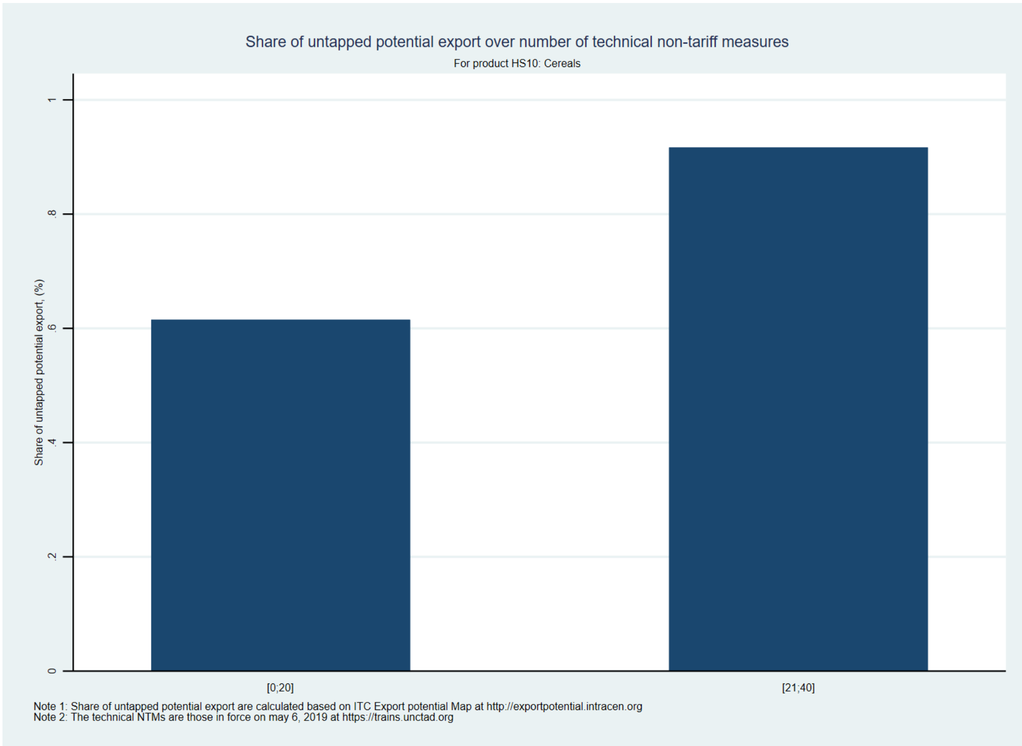

FIGURE 1.10 – Share of untapped export potential for product HS10 : Cereals

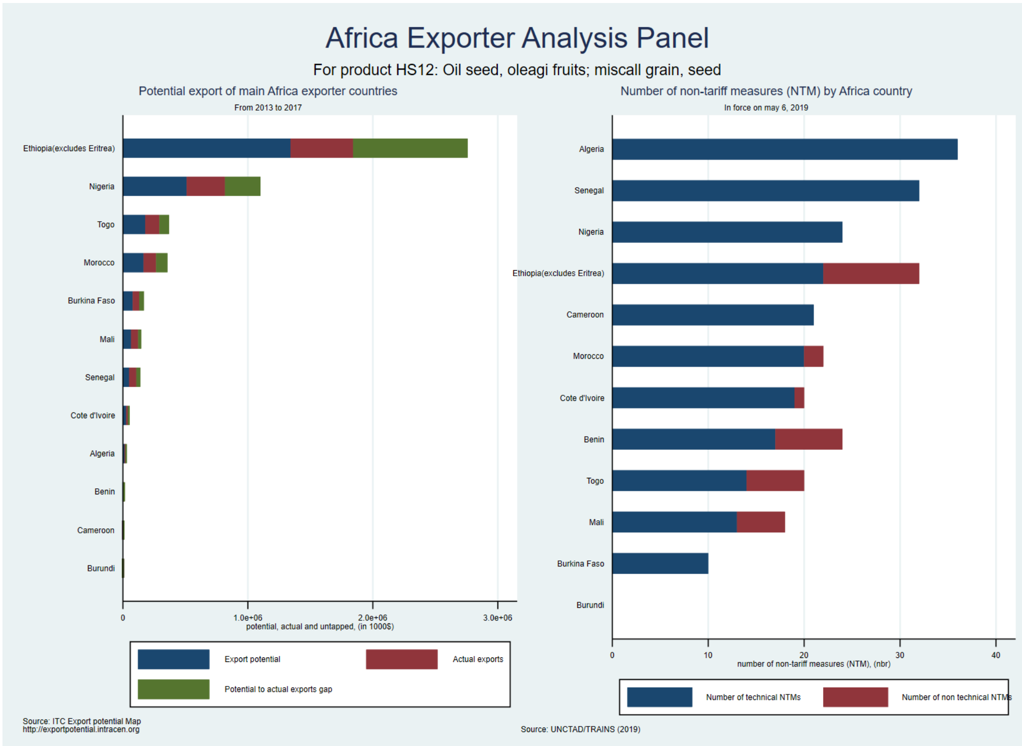

FIGURE 1.11 – Africa export potential panel for product HS12 : Oil seed, oleagi fruits ; miscall grain, seed

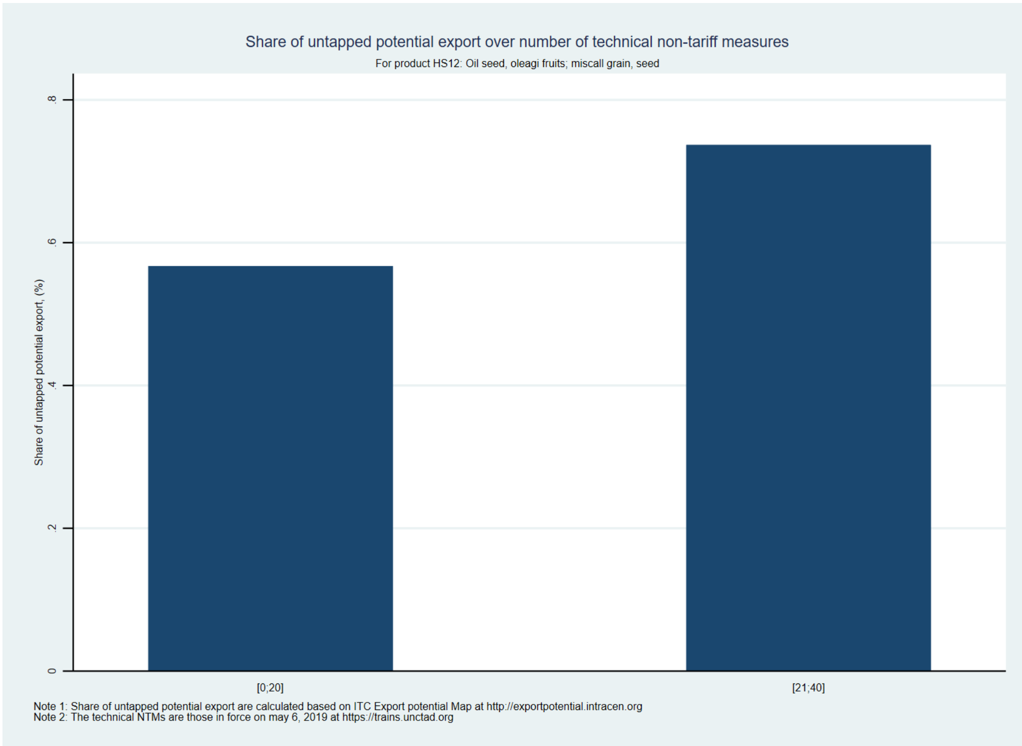

FIGURE 1.12 – Share of untapped export potential for product HS12 : Oil seed, oleagi fruits ; miscall grain, seed

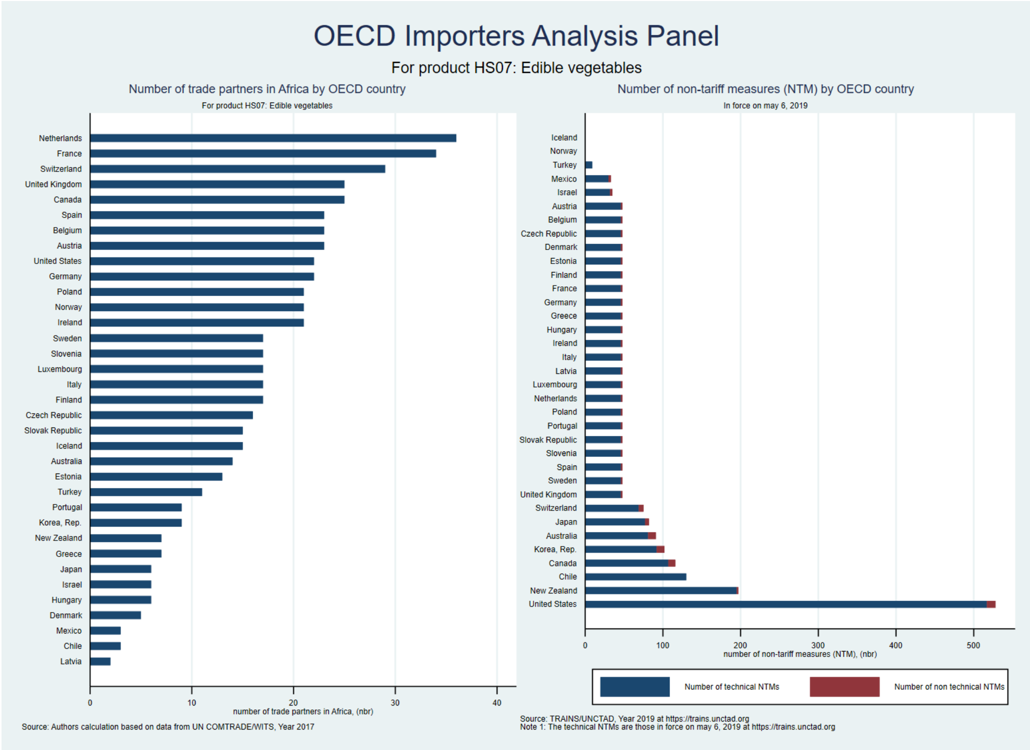

FIGURE 1.13 – Number of partners and technical NTMs on edible vegetables (HS07)

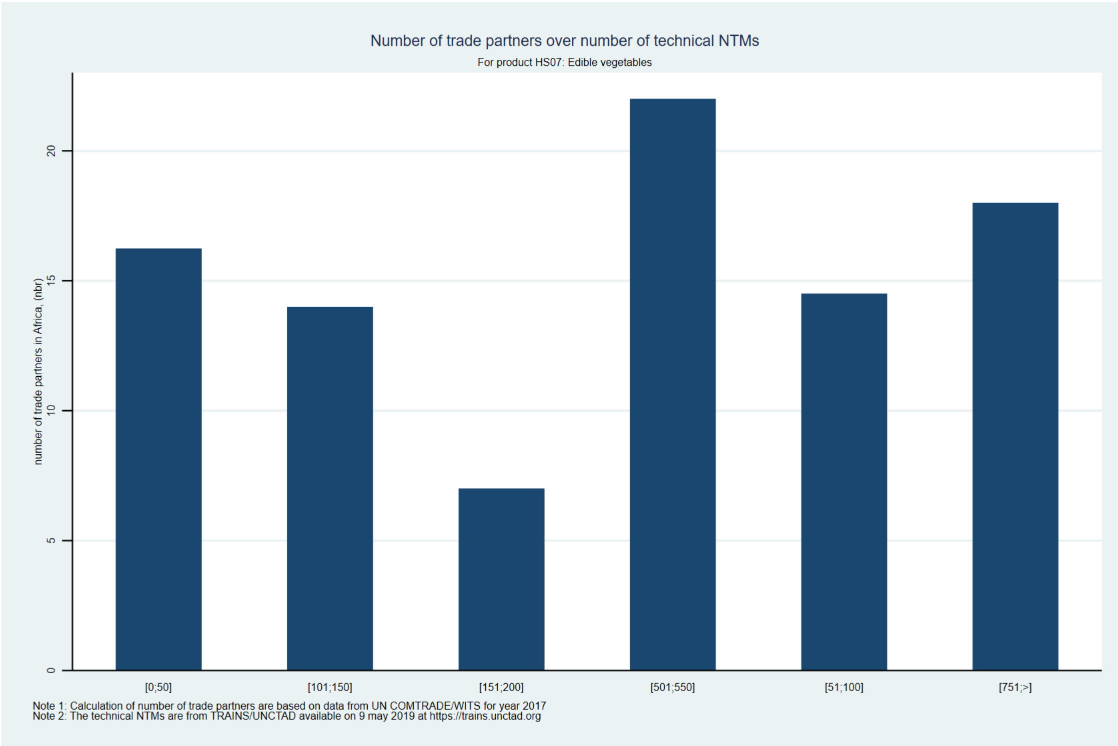

FIGURE 1.14 – Number of trade partners over number of technical NTMs for edible vegetables (HS07)

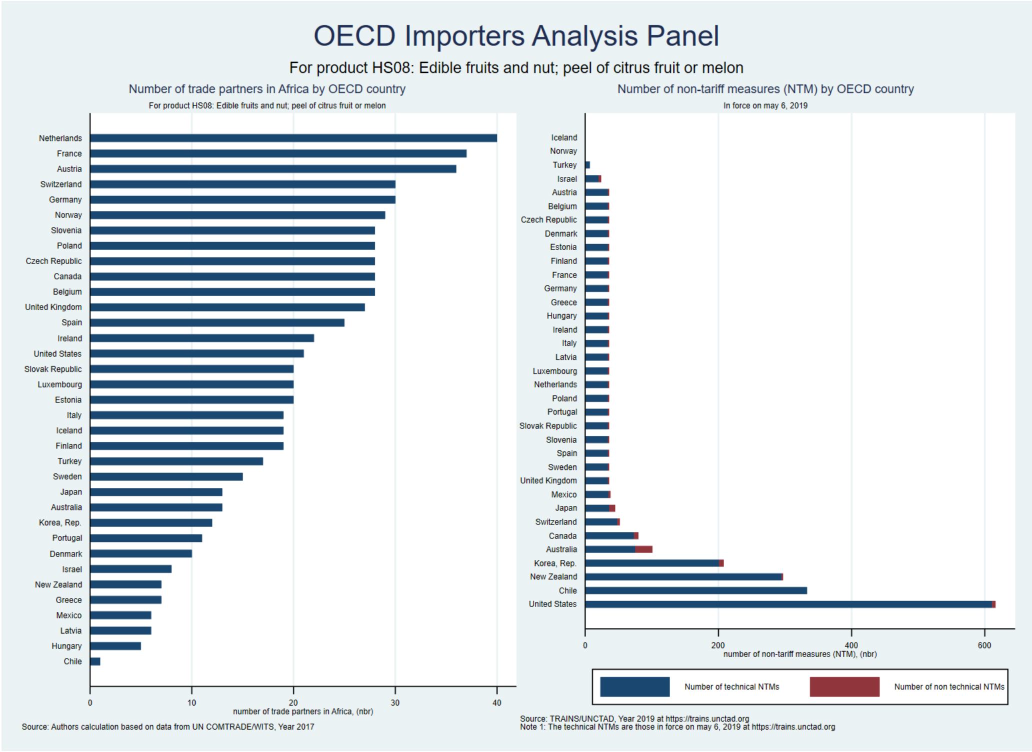

FIGURE 1.15 – Number of partners and technical NTMs on Edible fruits and nut (HS08)

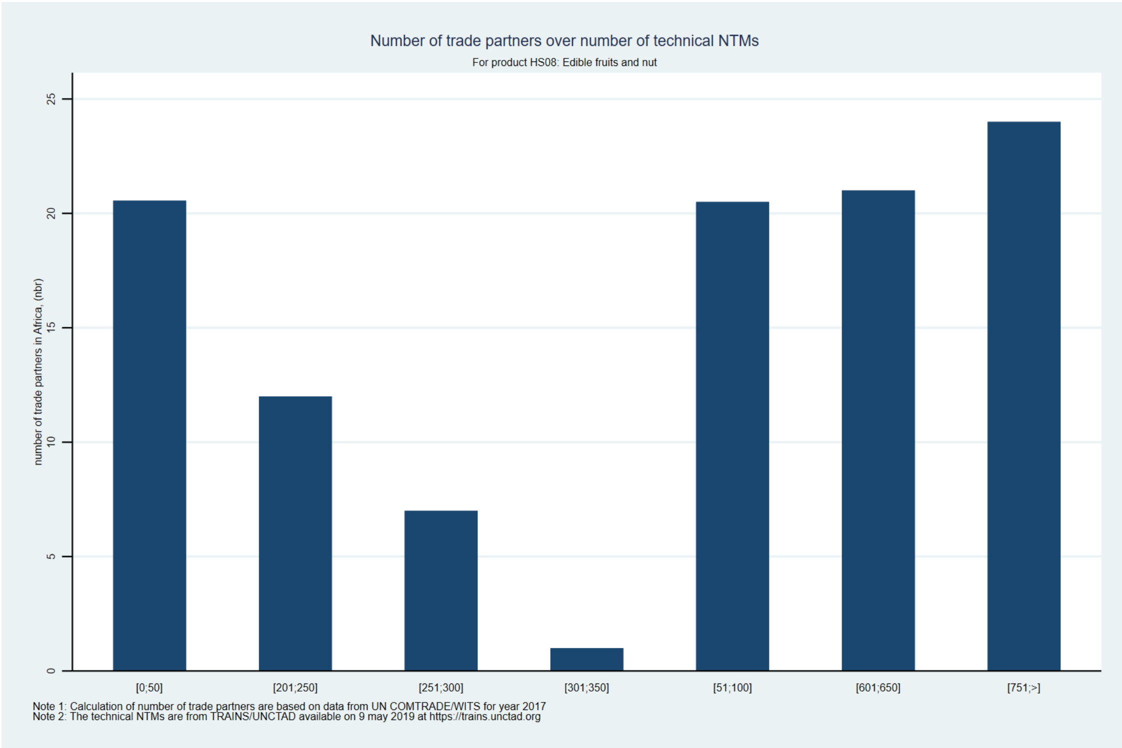

FIGURE 1.16 – Number of trade partners over number of technical NTMs for Edible fruits and nut (HS08)

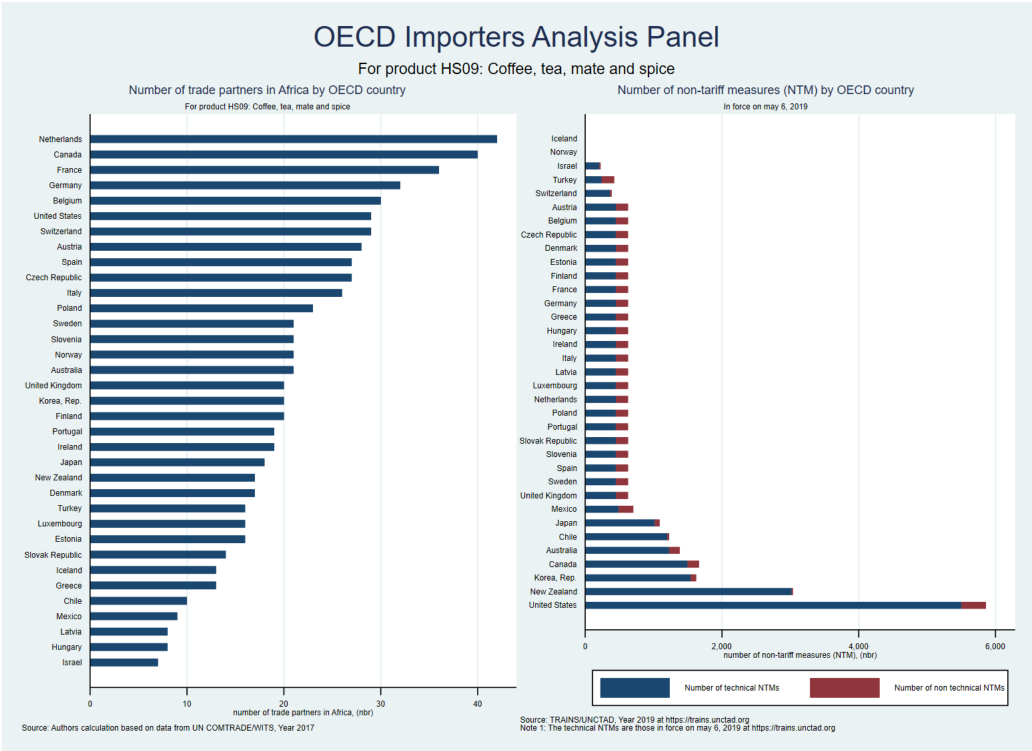

FIGURE 1.17 – Number of partners and technical NTMs on Coffee, tea, mate and spice (HS09)

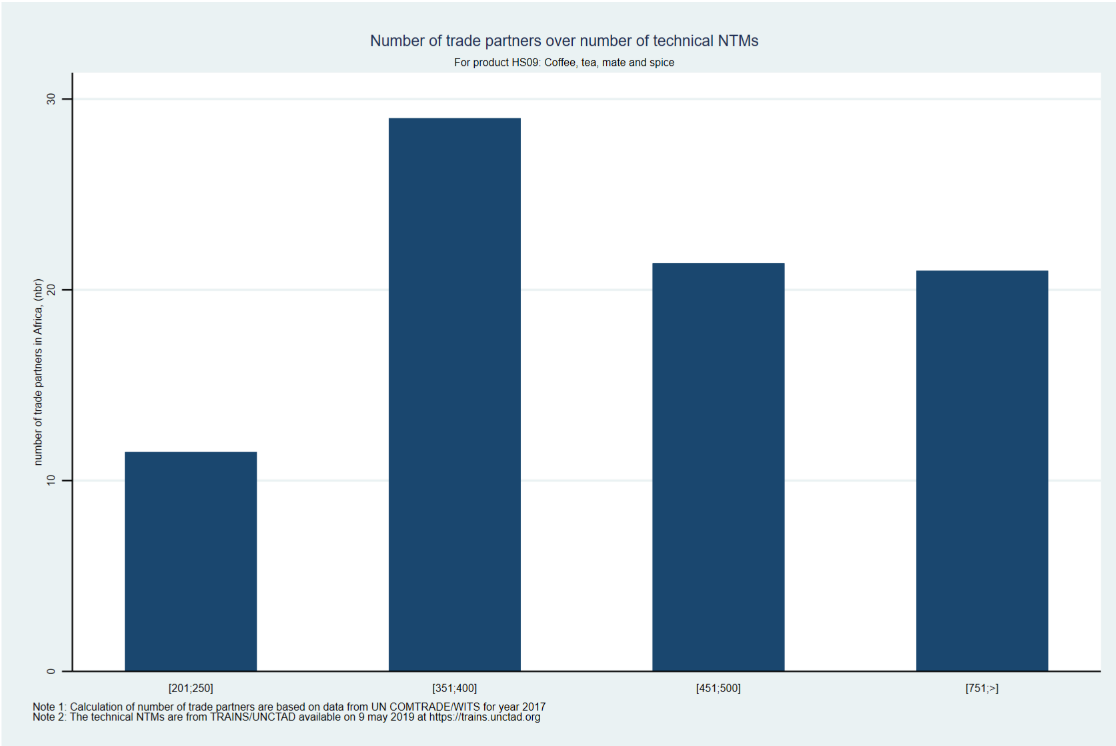

FIGURE 1.18 – Number of trade partners over number of technical NTMs for Coffee, tea, mate and spice (HS09)

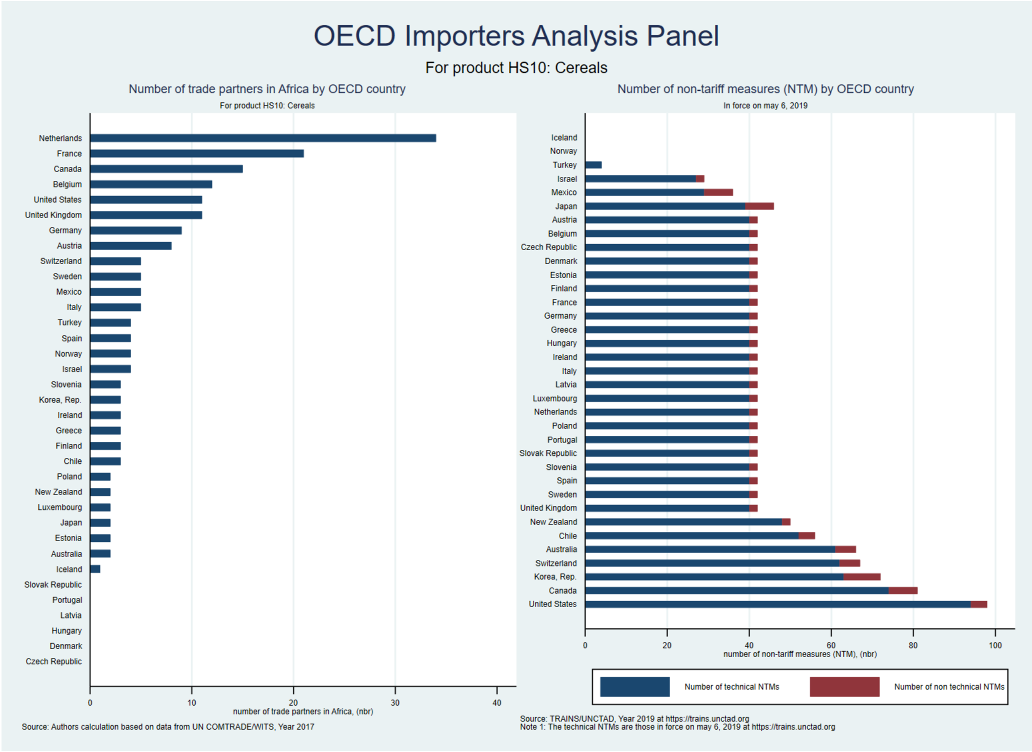

FIGURE 1.19 – Number of partners and technical NTMs on Cereals (HS10)

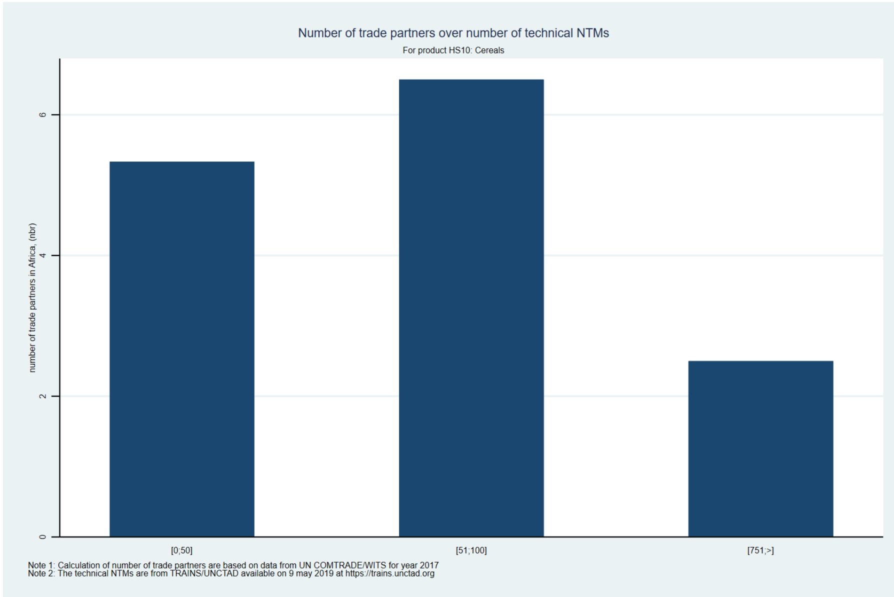

FIGURE 1.20 – Number of trade partners over number of technical NTMs for Cereals (HS10)

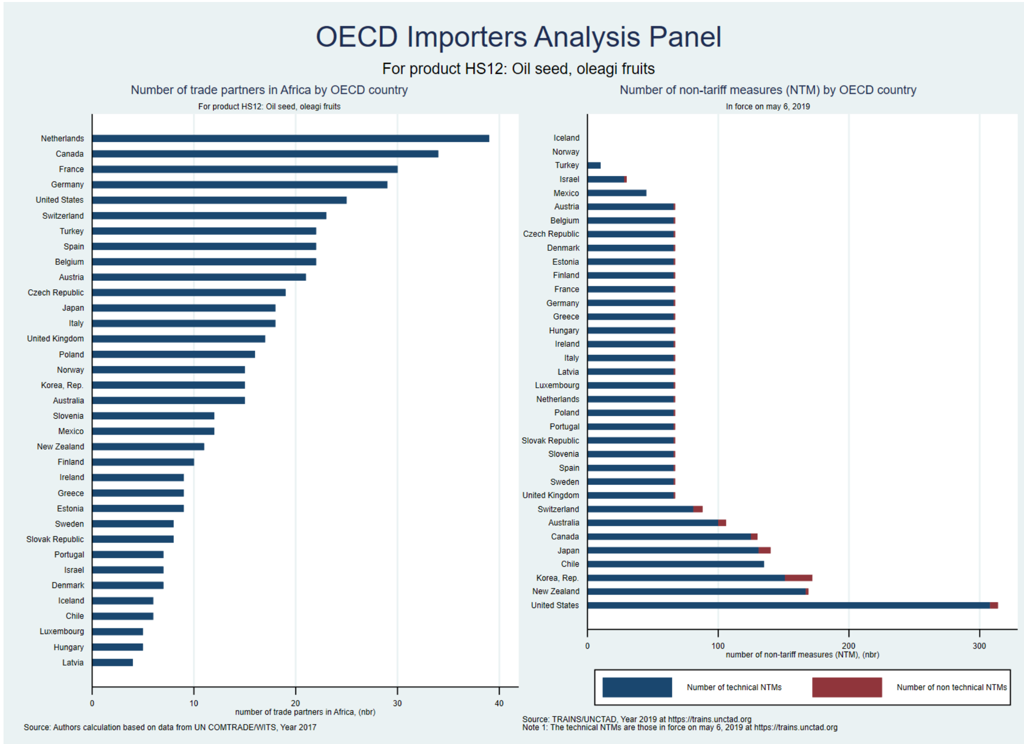

FIGURE 1.21 – Number of partners and technical NTMs on Oil seed, oleagi fruits (HS12)

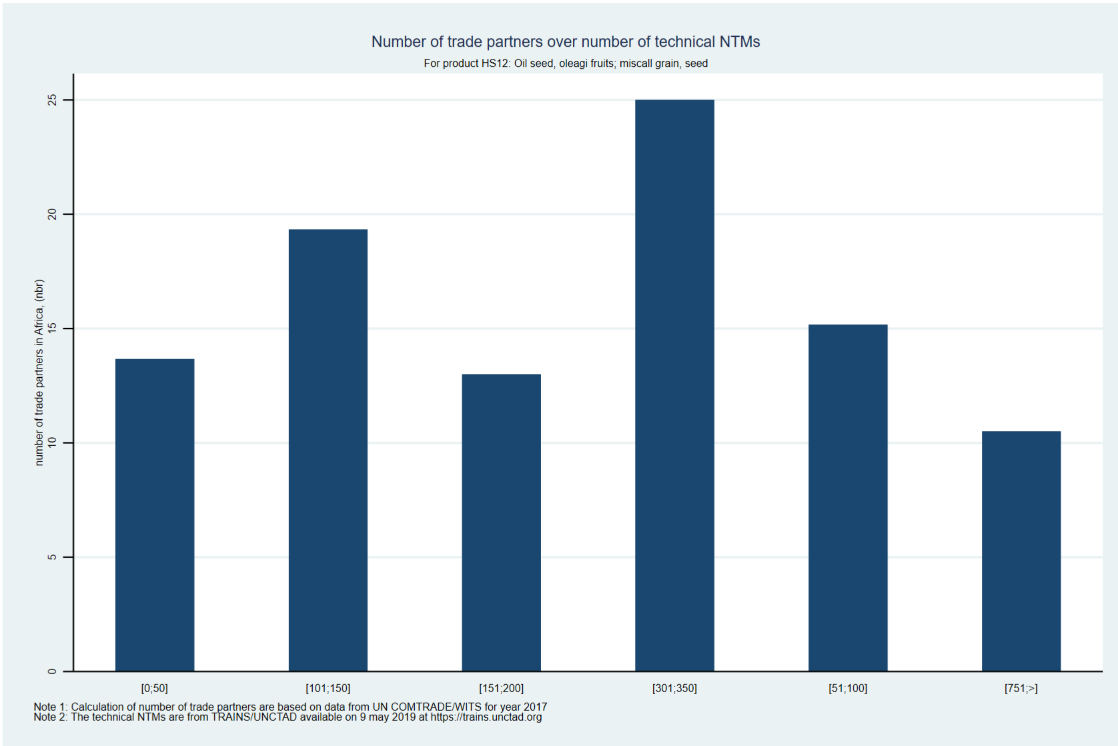

FIGURE 1.22 – Number of trade partners over number of technical NTMs for Oil seed, oleagi fruits (HS12)

Appendix B : Additional tables

TABLE 1.4 – List of exporting and importing countries

Exporters		Importers	
Algeria	Libya	Australia	Slovak Republic
Angola	Madagascar	Austria	Slovenia
Benin	Malawi	Belgium	Spain
Botswana	Mali	Canada	Sweden
Burkina Faso	Mauritania	Chile	Switzerland
Burundi	Mauritius	Czech Republic	Turkey
Cameroon	Morocco	Denmark	United Kingdom
Cape Verde	Mozambique	Estonia	United States
Central African Republic	Namibia	Finland	
Chad	Niger	France	
Comoros	Nigeria	Germany	
Congo, Dem. Rep.	Rwanda	Greece	
Congo, Rep.	Sao Tome and Principe	Hungary	
Cote d'Ivoire	Senegal	Iceland	
Djibouti	Seychelles	Ireland	
Egypt, Arab Rep.	Sierra Leone	Israel	
Equatorial Guinea	Somalia	Italy	
Eritrea	South Africa	Japan	
Ethiopia(excludes Eritrea)	Sudan	Korea, Rep.	
Gabon	Swaziland	Latvia	
Gambia, The	Tanzania	Luxembourg	
Ghana	Togo	Mexico	
Guinea	Tunisia	Netherlands	
Guinea-Bissau	Uganda	New Zealand	
Kenya	Zambia	Norway	
Lesotho	Zimbabwe	Poland	
Liberia		Portugal	

TABLE 1.5 – List of plant products

HS Code	Description	Number
	HS-07 : Edible vegetables	
HS0701	Potato	1
HS0702	Tomato	1
HS0703	Bulb onion ; green onion ; bulb shallot, garlic ; leek,	5
HS0704	Cabblage ; cauliflower ; kohlrabi ; kale	4
HS0705	Lettuce(head) ; lettuce(leaf) ; chicory(tops) ; chicory(root) ;	4
HS0706	Carrot ; turnip(top) ; turnip(root),	3
HS0707	Cucumber ; gerkhin(west indian)	2
HS0708	Bean(haricot)	1
HS0709	Artichoke(globe) ; asparagus ; celery ; mushrooms ; truffles ; spinach	6
HS0714	Casava(manioc) ; arrowroot ; artichoke ; sweet potato ;	4
	HS-08 : Edible fruits and nut ; peel of citrus fruit or melon	
HS0801	Coconuts ; brazilnut ; cashewnut ;	3
HS0802	Almond ; hazelnut ; walnut ; chestnut ; pistachio ;	5
HS0803	Banana ; plantain ;	2
HS0804	Avocado ; date ; fig ; guava ; pineapples ; mango ; mangosteen	7
HS0805	Orange ; mandarin ; clementine ; lemon ; lime ; grapefruit ;	6
HS0806	Grape	1
HS0807	Watermelon ; papaya	2
HS0808	Apple ; pears ; quince	3
HS0809	Appricot ; cherry(black) ; peach ; nectarine ; plum prune ;	5
HS0810	Strawberry ; raspberry ; blackberry ; mulberry ; loganberry ; currant (black) ; currant (red/white) ; gooseberry ; cranberry	9
	HS-09 : Coffee, tea, mate and spice	
HS0904	pepper	1
HS0910	Ginger	1

TABLE 1.6 – List of plant products (continued)

HS Code	Description	Number
	HS-10 : Cereals	
HS1001	Wheat	1
HS1002	Rye	1
HS1003	Barley(grain)	1
HS1004	Oat	1
HS1005	Corn(grain)	1
HS1006	Rice	1
HS1007	Sorghum	1
HS1008	Canary(seed), millet	2
	HS-12 : Oil seed, oleagi fruits ; miscall grain, seed	
HS1201	Soyabean	1
HS1202	Bambara groundnut	1
HS1204	linseed	1
HS1205	Rape or colza seeds	1
HS1206	Sunflower seed	1
HS1207	Palm nut ; cotton seed ; castor oil plant ; sesame seed ; mustard seed ; safflower seed ; poppy seed ; shea nut ; mustard spinach ; peanut	10
HS1210	Hop dried cone	1
HS1211	Liquorice ; ginseng root	2
HS1212	Seaweed ; sugar beet ; sugar cane ; algae	4
HS1214	Alfalfa(Lucerne)	1
Total		**108**

Chapitre 2

African Trade of Mangoes to OECD Countries : Disentangle the effects of compliance to Maximum Residue Limits on Production, Export supply and Import Demand.

2.1 Résumé

Les mesures techniques non tarifaires (MTNT) strictes, telles que les limites maximales de résidus (LMR) de pesticides, peuvent potentiellement réduire la propension à produire et le volume de production et créer une incertitude sur la probabilité d'exporter ainsi que sur le volume disponible pour l'exportation. Cet article démêle théoriquement et empiriquement les effets des LMR pour les pesticides sur la production, l'offre d'exportation et la demande d'importation. Nous adoptons une approche de modélisation basée sur les coûts et les bénéfices associés aux normes de sécurité sanitaire des aliments et utilisons notre cadre théorique pour évaluer les effets empiriques nets des LMR de pesticides sur la production de mangues en Afrique et le commerce avec les pays membres de l'OCDE. Théoriquement, nous montrons que les effets des LMR sur la production sont négatifs tandis que leurs effets nets sur le commerce bilatéral peuvent être positifs, nuls ou négatifs selon que l'effet de la qualité perçue par les consommateurs sur la demande d'importation est supérieur, égal ou inférieur à l'effet du coût de mise en conformité sur l'offre d'exportation. Nous utilisons des données transversales pour 12 pays africains qui ont produit et exporté des mangues conformes aux LMR vers 31 pays de l'OCDE en 2016, et nous constatons que, d'une part, les effets nets des LMR de pesticides sur la production de mangues sûres sont négatifs. D'autre part, ils sont positifs sur le commerce des mangues entre les pays africains et les pays membres de l'OCDE. Nos résultats soulignent que le ren-

forcement ou l'imposition de LMR strictes pour les pesticides dans les pays développés peut favoriser les échanges commerciaux alors qu'ils entravent fortement la production dans les pays africains.
Mots-clés : Afrique, Mangues, Limites Maximales de Résidus de Pesticides, OCDE, Commerce.
Codes JEL : Q17, Q18, F13, F14.

2.2 Abstract

This article theoretically and empirically disentangles the effects of MRLs for pesticides on production, export supply and import demand. We adopt a modelling approach based on the costs and benefits associated with food safety standards and use our theoretical framework to assess the empirical net effects of MRLs for pesticides on African mango production and trade with OECD member countries. On the one hand, we theoretically highlight that for a given production technology and a level of elasticity of production costs with respect to the MRL gap, producers will likely (probability and quantity) produce standard-compliant products if they are able to completely pass-through the standard-compliance costs to the unit price they receive from exporters ; otherwise, they will exit standard-compliant products market. On the other hand, we theoretically show that the net effects of the MRL gap on bilateral trade can be positive, zero or negative depending on the effects of consumers' perceived quality (positive), trade costs (negative) and standard-compliant production cost (negative). We use a cross-sectional data set for 12 African countries that produced and exported MRL-compliant mangoes to 31 OECD countries in 2016 and find that, on the one hand, the net effect of MRLs is positive for the level of standard-compliant mangoes production and negative for the likelihood of producing. On the other hand, they are positive in mango trade between African and OECD member countries. Our results highlight that the tightening or imposition of strict MRLs for pesticides in developed countries may be trade promoting, while they severely impede production in African countries.
Keywords : Africa, Mangoes, Maximum Residue Limits for Pesticides, OECD, Trade.
JEL Codes : Q17, Q18, F13, F14.

2.3 Introduction

In recent decades, the use of technical non-tariff measures (TNTMs), such as maximum residue limits (MRLs), for pesticides has increased in developed countries to provide standards for food safety (Beghin et al., 2015; MAST/UNCTAD, 2012). However, although these standards are set to avert sanitary and phytosanitary (SPS) risks, they may potentially reduce the propensity to produce and the volume of production in developing countries and create uncertainty regarding the volume available for exporting as well as the probability of exporting. While there are many studies in the literature that investigated the effect of standards differences on trade margins, export prices or product quality (Curzi et al. (2020) ; Fernandes et al. (2019) ; Fiankor et al. (2020) ; Medin (2019) ; Otsuki et al. (2001) ; Xiong and Beghin (2014) ; Xiong and Beghin (2011) ; etc.), in our knowledge there is not yet study that investigated formally and empirically the extent to which these measures affect standards-compliant production in developing countries together with their exports to developed countries with higher standards. The objective of this article is to theoretically and empirically disentangles the effects of MRLs for pesticides, a specific SPS measure, on production, export supply and import demand.

The MRLs for pesticides are set by governments to restrain the use of pesticides and to protect consumers from the harmful effects of pesticide (insecticides, herbicides, fungicides, etc.) residues that may be present in domestic or imported goods. The use of MRL measures by the World Trade Organization (WTO) member states is governed by the Agreement on the Application of Sanitary and Phytosanitary Standards (SPS) [1], which encourages members to use international recommended standards (e.g., CODEX Alimentarius) [2]. However, several member states of the Organisation for Economic Co-operation and Development (OECD) use many non-internationally defined measures. These countries have the highest severity scores for MRLs for pesticides. Indeed, according to Li et al. (2017), Australia, Japan, European Union (EU) member states, Turkey and Canada have stringency scores above unity, indicating that they apply more stringent measures than those recommended in the CODEX framework. Moreover, most developing countries, particularly those in Africa, have the lowest number of MRLs for pesticides, and in most cases, they are aligned with or less stringent than CODEX standards. For instance, Figure 2.1 shows that the number of pesticides for which MRLs are defined by African countries ranges from 0 to 42, while there are more than 600 regulated pesticides in most OECD member countries.

This weakness or lack of MRL standards in African countries compared to the very harsh measures in developed countries may represent an obstacle to both their production and export, especially in sectors with high export potential, such as mangoes classified in Harmonized System HS.08.04.50. From 1996 to 2016, mango exports from Africa recorded negative annual growth rates for the main African producers and exporters of mangoes (Egypt, Côte d'Ivoire, Ghana, Burkina Faso, Kenya, South Africa, Senegal, Mali, Morocco and Gambia). For instance, according to World Integrated Trade So-

1. https://www.wto.org/english/docse/legale/15sps01e.htm
2. CODEX is the international framework for food standards involving the WHO and FAO : http://www.fao.org/fao-who-codexalimentarius/home/en/.

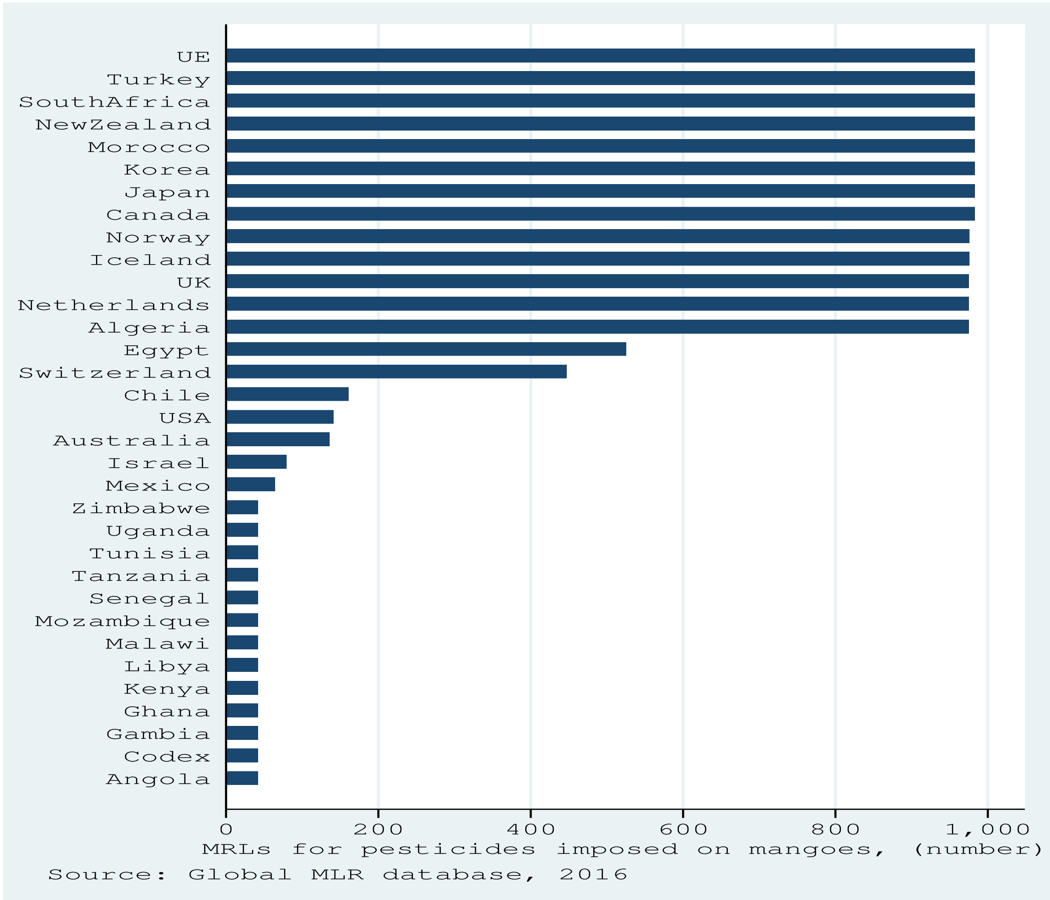

FIGURE 2.1 – Number of MRLs for pesticides imposed on mangoes by country, 2016.

lution (WITS) database the rates ranged from 181.5% in 2008 to -35.9% in 2016 for Morocco. South Africa recorded -17.5% in 1998 to -52.0% in 2016. For Mali the rates went from 138.7% in 1999 to -26.2% in 2012. Côte d'Ivoire recorded -4.4% in 2001 to 31.6% in 2016 and for Burkina Faso the rates went from 22.4% in 2001 to 31.4% in 2016. However, these different countries remain among the larger exporting countries in African, with the greatest actual and potential exports as displayed in figure 2.2. In this article, we focus on these countries in our empirical investigations.

The export market for mangoes has a structure in which each exporting country supplies a variety of mangoes differentiated by origin and takes the price of the varieties of the other countries as given (the largest suppliers in the world are Thailand, Mexico and India). Tables 2.7, 2.8 and 2.9 in appendix B show that the average unit value for different exporters over the 1996 to 2016 period at the main destination markets differed by country of origin. Each of the exporting countries in Africa also has an untapped export potential exceeding half of their export potential (ITC) [3]. This situation could be explained by their constraints [4] (deficient infrastructures and insufficient technical and storage capa-

3. `https://exportpotential.intracen.org/en/`
4. For instance, in 2011, EU countries rejected 85 containers of mangoes exported by seven member countries of the

cities) to comply with the strict standards of their partners in OECD countries, which, at more than 71% in 2016, represent the main destinations for their mango exports (WITS). For instance, in 2004, the trade ministers from the Alliance of the African, Caribbean and Pacific (ACP) Group of States, the African Union (AU) and the Least Developed Countries (LDCs) asked *"WTO members [to] exercise restraint in applying TBT and SPS measures to products of G-90 countries and [to] provide technical and financial assistance for compliance with SPS and TBT requirements for the export of G-90 agricultural commodities. "* (Disdier et al., 2008, pp.336).

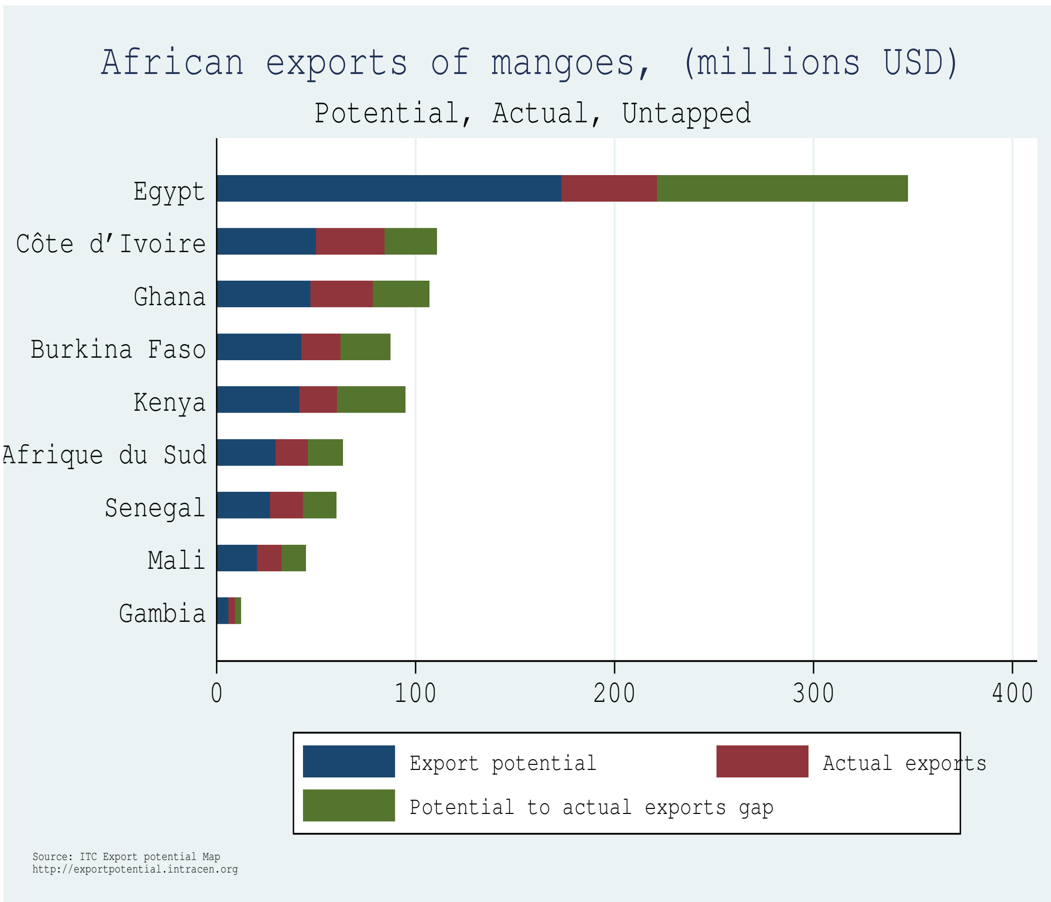

FIGURE 2.2 – African exports potential, actual and untapped, 2013-2017

However, there is no consensus in the literature on the empirical effects of MRL measures on international bilateral trade, especially for developing countries. Indeed, some studies (Fernandes et al., 2019, 2015; Fontagné et al., 2015; Otsuki et al., 2001) have found that MRL measures reduce trade between countries. For example, Fernandes et al. (2019) have estimated the effect of MRLs for pesticides on exporters' firms of agricultural products in 42 developing countries. They found that more restrictive standards in the importing country, relative to the exporting country, decreases firms' probability of exporting as well as their export values and quantities. Otsuki et al. (2001) previously predicted that

Economic Community of West African States (ECOWAS) because of non-compliance (ITC/ECOWAS-TEN, 2011).

extending the higher measures on aflatoxin to all EU member countries would reduce exports from African countries by 64% in 2002, or a loss of 670 million US dollars. In contrast, Xiong and Beghin (2011) found that aflatoxin measures in the EU have not been an obstacle to peanut exports from African countries. Disdier and Marette (2010) and Beghin et al. (2012) shown that the MRLs for antibiotics set on shrimp by the United States, the EU, Canada and Japan have reduced their imports of this product. Several other studies (e.g., Curzi et al. (2020), Xiong and Beghin (2014) and Medin (2019)) considering market imperfections (asymmetric information between producers and consumers) highlighted the ambiguous trade effect of regulatory SPS standards. Curzi et al. (2020) found that SPSs enhance the international trade of Peru. Xiong and Beghin (2014) and Medin (2019) shown that the implementation of stringent MRL measures reduces export supply but increases import demand and improves the welfare of trading partners. Our modelling approach follows this latter literature, except that we take into account the costs of conforming with standards on the production side, which is realistic when considering the African context. The agents considered are (i) producers that produce the standard-compliant primary good ; (ii) exporters of the good ; and (iii) consumers who create final consumption demand. We model producers and exporters separately while considering a vertical linkage between them to take into account the reality of the organizational structures of agri-food chains in African countries.

Our article contributes theoretically and empirically to the literature on the economic implications of MRLs for pesticides by providing a different modelling approach that disentangles the impact on production from those on exports which is the modelling approach usually used in the literature. To the best of our knowledge, it is a the first time. Indeed, we theoretically disentangle the effects of MRLs for pesticides on production, export supply, and import demand. This is important because, in most of time, producers and exporters are different as are their objectives. Producers must make a trade-off between cost (negative) and price (positive) effects. For the exporter, there is a third effect (negative), a trade cost effect. Then, we use our theoretical framework to assess the empirical net effects of the MRLs for pesticides in force in OECD member countries on African mango production and bilateral exports of standard-compliant mangoes. In complement to previous studies such as Medin (2019) and Xiong and Beghin (2014), we take into account the standard-compliance costs on the side of producers. Indeed, our proposed modelling approach takes into account both the MRL-compliance costs for the side of upstream producers through the production costs and the side of exporters via the bilateral "iceberg" trade costs. In the importing country, we take into account the perceived quality effect of standards by including a quality parameter in the consumer utility function. This modelling approach enables us to derive the net effect of MRLs for pesticides, which is the combined effect of cost-increasing and demand-enhancing effects. We demonstrate theoretically that the net effects of the MRL gap on bilateral trade can be positive, zero or negative depending on whether the consumers' perceived quality effect on import demand is greater than, equal to or less than the compliance costs effect on export supply through iceberg trade costs and unconditional expected standard-compliant production. Our empirical results support that, on the one hand, the net effect of MRLs for pesticides is positive for the level of standard-compliant mangoes production and negative for the likelihood of producing. On the other hand, it is positive for mango trade between African and OECD member countries. Our results highlight that the tightening or imposition of strict MRLs for pesticides in OECD member countries is an obstacle for mango producers in African exporter countries, although they are likely to increase import demand by guaranteeing MRL-compliant products for consumers in OECD countries. Although this study focuses on mangoes, its theoretical and empirical approaches can be applied to a number of other perishable agricultural products exported by African countries (e.g., green beans, oranges, bananas). The remainder of the paper is organized as follows. In section 2.4, we describe our modelling approach. In section 2.5, we provide the empirical strategy. In section 2.6, we present and discuss the empirical results. In the last section, we draw conclusions.

2.4 Modelling Approach

This section presents a theoretical framework for analysing the costs and benefits associated with MRLs for pesticides. The framework includes (i) producers that produce the standard-compliant primary good ; (ii) exporters of the good ; and (iii) consumers who create final consumption demand in the importing country. The framework is designed to be applied with data on MRL-compliant mango production and trade between Africa and OECD member countries. A number of recent studies using firm-level data to investigate the trade effect of SPS standards are linked to heterogeneous firms models Melitz (2003). Indeed, Melitz (2003) assumes, in each exporting country, a continuum of nonzero-profit [5] heterogeneous (in terms of productivity) firms competing in each export market. We assume that in each exporting country, there is a representative exporter competing with other countries' exporters at each destination, each choosing to export a different variety of products [6]. In addition, we disentangle producers and exporters to take into account both the production- and trade-side effects of MRLs. We assume that there are several small producers individually selling their already MRL-complaint mangoes to a representative exporter in each origin country. We thus differ from Melitz (2003)'s model, since in their framework, the costs of complying with standards are taken into account on the side of exporting firms that are heterogeneous in terms of productivity. We model these costs in terms of variable production costs for upstream producers that are price takers and homogenous in terms of productivity.

2.4.1 Exporting country

We assume that African exporting countries of mangoes face deficient infrastructure and insufficient technical and storage capacities to comply with OECD countries' technical NTMs. Consequently, complying with higher standards is costly for upstream producers in Africa. In addition, due to the higher production costs to produce standard-compliant products, the standards will not only affect the likelihood of production and the volume of production but also create uncertainty regarding the

5. Nonzero-profit firms refer to the set of firms that have a greater productivity than a certain threshold productivity. The latter is defined as the productivity required for a firm to make zero profit to a given export market.

6. We tested for price differences across exporting countries in each destination. The corresponding results are presented in tables 2.7, 2.8 and 2.9 in appendix B. Then we assume that each country exports different variety.

likelihood of exporting as well as the volume of exports to a given OECD member country. In the following, we will show these implications of MRLs for pesticides.

Production

We assume that there are several small producers of standard-compliant mangoes with Cobb-Douglas technology with decreasing returns to scale. A number of empirical studies in the literature support the rationale of assuming "decreasing returns to scale production technologies" [7]. A variety of factors are highlighted to explain this phenomenon, including imperfections in land and labor markets (Ali and Deininger, 2014; Barrett et al., 2010; Barrett, 1996; Henderson, 2015) ; imperfections in credit markets (Lamb, 2003) ; farmer heterogeneity (Assunção and Braido, 2007) ; land quality differentials (Ali and Deininger, 2014; Kimhi, 2006) ; price uncertainty (Assunção and Braido, 2007) ; and moral hazard (Feder, 1985), especially for small producers, as shown in several empirical studies (see, e.g., Helfand and Taylor (2020); Rada and Fuglie (2019)). In particular, complying with MRL standards will result in an increase in the demand for (more specialized or expensive) inputs (Maskus et al., 2013) and, for labor, an increase in supervision. This means that in the context of MRL standards, producers will bear higher costs to produce the same level of production as before.

The producers sell their products individually to a few exporters at a price ($\bar{W}_i$). We also assume that there is another category of producers that supply low-quality mangoes in the domestic market. To simplify, we focus our analysis on standard-compliant mango producers focusing exclusively or largely on exports [8]. Standard-compliant mangoes producers are assumed to operate in niche markets. It is assumed that these producers are price takers for high-quality mangoes, and they have a production cost of the form $\xi_i \bar{X}_{ij}^{\alpha}$ with $\alpha > 1$, $\bar{X}_{ij}$ being the volume of mangoes produced in country (i) according to country j standards and $\xi_i = \xi_0 \omega_i^{\alpha_L} r_i^{\alpha_K}$ being a combination of factor prices including the wage (ω_i), the price of capital (r_i) and a constant (ξ_0), which depends on the parameters of total and individual factor productivity. In addition, according to Maskus et al. (2013), Marette and Beghin (2010) and Gaigné and Larue (2016), when producers implement a higher standard, they make additional investment efforts and adjust their demands for production factors. These adjustments [9] result in an increase in their production costs to $\tilde{C}_{ij} \xi_i \bar{X}_{ij}^{\alpha}$, where $\tilde{C}_{ij} \geq 1$ measures the additional effort required to comply with the standards. Consequently, we define producer profit as follows :

$$\pi_i^p = \bar{W}_{ij} \bar{X}_{ij} - \xi_i \tilde{C}_{ij} \bar{X}_{ij}^{\alpha} - F \tag{2.1}$$

7. For instance, Julien et al. (2019) investigated short panels of Living Standards Monitoring Surveys-Integrated Agricultural (LSMS-IA) data for three low-income East African countries and found that decreasing returns to scale production technologies prevail in these countries.

8. Domestic consumption of Standard-compliant mangoes is assumed to be negligible compared to exports of mangoes.

9. This is the total investment made by the producers to comply with the standards of the importing country. These investments may include the acquisition of new technology or facilities, the adoption of new goods production practices or the recruitment of additional labor (Maskus et al. (2013), Gaigné and Larue (2016)). Maskus et al. (2013) found that the implementation of an NTM can lead to an increase in the production costs of firms on the order of 0.055 to 0.325 %.

where F is a fixed cost. The maximization of the profit given in equation (2.1) leads to the supply function defined by equation (2.2).

$$\bar{X}^{*}_{ij}(\bar{W}_{ij},\xi_i,\tilde{C}_{ij}) = \left(\frac{\bar{W}_{ij}\left(\tilde{C}_{ij}\right)}{\alpha\xi_i\tilde{C}_{ij}}\right)^{\frac{1}{\alpha-1}} \tag{2.2}$$

Since equation (2.2) expresses the optimal quantity of mangoes produced in exporting country i according to importing country j standards, we define the total quantity produced for all destination markets by $\bar{X}_i = \sum_j^{\Omega_i} \bar{X}^{*}_{ij}$, where Ω_i is the set of OECD partners for country i. Substituting $\bar{X}^{*}_{ij}$ into equation (2.1), we obtain the following profit function.

$$\pi_i^{p*} = (\alpha-1)\left(\frac{\bar{W}^{\alpha}_{ij}\left(\tilde{C}_{ij}\right)}{\alpha\xi_i\tilde{C}_{ij}}\right)^{\frac{1}{\alpha-1}} - F \tag{2.3}$$

Net effect of MRLs on the level of standard-compliant production

According to Xiong and Beghin (2014), the net effect of MRLs for pesticides is defined as the sum of their beneficial effect related to consumers' perceived quality and their cost effect affecting exporting countries. Based on this definition, these authors derived a net effect for each of the two margins of trade (extensive and intensive). In contrast to Xiong and Beghin (2014), we assume that the costs associated with the standard gap between exporting and importing countries do not affect trade directly through trade costs but indirectly through the production costs and unit price received by upstream producers from exporters. Indeed, we assume that only standard-compliant mangoes are exported, and then, for producers, complying with the standards of importing countries will possibly increase the unit value of standard-compliant products. As a result, imposing or strengthening standards in importing countries will first affect the production margins (probability of producing and production quantities) through the compliance production costs and producers' unit price and then the margins of trade via consumers' perceived quality and conditional and unconditional expected compliant production. Similar to Xiong and Beghin (2014), we assume that the additional efforts of producers in an exporting country (i) required to comply with the standards of an importing country (j) are proportional to the MRL gap between the two partner countries, so we have : $\tilde{C}_{ij} = \exp\left(\gamma max\left[mrl_j - mrl_i, 0\right]\right)$ where $\gamma \geq 0$ is a parameter measuring the magnitude of the impact of the MRL gap on the compliance costs $\tilde{C}_{ij}$.

Given that complying with the standards of importing countries will possibly increase the unit value of standard-compliant products for farmers (Fernandes et al., 2019), we define producer prices ($\bar{W}_i$) as a positive function of MRL-compliance costs ($\tilde{C}_{ij}$) as follows : $\bar{W}_{ij} = \bar{W}_i\left(\tilde{C}_{ij}\right)^{\eta}$. $\bar{W}_i$ represents the producer prices in the absence of standards and $\eta \in [0\ 1)$ is a parameter measuring the extent to which producers pass through the MRL-compliance costs to the prices they receive from exporters [10]. The net effect on the production level is obtained by exploiting equation (2.2) for optimal standard-compliant production as follows :

$$\frac{\partial ln(\bar{X}^*_{ij})}{\partial max[mrl_j - mrl_i, 0]} = (\eta - 1)\left[\frac{\gamma}{(\alpha - 1)}\right]\begin{cases} = 0 & \text{if} \quad \eta = 1 \quad \text{or} \quad \gamma = 0 \\ > 0 & \text{if} \quad \eta > 1 \\ < 0 & \text{if} \quad \eta < 1 \end{cases} \tag{2.4}$$

with $\alpha > 1$. Equation (2.4) shows that the net effect of the MRL gap on the production level is zero or positive if and only if the elasticity (η) of producer prices with respect to the MRL-compliance costs is equal to or greater than one, which indicates complete price transmission for the former case or strong upward asymmetric price transmission for the latter case. However, if the elasticity is less than one (incomplete price transmission), then the net effect of the MRL gap on production will be negative.

— *For a given production technology parameter (α) and a level of elasticity (γ) of production costs with respect to the MRL gap, producers will increase their level of MRL-compliant production if there is a perfect pass through ($\eta = 1$) or strong ($\eta > 1$) upward price transmission ; otherwise ($\eta < 1$), MRL-compliant production will decrease.*

A number of empirical studies found that small producers are excluded of value chains because of the presence of stricter standards (Dolan and Humphrey, 2000; Gibbon, 2003; Maertens and Swinnen, 2009; Minot and Ngigi, 2004; Swinnen, 2016). To model this effect, we use the profit function defined by equation (2.3) and define an indicator variable I_{ij} that takes the value of 1 if there is at least one producer in the country (*i*) able to produce mangoes conforming to the standards of country (*j*) with a positive profit, and zero otherwise. The conditional probability (relative to the observable characteristics $\bar{Z}_{ij}$) of producing standards-compliant mangoes is obtained using the profit function defined by equation (2.3).

$$Prob\Big(I_{ij} = 1|\bar{Z}_{ij}\Big) \equiv Prob(\pi_i^{p*}(\xi_0) > 0|\bar{Z}_{ij}) \tag{2.5}$$

where $\bar{Z}_{ij}$ is a set of variables specific to exporting countries and all variables linking the exporting and importing countries that are likely to affect exports through the production channel. These variables include, among others, the wage (ω_i), price of capital (r_i) and cost ($\tilde{C}_{ij}$) associated with the MRL gap between importing and exporting countries. ξ_0 is a parameter that captures the productivity chocks in country (*i*). Equation (2.5) explains the decision of producers to participate or not in the production of

10. Based on empirical evidence on vertical price transmission along value chains (Brosig et al., 2011; Goodwin and Holt, 1999; Kinnucan and Forker, 1987; Mutlu Çamoğlu et al., 2015; Ozturk, 2020; Vavra and Goodwin, 2005; Wohlgenant, 1999) and especially in Africa (Abdulai, 2007; Guvheya et al., 1998), we assume incomplete price transmission between primary producers and exporters, so $\eta < 1$.

high-quality mangoes for export and is used to assess the empirical marginal net effect of standards on the likelihood of producing high-quality or standard-compliant mangoes in exporting country. We derive the analytical expression of the net effect of MRLs on the likelihood of producing standard-compliant product by exploiting the equation (2.5) and assuming the productivity chocks (ξ_0) to be normally distributed (see the result in appendix C).

Export supply

Following Xiong and Beghin (2014), we derive the export supply function (X_{ij}) of country i to market j from exporter's revenues maximization problem[11] as follows :

$$X_{ij} = T_{ij}^{\tau-1} W_{ij}^{-\tau} \Psi_i^{-1} \bar{X}_i \tag{2.6}$$

where $\Psi_i = \left[\sum_{j\in\Omega_i} T_{ij}^{\tau-1} W_i^{1-\tau}\right]^{\frac{\tau}{\tau-1}}$, the total weighted cost of exporting to all destination markets Ω_i. W_{ij} is the unit price of mangoes produced in country i and sold to consumers in country j. The parameter $\tau < 0$ is the elasticity of transformation or the exporter's ability to substitute destination countries for each other when one becomes more stringent with respect to MRLs. $T_{ij} > 1$ is the "iceberg" trade cost of exporting mangoes from country i to market j. We specify the bilateral iceberg trade costs T_{ij} by including an additional variable (mrl_j) that will capture the direct effect of compliance costs with MRL standards required for exporters in countries i. From the expression of iceberg trade costs, the equations (2.6) and and (2.3), it follows that the volume of bilateral exports is affected by the MRL standards through the iceberg trade costs and the consumers' prices. Because country i's bilateral exports are conditioned by the availability of total exportable production ($\bar{X}_i > 0$), the standard-compliant production will decrease if the pass-through parameter (η) of producer prices is less than one, and then the impact on the volume of bilateral exports will be negative.

2.4.2 Importing country

The OECD member countries represent the main destination markets for the exports of mangoes by African countries, with a share greater than 71% in 2016 (WITS). Furthermore, these countries apply the most stringent MRLs for pesticides, although the level of stringency differs by country (Li et al., 2017). Since the MRLs for pesticides imposed on mangoes differ according to the exporting country, we assume that in each OECD importing country, consumers differentiate mangoes by their origin and valuate the safety attributes associated with the MRL measures by internalizing them in their demand functions (Eaton et al., 2004; Medin, 2019; Josling et al., 2004). Furthermore, we do not consider producers in importing countries because most OECD member countries do not produce mangoes.

11. See appendix D for the formulation of exporter's revenues maximization problem

Import demand

Consumers in importing countries consume a set $\Omega\nu$ of varieties [12] of mangoes and an aggregate of other goods, the price of these goods is standardized to unity. Following Xiong and Beghin (2014) and Curzi and Pacca (2015), we represent the preferences of a representative consumer by a CES utility function, which is defined by :

$$U_j = \left(\left[\sum_i \int_{\Omega\nu i} \Theta_{ij}(\nu)^{\frac{\varepsilon-1}{\varepsilon}} D_{ij}(\nu)^{\frac{\varepsilon-1}{\varepsilon}} d\nu \right]^{\frac{\varepsilon}{\varepsilon-1}} \right)^K \bar{D}^{1-K} \tag{2.7}$$

where the parameter $\Theta_{ij}\ (\nu)$ [13] is defined as the representative consumer's perceived quality of variety ν produced in country i and sold in country j; $D_{ij}\ (\nu)$ is the quantity demanded by consumers for this variety in country j. $\varepsilon > 1$ is the elasticity of substitution between different varieties of mangoes. K is the share of income allocated to mango consumption. Assuming that the total income of the importing country j is equal to I, then the income allocated to mango consumption is given by E_j = k * I.

Given the income E_j and prices $W_{ij}\ (\nu)$ of the different varieties of mango available in country j, the maximization of the utility function given by equation (2.7) subject to budget constraints leads to demand function M_{ij} for variety m given by equation (2.8). From this equation, the demand for country i's mangoes is a function of the unit price of mangoes W_{ij}, the unit prices of other varieties of mango embodied in price index P_j, the consumer's perceived quality Θ_{ij}^m and the income E_j allocated to mango consumption in country j.

$$M_{ij}(W_{ij}, \Theta_{ij}^m, E_j) = (\Theta_i^m)^{\varepsilon-1} (W_{ij})^{-\varepsilon} (P_j)^{-1} E_j \tag{2.8}$$

where $P_j = \sum_i \int_{\Omega\nu i} [\Theta_{ij}(\nu))^{\varepsilon-1} (P_{ij}(\nu))^{1-\varepsilon}] d\nu$ is the consumer price index of mangoes available in country j.

Consumers' perceptions of the quality of mangoes are determined by the policies of importing countries in terms of quality and safety standards, such as MRLs for pesticides (Xiong and Beghin, 2014). We assume that standards will be more stringent in countries where consumers demand more quality and safety attributes. This implies a positive relationship between consumers' perceived quality and the level of standards (Fiankor et al., 2020) : $\Theta_{ij}^m(mrl_j) = \beta_0 exp(\beta_\theta mrl_j)$, where β_0 represents country j consumers' quality perception of mangoes in the absence of MRL measures. The parameter $\beta_\theta > 0$

12. Variety here refers to any fruit species with an origin or place of production. For example, mangoes from Mali represent a variety, as do mangoes from Burkina Faso. Similarly, oranges from Morocco constitute a variety. This definition implies that while consumers differentiate the fruits among themselves, for given species of fruit, they differentiate them according to their origin.

13. The quality of each variety is modelled as a demand shift parameter related to consumers' valuation of all tangible or intangible attributes (e.g., origin of variety, pesticide residues) other than price (Hallak and Sivadasan, 2013)

measures the magnitude of the impact of MRL standards on the level of consumers' perceived quality of imported mangoes

2.4.3 Bilateral market equilibrium

The equilibrium price in each OECD country for mangoes exported by each African country is determined by the equilibrium between export supply and import demand. Thus, the price (W_{ij}^*) and the volume exchanged (V_{ij}) in equilibrium are obtained by equating equations (2.6) and (2.8) :

Equilibrium price :

$$W_{ij}^* = \left(\Theta_{ij}^m\right)^{\frac{(\varepsilon-1)}{(\varepsilon-\tau)}} \left(\frac{E_j}{P_j}\right)^{\frac{1}{\varepsilon-\tau}} \left(\frac{\Psi_i}{\bar{X}_i}\right)^{\frac{1}{\varepsilon-\tau}} (T_{ij})^{\frac{1-\tau}{\varepsilon-\tau}} \tag{2.9}$$

Bilateral equilibrium trade :

$$V_{ij} = \left(\Theta_{ij}^m\right)^{\frac{-\tau(\varepsilon-1)}{(\varepsilon-\tau)}} \left(\frac{E_j}{P_j}\right)^{\frac{-\tau}{\varepsilon-\tau}} \left(\frac{\bar{X}_i}{\Psi_i}\right)^{\frac{\varepsilon}{\varepsilon-\tau}} (T_{ij})^{\frac{-\varepsilon(1-\tau)}{\varepsilon-\tau}} \tag{2.10}$$

The equilibrium price (W_{ij}^*) given by equation (2.9) increases with the income (E_j) of importer country j, consumers' perceived quality (Θ_{ij}^m) and trade costs (T_{ij}). It decreases with the exporting country's supply capacity ($\bar{X}_i$). Bilateral trade volume (equation (2.10)) increases with the income (E_j) of importing country j, consumers' perceived quality (Θ_{ij}^m) and the exporting country' supply capacity ($\bar{X}_i$). It decreases with trade costs (T_{ij}).

Net effects of MRLs on bilateral trade

Given our definition of the net effect of MRLs on trade, which takes into account both the consumers' perceived quality in importing countries and the compliance production costs effect in exporting countries, we exploit equation (2.10) to derive a net effect for each of the two trade margins (extensive and intensive). In contrast to Xiong and Beghin (2014)'s approach, we assume that the costs associated with the standard gap between exporting and importing countries affect trade through trade costs and the production costs of upstream producers because only standard-compliant products are accepted and exported. As a result, evaluating the MRL effects on the likelihood of exporting (extensive margin) and import demand (intensive margin) requires considering the effects on the likelihood of producing and the volume of production through the expected conditional and unconditional production. The analytical expressions for the net effect of MRLs on trade margins are defined as follows :

Net effect of MRLs on the volume of exports to a given destination :

$$\frac{\partial ln(V_{ij})}{\partial mrl_j} == \frac{1}{(\varepsilon-\tau)} \left[\beta_\theta \tau(1-\varepsilon) - \left(\lambda \varepsilon(1-\tau) + (\eta-1)\left[\frac{\varepsilon\gamma}{(\alpha-1)}\right]\right)\right] \leq\geq 0 \tag{2.11}$$

Net effect of MRLs on the likelihood of exporting to a given destination :

$$\frac{\partial Pr(V_{ij}^*=1)}{\partial mrl_j} == \frac{1}{(\varepsilon-\tau)} \left[\beta_\theta \tau(1-\varepsilon) - \left(\lambda \varepsilon(1-\tau) + (\eta-1)\left[\frac{\varepsilon\gamma}{(\alpha-1)}\right]\right)\right] \leq\geq 0 \tag{2.12}$$

Here, V_{ij}^* is a binary variable that takes a value of 1 if there is a producer in exporting country *i* able to produce mangoes that conform to importing country *j*'s standards and if an exporter in country *i* can export.

Given that the sign of expressions (2.11) and (2.12) depends on $\left[\beta_\theta \tau(1-\varepsilon) - \left(\lambda\varepsilon(1-\tau) + (\eta-1)\left[\frac{\varepsilon\gamma}{(\alpha-1)}\right]\right)\right]$, the elasticity of the two trade margins with respect to MRLs for pesticides depends on the sign of the gap between the effect on consumer perceived quality on import demand $[\beta_\theta \tau(1-\varepsilon)]$ and, compliance costs effect on export supply through both the bilateral trade costs $[\lambda\varepsilon(1-\tau)]$ and the expected compliant production level $\left[(\eta-1)\left[\frac{\varepsilon\gamma}{(\alpha-1)}\right]\right]$. This elasticity of MRLs on trade margin can be *positive, zero, or negative* depending on whether the perceived quality effect is *greater than, equal to, or less than* the compliance cost effect.

Table 2.1 presents a summary of the effects of MRLs on both production and bilateral trade. This table also provides an overview of our framework versus that of Xiong and Beghin (2014).

TABLE 2.1 – Summary of the effects of MRLs on Production and Exports

Variable	Benchmark : Xiong et Beghin (2014)		Our model			
	Pr(to export)	Export	Pr(to produce)	Production	Pr(to export)	Export
Perceived quality	$(+)^a$	$(+)^b$			$(+)^{\bar{a}}$	$(+)^{\bar{b}}$
Production	$(+)^c$	$(+)^d$				
Expected production					$(+)^{\bar{c}}$	$(+)^{\bar{d}}$
Producer prices			$(+)^{\bar{\bar{g}}}$	$(+)^{\bar{\bar{h}}}$		
Compliance costs with MRL	$(-)^e$	$(-)^f$	$(-)^{\bar{g}}$	$(-)^{\bar{h}}$	$(-)^{\bar{e}}$	$(-)^{\bar{f}}$
Net Effect (NE)	a+e	b+f	$\bar{\bar{g}}+\bar{g}$	$\bar{\bar{h}}+\bar{h}$	$\bar{a}+\bar{\bar{c}}+\bar{e}$	$\bar{b}+\bar{\bar{d}}\ \bar{f}$

Note : $\bar{\bar{c}} = \bar{c}*[\bar{g}E(\bar{X}_{ij}^{ob} \mid \bar{X}_{ij}^{ob} > 0, \bar{Z}) + \bar{h}\,Pr(\bar{X}_{ij}^{ob} > 0 \mid \bar{Z})]$ and $\bar{\bar{d}} = \bar{d}*[\bar{g}E(\bar{X}_{ij}^{ob} \mid \bar{X}_{ij}^{ob} > 0, \bar{Z}) + \bar{h}\,Pr(\bar{X}_{ij}^{ob} > 0 \mid \bar{Z})]$

2.5 Data and Empirical Strategy

Based on our theoretical framework, we build our empirical strategy to estimate the effects of the MRLs for pesticides in force in OECD countries on the production and exports of standard-compliant mangoes from Africa in 2016. In our theoretical framework, we assume that production and export data are generated through a four-step process. Production is the result of (i) the decisions of producers that can or cannot produce standard-compliant mangoes and (ii) the choice of production level. Then, with nonzero quantities of standard-compliant mangoes produced, the export flows are derived from (iii) the decision to export and then, if affirmative, (iv) the choice of the quantity to be exported to each destination. Thus, the estimation strategy first consists of evaluating the effects of MRLs on the likelihood of producing standard-compliant mangoes and the quantity produced. Then, in a second step, we determine the probability of exporting and the export volume given the quantities of expected compliant mangoes produced.

2.5.1 Data description

We use cross-sectional data on 12 African countries that produced and exported mangoes to 31 OECD countries in 2016 [14]. Our data set contains bilateral trade data that are downloaded from UN WITS/COMTRADE [15], trade cost data from CEPII [16], real interest rate (as a proxy for capital price), number of documents required to import and time required to import are from the World Bank web portal [17]. The labour costs proxied by the average monthly earnings in each exporting country are from the International Labour Organization (ILOSTAT) portal [18]. The unit prices received by upstream producers of mangoes in exporting countries measured by the average annual producer prices for the item "Mangoes, mangosteens, guavas" from the FAOSTAT website [19]. In appendix H, we provide more details on the sources of the non-usual data, namely, the price of capital variable, the wage and the producer prices.

Bilateral exports are used to measure destination-oriented MRL-compliant production because we do not have data on mangoes produced by each exporting country for each of its partners. As we are only interested in MRL-compliant mangoes being produced in each exporting country to be largely or exclusively exported to every importing country, we proxy for destination-oriented MRL-compliant production by using bilateral exports. However, it should be emphasized that exports are not an exact measure of MRL-compliant production but a fraction of it. Indeed, some of the mangoes produced may not be purchased or exported by exporters even though they meet the requirements of certain importing countries. Ideally, we would like to obtain information about the real production that each exporting country produces in conformity with the MRL measures of every importing country. However, the potential downward measurement bias is captured, since domestic consumption of high-quality mangoes is assumed to be negligible. Therefore, the observed bilateral exports can be considered the best proxy for destination-oriented MRL-compliant production. Proxying for the origin country's output by total bilateral exports and destination expenditures by total bilateral imports are conditions to be satisfied in international trade so that "general gravity" is equivalent to "structural gravity" (Fally, 2015). In addition, for a given exporting country, the observed total production of MRL-compliant mangoes is proxied by its total exports (to all destinations and not only to OECD countries). Hence, *hereafter we mean destination-oriented MRL-compliant production as bilateral exports and total MRL-compliant production as total exports*.

Table 2.2 presents the descriptive statistics of these different variables. The average trade value between the 12 African and 31 OECD countries was 0.747 million of US dollars in 2016. The distance between exporting and importing countries is, on average, 6890 km. The number of documents required to import and time required to import are 4 official documents and 10 days, respectively. The

14. The lists of exporting and importing countries are presented in Tables 2.12 and 2.13 in appendix B, respectively.
15. https://wits.worldbank.org
16. http://www.cepii.fr
17. https://data.worldbank.org/
18. https://www.ilo.org/ilostat
19. http://www.fao.org/faostat

mean real interest rate in the 12 African countries is 11.447%, and the mean of their average monthly earnings is 118.583 US dollars. The zero trade values represent 57.30%. The pairs of countries that share a common official or primary language equal 17.50%, and 53.80% of pair countries belong to the ACP-UE trade agreement. Only 2.69% of pair countries were in a colonial relationship after 1945. The average quality is estimated over all African countries at 1161 of US dollars in 2016. The distribution of mangoes quality for each African country across OECD members is displayed in appendix H (see figures 2.7, 2.8 and 2.9)

TABLE 2.2 – Descriptive statistics of variables

Continuous variables	Count	Mean	Sd	Min	Max
Trade value (1000 USD)	159	747.723	2132.565	.001	14991.510
Export quality estimates (1000 USD)	372	1.161	0.7478	0.051	7.845
GDP importer (1000 USD)	372	1.49e+12	3.33e+12	2.03e+10	1.86e+13
Distance (Km)	372	6889.202	3594.217	442.805	19333.78
Document to import (Number)	372	4.300	1.413	2.000	8.000
Time to import (days)	372	9.529	3.571	5.000	18.000
Production (export to world, 1000 USD)	310	7401.490	11470.480	.074	35953.930
Producer prices (average annual producer prices, USD/Kg)	372	.332	.334	.058	1.291
Wage (average monthly earnings, USD)	372	118.583	75.773	36.000	278.000
Real interest rate (Rrealrate, %)	372	11.447	12.798	1.222	49.9801
MRL stringency index scores (OECD)	CODEX pesticides (42)	1.414	0.252	0.708	1.708
MRL stringency index scores (AFRICA)	CODEX pesticides (42)	0.991	0.021	0.943	1.000
Binairy variables			Proportion		
Trade binary variable	0		0.573		
	1		0.427		
Pair in colonial relationship post 1945	0		0.973		
	1		0.027		
Common official or primary language	0		0.825		
	1		0.175		
ACP country exporting to EU member	0		0.462		
	1		0.538		

The data on MRLs for pesticides for mangoes in each country come from the "Global MRL Database" [20]. This database is one of the most comprehensive data sources on MRL policies for several countries. Indeed, it includes, on the one hand, the MRLs for more than 970 pesticides defined for 850 plant products and covers 125 countries. On the other hand, it contains the MRLs for 300 veterinary drugs for all animal products for which the MRLs are defined in the United States. Specifically, we are interested in the MRLs in force in African countries, those in OECD countries and CODEX. Of these countries, the MRL database covers 16 African countries, all 31 OECD countries and CODEX (see Table 2.10). For African countries (Burkina Faso, Comeroon, Côte d'Ivoire, Madagascar, Mali and Nigeria) not covered by the database, we assumed that these countries refer to or apply international CODEX standards. Indeed, nearly all 16 African countries in the database refer to default CODEX standards, except Algeria and Gambia, which set EU standards as a default measure. Table 2.10 describes the MRLs for pesticides in force in different countries. This table shows that Australia and the United States appear to be the most stringent in terms of MRL policies. These countries do not recognize pesticides defined by other legislation and have not established any default MRL values. Other countries, such as Japan, South Korea, Turkey and Canada, appear to be more stringent than

20. https://www.globalmrl.com/home/

average. Indeed, the first three countries have the lowest default MRL values of 0.01 part per million (0.01 ppm or 0.01 mg/kg) and 0.1 ppm for Canada. Finally, the remaining African countries refer totally or partially to CODEX standards. In addition, we observe that the number of pesticides regulated by MRL standards is heterogeneous between importing and exporting countries and among importing counties, as mentioned in Winchester et al. (2012). Indeed, the number of pesticides regulated by African countries ranges from 0 to 42 substances. In contrast, it is above 600 pesticides for many OECD member countries [21]. We control for such heterogeneity by calculating the stringency index of MRLs for the different countries using a robust index proposed by Li and Beghin (2014) and defined by equation (2.13). According to Li and Beghin (2014), their index is invariant to regulatory intensity since the index is an average of the sum of the scaled MRL gap of each country by the total number of pesticides. In addition, the index is invariant to the scale of different residue levels because the differences between domestic (importer and exporter) and international MRLs are scaled by the CODEX standards. Furthermore, the index takes into account the cases with the lowest number of substances regulated and more stringent MRLs for regulated pesticides. Indeed, the index assigns more weight to the lower MRL values (i.e., more stringent regulations) by allowing protectionist MRLs (below CODEX standards) to contribute exponentially to the index. The index is computed as follows :

$$mrl_{jk} = \frac{1}{N_{(k)}} \sum_{n_{(k)}=1}^{N_{(k)}} \exp\left(\frac{MRL_{codex}, kn_{(k)} - MRL_{j}, kn_{(k)}}{MRL_{codex}, kn_{(k)}} \right) \tag{2.13}$$

where mrl_{jk} denotes the country j relative (with respect to CODEX) mrl stringency index for product (k). $MRL_{j}, kn_{(k)}$ is the MRL value defined by country j, for product k, and targeting pesticide $n_{(k)}$. $MRL_{codex}, kn_{(k)}$ is the MRL value recommended by CODEX for the same product and pesticide. $N_{(k)}$ is the total number of pesticides applicable to product (k). For a given country, the mrl stringency index score is interpreted with respect to unity. A score larger than 1 indicates that the MRL standards for pesticides are more stringent than CODEX on average, and scores below 1 indicate that the standards are laxer than CODEX. A score of 1 indicates that domestic MRLs are aligned, on average, with the CODEX standards (non-protectionist policy). Thus in table 2.2, it follows that, OECD countries, with an average score of 1.414, are more stringent than CODEX, and African countries with 0.991 are laxer than CODEX. The means mrl stringency scores are computed for 31 OECD countries and for 6 African countries [22]. In addition, we did not compute the index for all pesticides regulated by each country (i.e., fewer than 42 substances for African countries and more than 600 for many OECD countries). We computed the index for only the pesticides regulated at the international level because CODEX standards are our benchmark. As all African countries are almost aligned with CODEX and then their mrl stringency index scores are egal to one, we present in figure 2.3 the scores computed

21. Figure 2.1 shows that the number of pesticides for which MRLs are defined by African countries is between 0 and 42, in contrast to more than 600 for most OECD member countries.

22. These 6 African countries are Egypt, Gambia, Kenya, Marocco, Mozambique, South Africa. The remainder 6 countries for which we did not obtain MRL information in the global MRL database are Burkina Faso, Comeroon, Côte d'Ivoire, Madagascar, Mali and Nigeria.

for only OECD countries. This figure shows that mrl stringency scores are above one for all OECD member countries, except New Zealand. These results simply imply that African countries will require additional costs to comply with the standards of their partners in OECD countries.

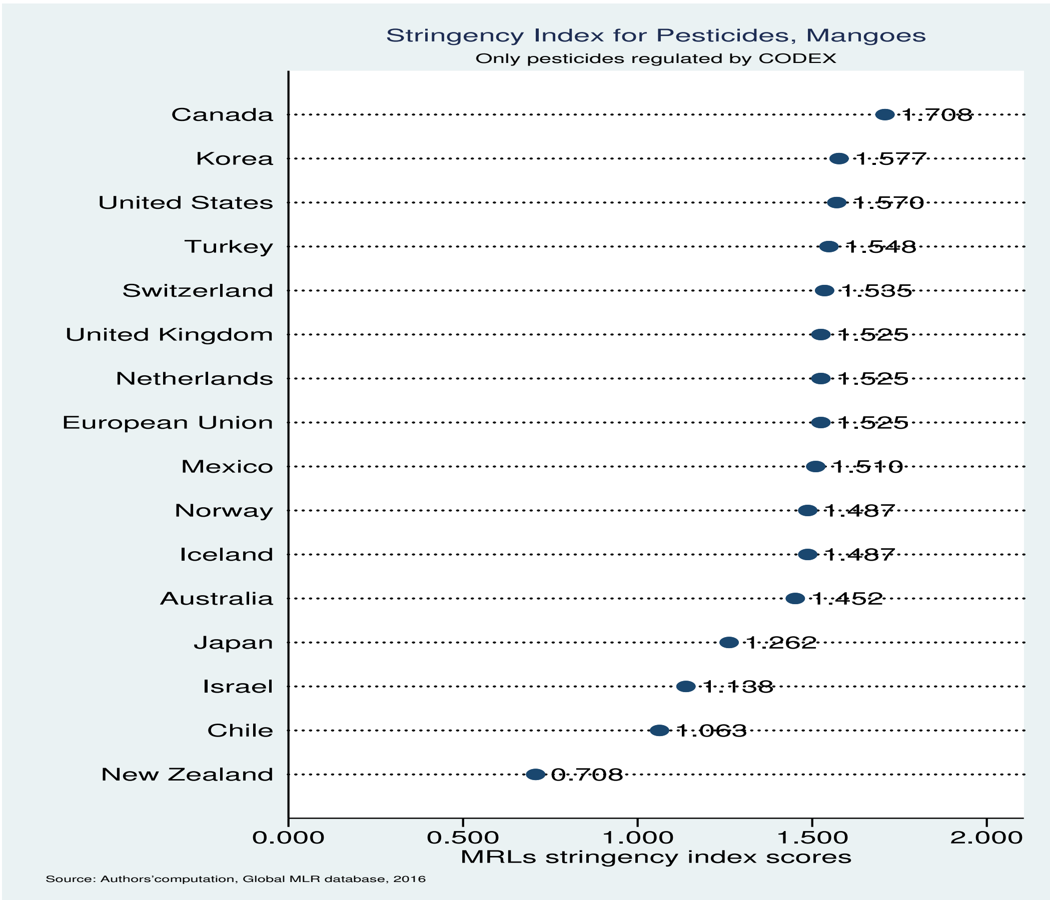

FIGURE 2.3 – MRLs Stringency Index for pesticides, OECD

2.5.2 Estimating the effect of MRLs on the likelihood of producing and the volume of production

An estimate of the volume of standard-compliant mangoes and the likelihood of production is performed using equations (2.2) and (2.5), respectively. According to our theoretical framework, the presence of zeros in the production data results from the decisions of producers that can decide to produce or not standard-compliant mangoes and then from their choice of the level of production. As a result, estimating the producers' supply equation (2.2) requires considering the zeros. One of the most frequently recommended approaches is to specify the production equation as a "Cragg (1971) lognormal hurdle" model (Achandi and Mujawamariya, 2016; Benali et al., 2018; Olwande et al., 2015; Reyes et al., 2012). Indeed, the Cragg lognormal hurdle model is a corner-solution model that is applied to situations where the dependent variable data are lognormally distributed, truncated and "pile up" at some given value but are continuous otherwise (Cragg, 1971; Wooldridge, 2010). In addition, this model assumption satisfies our theoretical production model's assumptions that, first, the producer has the ability to produce MRL-compliant mangoes and, second, produces a given volume of mangoes, possibly. We thus adopt the Cragg lognormal hurdle specification using equation (2.2) for the level of production and equation (2.5) for the decision-making process. In the first step, we use a probit model to estimate the likelihood of producing MRL-compliant mangoes. To do this, we define a binary variable (I_{ij}) that takes a value of 1 if the observed compliant production ($\bar{X}_{ij}^{ob}$) is positive and zero otherwise. The second step consists of using the ordinary least squares (OLS) method to estimate the log of production equation (2.2) using only positive values. Following Wooldridge (2010), we relate the observed production ($\bar{X}_{ij}^{ob}$) to the unobserved production ($\bar{X}_{ij}^{*}$) given in equation (2.2), as follows :

$$\bar{X}_{ij}^{ob} = \begin{cases} \bar{X}_{ij}^{*} = \exp(\bar{Z}_{ij}\gamma + \mu_{ij}) & \text{if} \quad I_{ij} = 1[\bar{Z}_{ij}\beta + v_{ij} > 0] \\ 0 & \text{otherwise} \end{cases}$$

From this expression, we define the positive production values by :

$$\bar{X}_{ij}^{ob} = I_{ij} \times \bar{X}_{ij}^{*} = 1[\bar{Z}_{ij}\beta + v_{ij} > 0] \exp(\bar{Z}_{ij}\gamma + \mu_{ij}) \tag{2.14}$$

with

$$\begin{pmatrix} v \\ \mu \end{pmatrix} \sim \mathscr{N}\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & 0 \\ 0 & \sigma_{\mu}^{2} \end{bmatrix} \right)$$

$\bar{Z}_{ij}$ is a set of explanatory variables of the likelihood of producing standard-compliant mangoes and the quantity produced. It includes the unit price of mangoes received by producers (W_i), the wage (ω_i), the price of capital (r_i) and the maximum residue limits for pesticides imposed by importing countries (mrl_j). We use the standards of importing countries instead of the gap because most African countries do not have an MRL policy, although some of them refer to CODEX standards in our database. This phenomenon is not observed in reality (Xiong and Beghin, 2011). In addition, we control for the possible endogeneity [23] of mrls stringency index following the two-stage predictor substitution (2SPS) method, which is an instrumental variable (IV)-based approach (Terza et al., 2008) and use political, economic and institutional factors suggested in Li et al. (2017) as instruments. The results related to these estimations is presented in table 2.11 in appendix E.

The empirical specification of the likelihood and the expected conditional and unconditional standard-compliant production are given by equations (2.15), (2.16) and (2.17), respectively.

Empirical specification of the likelihood of producing a standard-compliant product :

23. The issue of the endogeneity of MRL policy is widely raised in the literature. Indeed, previous studies, including Li et al. (2017) and Xiong and Beghin (2014), highlighted that the use of food safety standards such as an MRL measures seems to result from the substantial reduction in customs tariffs, domestic firms' lobbying efforts or protectionist motives, and legitimate social objectives such as public health.

To specify the likelihood of producing MRL-compliant mangoes, we use the equation (2.5) for the decision-making process and assume the logarithm of total productivity shocks (ξ_0) to be normally distributed. The conditional probability (relative to the observable characteristics $\bar{Z}_{ij}$) of producing standard-compliant mangoes is defined in equation (2.15).

$$Prob\Big(I_{ij}=1|\bar{Z}_{ij}\Big) \equiv Prob(\pi_i^{p*}(\xi_0)>0|\bar{Z}_{ij}) = \Phi\Big(\beta_0+\beta_1 ln(W_i)+\beta_2 ln(\omega_i)+\beta_3 ln(r_i)+\beta_4 ln(mrl_j)\Big) \tag{2.15}$$

where $\Phi(.|.)$ is the standard normal cumulative distribution function (cdf) and mrl_j refers to mrl stringency index score of importing country defined by equation (2.13).

Empirical specification of the conditional standard-compliant production ($\bar{X}_{ij}^{ob}>0$) :

$$E\left(\bar{X}_{ij}^{ob}|\bar{X}_{ij}^{ob}>0,\bar{Z}_{ij}\right) = exp\left(\gamma_0+\gamma_1 ln(W_i)+\gamma_2 ln(\omega_i)+\gamma_3 ln(r_i)+\gamma_4 ln(mrl_j)+\frac{\sigma_\mu^2}{2}\right) \tag{2.16}$$

Empirical specification of the unconditional standard-compliant production :

$$E\Big(\bar{X}_{ij}^{ob}|\bar{Z}_{ij}\Big) = \Phi\Big(\bar{Z}_{ij}\beta\Big)exp\Big(\bar{Z}_{ij}\gamma+\frac{\sigma_\mu^2}{2}\Big) \tag{2.17}$$

According to Wooldridge (2010), the parameters β, γ and σ_μ can be estimated in two steps. The first step consists of estimating β with a probit model, and then, in the second step, the parameters γ and σ_μ are obtained by estimating the logarithm of the positive values using the OLS method.

From equations (2.15), (2.16), and (2.17), the average partial net effects of MRLs on the likelihood of producing and on both the conditional and unconditional expected MRL-compliant production of mangoes are computed by following the K-R (Krinsky and Robb) procedure suggested in Krinsky and Robb (1986) and Krinsky and Robb (1990) using the corresponding formulas presented in appendix E. The K-R method is based on the assumption that the estimators of model parameters are consistent and have an asymptotically normal multivariate distribution (Shang and Tonsor, 2017; Ghazalian et al., 2012; Marquez, 1990; Pfaffermayr, 2020). Based on this assumption, we draw multiple vectors of β_n and γ_n, n=1...10 000 from multivariate normal distributions that have mean vectors equal to the estimated vectors of coefficients $\hat{\beta}$ and $\hat{\gamma}$ in the probability and expected production equations and the corresponding estimated variance-covariance matrix. For each new vector of β_n and γ_n drawn, we compute a new value of the net effects of MRLs on the standard-compliant production using the equations (2.15) for the likelihood of producing, (2.16) for the conditional expected MRL-compliant production of mangoes and (2.17) for the unconditional expected MRL-compliant production . Then, after 10,000 replications, we calculate the mean and standard error of the net effects of MRLs.

2.5.3 Estimating the effect of MRLs on the likelihood of exporting and the volume of exports

We use the bilateral equilibrium trade equation (2.10) to estimate the effect of MRLs on the volume of bilateral trade. Similar to Xiong and Beghin (2014), we use a two-step procedure where the first consists of using a probit model to estimate the probability of exporting or the extensive margin. In the second step, we use the OLS method to estimate the log of positive values of exports or the intensive margin. In this latter step, we control for possible sample selection bias by including the inverse of mills ratio (IMR) computed with the estimates from the first step (Heckman, 1979). Another issue in the estimation of equation (2.10) is related to the identification of parameters. According to Heckman (1979), the identification issue can be addressed by excluding a variable in the level equation. In the trade literature, the excluded variable may potentially affect the fixed cost of trade but not the variable cost of trade. We assume that the common language variable can potentially affect the fixed cost of trade. Our choice is also based on the pragmatic consideration that the common language variable is statistically insignificant in the OLS estimation of positive trade flows. Thus, we excluded this variable in the iceberg trade cost ($\bar{T}_{ij}$ = T_{ij} without common language) when estimating the outcome equation (2.19). We assume that exporters make their export decisions by considering the expected volume of standard-compliant mangoes E($\bar{X}_{ij}^{ob}$ | $\bar{Z}_{ij}$) = Pr($\bar{X}_{ij}^{ob} > 0$ | $\bar{Z}_{ij}$)×E($\bar{X}_{ij}^{ob}$ | $\bar{X}_{ij}^{ob} > 0$, $\bar{Z}_{ij}$). In this case, we use the expected volume of production as our measure of standard-compliant production when we estimate the trade equation (2.10). The empirical specifications of the likelihood of exporting and the volume of exporting are :

Empirical specification of the likelihood of exporting a standard-compliant product :

$$Pr(V_{ij}>0|Z_{ij}) = \Phi\Big(\alpha_0^* + \alpha_1^* ln(\Theta_{ij}^m) + \alpha_2^* ln(E_j) - \alpha_3^* ln(P_j) - \alpha_4^* ln(\Psi_i) + \alpha_5^* ln(\bar{X}_i) - \alpha_6^* ln(T_{ij})\Big) \tag{2.18}$$

with Φ (.) being the normal cumulative distribution function.

Empirical specification of the export volume :

$$\begin{aligned} ln(V_{ij}|V_{ij}>0,Z_{ij}) = \quad & \alpha_0 + \alpha_1 ln(\Theta_{ij}^m) + \alpha_2 ln(E_j) - \alpha_3 ln(P_j) - \alpha_4 ln(\Psi_i) + \alpha_5 ln(\bar{X}_i) \\ & -\alpha_6 ln(\bar{T}_{ij}) + \lambda IMR_{ij} + \varepsilon_{ij} \end{aligned} \tag{2.19}$$

where $\bar{X}_i = \sum_j^{\Omega_i} Pr(\bar{X}_{ij}^{ob} > 0|\bar{Z}_{ij}) * E(\bar{X}_{ij}^{ob}|\bar{X}_{ij}^{ob} > 0, \bar{Z}_{ij})$ is derived from equations (2.27) and (2.28). α_k^* ; α_k with k= 1, ...,6 and λ being parameters to be estimated.

E_j is the income of importing country *j* allocated to the consumption of mangoes, which is measured by the total import value of mangoes by country *j*. P_j is the price index of mango varieties consumed in country *j*. This unobservable index is measured by a proxy proposed in (Yotov et al., 2016, p.43), i.e., $P_j \equiv \ln\left(\sum_{i=1}^{\Omega_j} Dist_{ij}/(\frac{X_{ij}}{X_j})\right)$. Similarly, the trade cost index of country *i*'s exports is measured by the log of the sum of distances weighted by the GDP ratio of the partner countries, i.e., $\Psi_i \equiv \ln\left(\sum_{j=1}^{\Omega_i} Dist_{ij}/(\frac{E_j}{E})\right)$.

Measuring consumers' perceived quality (Θ_{ij}^m)

Θ_{ij}^m is country j consumers' perceived quality of mangoes (m) imported from country i. To measure perceived quality, several proxies have been suggested in the literature. For instance, Hallak (2006), and Hallak and Schott (2011) used price (unit value) as a measure of quality. However, other authors such as Khandelwal (2010), Amiti and Khandelwal (2013) and Curzi and Pacca (2015) have reported that price differences in a destination market for the same product can be attributed to differences in production costs, and thus, price is not an ideal measure of quality. These authors thus combined price with market share to measure quality. They have noted that high-quality products are those with a higher demand share for given price and income levels. In this study, we use this measure of the quality suggested by Amiti and Khandelwal (2013) and used, among others, by Piveteau and Smagghue (2019). In practice, the measure of quality for a given product is the difference between the demand observed for that product and that predicted using price and income [24]. Following (Curzi and Pacca, 2015, p.150), we derived the quality from the CES demand function given by equation (2.8) and set the trade elasticity at the median value ($\sigma = 3$) estimated in Broda and Weinstein (2006). According to (Khandelwal et al., 2013, p.2187) and (Curzi and Pacca, 2015, p.150), quality is estimated by taking the residuals of consumers' CES import demand and dividing them by the destination market elasticity of substitution minus one. Following these authors, we infer the quality of mangoes from the consumer CES import demand (import value) equation following a two-step procedure. However, the issue of endogeneity of consumers' prices is widely raised in the literature (Broda and Weinstein, 2006; Feenstra et al., 2018; Hallak and Schott, 2011; Piveteau and Smagghue, 2019) when estimating the consumers perceived quality through consumers' demand residuals, because prices are likely to be correlated to these residuals (quality). In addition, a fraction of prices may be present in the residuals due to measurement error because trade unit values are used to proxy these prices. A number of methods have been proposed in trade literature to deal with that endogeneity. To address this issue, first we use time series data from 2000 to 2018 and, second, we follow the approach suggested by Hallak and Schott (2011) and use importer-time-variant and exporter-time-variant fixed effects and real exchange rates as instrument. The rational of using real exchange rates to control for endogeneity could also be found in Piveteau and Smagghue (2019). Detailed information related to the estimation of mangoes quality and the distribution of 12 African countries' export quality across 31 OECD countries are reported in appendix G.

2.5.4 Estimating the Net Effects of MRLs on Bilateral Trade

Consistent with our theoretical framework and empirical specification of the unconditional expected compliant production (equation (2.17)) and trade (equations (2.18) and (2.19)), the net effects of MRLs for pesticides on the likelihood of exporting and trade value are defined by equations (2.20) and (2.21), respectively :

24. The quality of a variety corresponds to the variation of its demand related to the valuation by consumers of all tangible or intangible attributes (e.g., comfort, origin of the variety, pesticide residues) other than the price (Hallak and Sivadasan, 2013; Khandelwal, 2010)

$$\textit{Net effect of MRLs on the likelihood of exporting} \equiv \frac{\partial Pr(V_{ij}>0|Z_{ij})}{\partial mrl_j}$$
$$= \bar{\alpha}_1^* + \bar{\alpha}_6^*$$
$$+\bar{\alpha}_5^* * \left[\beta_1 \times \frac{\phi(\bar{Z}_{ij}\beta)}{\Phi(\bar{Z}_{ij}\beta)} + \beta_4 \times \frac{\phi(\bar{Z}_{ij}\beta)}{\Phi(\bar{Z}_{ij}\beta)} + \gamma_1 + \gamma_4\right] \tag{2.20}$$

with $\bar{\alpha}_1^* = \alpha_1^* \ \phi(Z_{ij}\alpha)$ being the marginal effect of MRL-related quality perceptions on the likelihood of exporting and $\bar{\alpha}_6^* = \alpha_6^* \ \phi(Z_{ij}\alpha)$ is the marginal effect of MRL-compliance costs on the likelihood of exporting. $\bar{\alpha}_5^* = \alpha_5^* \ \phi(Z_{ij}\alpha)$ being the marginal effect of unconditional expected production on the likelihood of exporting and $\left[\beta_1 \times \frac{\phi(\bar{Z}_{ij}\beta)}{\Phi(\bar{Z}_{ij}\beta)} + \beta_4 \times \frac{\phi(\bar{Z}_{ij}\beta)}{\Phi(\bar{Z}_{ij}\beta)} + \gamma_1 + \gamma_4\right]$ capturing the response of unconditional expected standard-compliant production with respect to MRLs for pesticides (see appendix E).

$$\textit{Net effect of MRLs on trade value} \equiv \frac{\partial ln(V_{ij}|V_{ij}>0,Z_{ij})}{\partial mrl_j}$$
$$= \alpha_1 + \alpha_5 * \left[\beta_1 \times \frac{\phi(\bar{Z}_{ij}\beta)}{\Phi(\bar{Z}_{ij}\beta)} + \beta_4 \times \frac{\phi(\bar{Z}_{ij}\beta)}{\Phi(\bar{Z}_{ij}\beta)} + \gamma_1 + \gamma_4\right] + \alpha_6 \tag{2.21}$$

where α_1 refers to the trade effect of MRLs related to consumer quality perception, α_6 is the direct effect of MRL-compliance costs on bilateral exports value and α_5 captures the effect of unconditional expected compliant-production on trade value.

To compute the net effects of MRLs on trade margins and the associated standard errors, we follow the same K-R procedure as before. In this case, we draw multiple vectors of β_n, γ_n, and α_n, n=1...10 000 from multivariate normal distributions that have mean vectors equal to the estimated vectors of coefficients $\hat{\beta}$, $\hat{\gamma}$ and $\hat{\alpha}$ in the production and trade equations and the corresponding estimated variance-covariance matrix. For each new vector of β_n, γ_n, α_n drawn, we compute a new value of the net effects of MRLs on trade by using the formulas defined by equations (2.20) and (2.21). Then, after 10,000 replications, we calculate the mean and standard error of the net effects of MRLs on trade.

2.5.5 Robustness Checks

As a robustness check, we perform two alternative estimations. First, we estimate a model following the approach of Xiong and Beghin (2014) that consists of taking into account the MRL-compliance cost in trade costs without considering any relationship between production in the exporting country and standards imposed by the importing country. We used the total exports to proxy for standard-compliant production instead considering expected unconditional complaint-production that embodied the information related to the probability of producing and the observed quantities of production. In addition, to control for that our measure for standard-compliant production does not include less stringent MRLs-mangoes production, we re-estimate the model by restricting the total export to the export toward only OECD countries.

Our second robustness check consists using alternative measures for multilateral resistance terms other than those suggested in (Yotov et al., 2016, p.43), especially we estimate equations (2.18) and (2.19) using predicted exporter and importer fixed effects that we computed as follows : $e_i = \ln\left(\frac{X_i}{\hat{\Psi}_i}\right)$ and $m_j = \ln\left(\frac{E_j}{\hat{P}_j}\right)$, respectively. We calculate these predicted values after computing more structural multilateral resistance indexes (Ψ_i and P_j) suggested in Fally (2015) citing Anderson and Van Wincoop (2003). The following system has been resolved to compute these indexes : $\left(\hat{P}_j = \sum_{j=1}^{\Omega_i} X_i \hat{T}_{ij}/(\hat{\Psi}_i)\right.$ and $\hat{\Psi}_i = \left.\sum_{j=1}^{\Omega_i} E_j \hat{T}_{ij}/(\hat{P}_j)\right)$, where X_i refers to the observed total export value in exporting country i, E_j to the observed expenditure by importing country j and $\hat{T}_{ij}$ is the estimated "iceberg" trade cost.

2.6 Results and Discussions

In this section, we present the results of the estimates of the effects of MRLs for pesticides in force in OECD countries on the production and exports of mangoes from Africa. These results are discussed in light of our theoretical conclusions and the empirical literature. First, we discuss the results of the effects of MRLs for pesticides on the likelihood of mango production and volume of mangoes produced. Then, we present the results for the likelihood and the volume of exports.

2.6.1 Effects of MRLs on the likelihood of producing mangoes and the volume of production

Table 2.3 shows the results of the estimates of equation (2.15) for the likelihood of producing standard-compliant mangoes, equation (2.16) for conditional standard-compliant production and equation (2.17) for unconditional standard-compliant production proxied by total exports. The results for the likelihood of producing MRL-compliant mangoes are presented in columns 2 and 3, and those relating to the volume produced are given in columns 4 to 6. The results show that the MRLs for pesticides in force in OECD countries have negative effects on the likelihood of producing standard-compliant mangoes and the volume of mangoes produced. The coefficients associated with the variable (*mrl stringency scores*) measuring the MRL stringency of OECD countries for mangoes are negative, which means that the maximum residue limits for pesticides in force in OECD countries reduce the odds of African countries producing MRL-compliant mangoes and the volume produced. In particular, a 1% increase in the mean value of stringency index scores over all OECD countries will result in an average decrease of 0.088% in the likelihood of producing and a decrease of 0.242% [25] in the volume of expected unconditional standard-compliant mangoes production in Africa.

TABLE 2.3 – Effects of MRLs on the likelihood and volume of mangoes produced

	Pr(production > 0)		ln(production value)		
	Coef.	APE^a	Coef.	APE^c	APE^u
ln(producer prices) ($\bar{W}_{ij}$)	0.199*	0.069*	1.309***	1.309***	0.191*
	(0.114)	(0.040)	(0.403)	(0.403)	(0.114)
ln(predicted mrl stringency scores) (mrl_j)	-0.252**	-0.088*	-0.309	-0.309	-0.242*
	(0.124)	(0.047)	(0.473)	(0.473)	(0.133)
ln(wage) (ω_i)	-0.165	-0.058	-2.487***	-2.487***	-0.159
	(0.164)	(0.064)	(0.571)	(0.571)	(0.165)
ln(real interest rate) (r_i)	-0.571***	-0.199***	-2.164***	-2.164***	-0.548***
	(0.088)	(0.028)	(0.298)	(0.298)	(0.103)
Constant	1.381		26.330***		
	(1.009)		(3.533)		
Sigma			2.960***		
			(0.161)		
Observations	372	372	159	159	372
R^2			0.278		
Adjusted R^2			0.259		
Pseudo R-squared	0.106				
Prob > chi2	0.000				

Standard errors in parentheses * p<.10, ** p<.05, *** p<.01

[a] APE means Average partial effect and their Standard errors in parentheses is calculated by using Bootstrap method.

[c] Average partial effect on the conditional expected value of production (for Production > 0).

[u] Average partial effect on the unconditional expected value of production (for Production ≥ 0)

For the other variables, we find that the signs of their coefficients are all in line with expectations. When we consider the variables for production costs, the results show that wages (ω_i) and the price of capital ($Rrealrate_i$) negatively affect both the likelihood of producing mangoes and the volume of mangoes produced. For instance, a 1% increase in the real interest rate, which measures the price of capital, leads to a 0.199% decrease in the likelihood of producing MRL-compliant mangoes and a 2.164% decrease in the volume of expected conditional standard-compliant mangoes production in Africa. The unit price received by producers (W_i) increases the production of MRL-compliant mangoes. A 1% increase in the producer price leads to an increase of 0.069% in the likelihood of producing MRL-compliant mangoes and an increase of 1.309% in the volume of expected conditional standard-compliant mangoes production.

25. This effect is calculated for all producing and importing pair countries, including pairs for which the quantity of destination-oriented MRL-compliant production is zero.

2.6.2 Effects of MRL on the likelihood of exporting and volume of exports

Table 2.4 presents the results of the estimates of equation (2.18) for the likelihood of exporting, or the extensive margin and equation (2.19) for the export value, or the intensive margin. The results of equation (2.18) are presented in column 3, and those of equation (2.19) are presented in column 4. The results presented in table 2.4 show both the trade-enhancing and -impeding effects of MRLs for pesticides on African exports countries of mangoes to OECD member countries. The enhancing effect is associated with consumers' perceived quality (*ln(perceived quality)*) and, the impeding effect is related to the mrl stringency of OECD countries (*ln(predicted mrl stringency scores)*). The latter effect is not significant for both the probability of exporting and the exports value of MRL-compliant mangoes. Although this result is not statistical significant, it is qualitatively identical to the recent results in the literature regarding the restrict effects of MRL for pesticides on agricultural trade of developing countries, especially Fernandes et al. (2019) that used firm-level data and Fiankor et al. (2020) that performed a model with country level data. In particular, Fiankor et al. (2020) highlighted that the MRLs measures impede South-North trade and increase product prices.

The MRLs for pesticides in force in OECD countries positively affect their import demand for mangoes from Africa and the likelihood of African countries exporting MRL-compliant mangoes. Indeed, the coefficients associated with the variable (*ln(perceived quality)*) measuring consumers' perceived quality are positive and significant at 5% for both the likelihood of exporting and the import value of OECD countries from Africa. A strengthening of MRL measures in OECD countries resulting in a 1% improvement in their consumers' perceived quality will result, on average, in an increase of 0.065% of African countries' probability of exporting mangoes that meet the standards and an average increase of 0.805% in their export demand. The implication of these results is that the presence of MRL policies reassures consumers about the quality and safety attributes of products consumed and then positively affects their demand (Eom, 1994; Fernandes et al., 2015; Josling et al., 2004). Moreover, these results corroborate our theoretical result that the imposition or strengthening of quality standards in importing countries leads to an increase in the probability of exporting and the volume of imports through an increased level of consumer perception regarding the quality of imported products. These demand-enhancing effects of MRLs are consistent with those of Xiong and Beghin (2014), Medin (2019) and Curzi et al. (2020). However, a recent study (Fiankor et al., 2020) did not find evidence that the MRL measures significantly increase consumer's perceived quality, and consequently increase import demand in destination countries. But, as expected, they found a positive relationship between MRL measures and product quality, which supports qualitatively our theoretical hypothesis regarding the consumer's perceived quality-enhancing effect of MRL measures in force in destination countries.

For the other variables, the results for the likelihood of exporting show that the signs of most of the coefficients are as expected, except common language ($Lang_{ij}$), membership in the ACP-EU trade agreement (Acp_{ij}), the number of required documents ($Doctoimport_j$) to import in destination countries and the time ($Importime_j$) required for exports. However, the coefficients associated with all these variables are not statistical significant. On the other hand, the results indicate that the likelihood of exporting MRL-compliant mangoes is higher for countries pair that were in colonial relationship and are geographical closed. In particular, the marginal effects of the colonial link variable ($Col45_{ij}$) and bilateral geographical distance ($Dist_{ij}$) are 0.528 and -0.113, respectively. The results also show that the two multilateral resistance terms (Remotindex_exp and Remotindex_import) significantly and positively affect the likelihood of exporting MRL-compliant mangoes.

In contrast to the results on the likelihood of exporting, the signs of the coefficients for the other variables in the estimates of the export value are as expected. For example, trade cost variables, such as bilateral geographical distance ($Dist_{ij}$), the number of required documents ($Doctoimport_j$) to import in destination countries and the time ($Importime_j$) required for exports, negatively affect the exports of mangoes from Africa. On the other hand, variables that reduce trade costs, such as colonial ties ($Col45_{ij}$) between trade partners and membership in a trade agreement (Acp_{ij}), promote bilateral trade of mangoes. However, among these trade cost variables, only the variables $Dist_{ij}$ and $Col45_{ij}$ significantly affect the imports of mangoes from Africa to OECD countries. For example, a 1% decrease in bilateral geographical distance leads to an increase of more than 1.3% on the intensive margin. This result is higher than that of Philippidis et al. (2013), who found a median coefficient of -0.954 for all agricultural and agri-food products and -1.053 for fruits and vegetables. The results related to the GDPs of OECD countries (Ggdp_imp) indicate that OECD countries with high income levels import many more mangoes than countries with low income levels. Similarly, exporting countries with a high expected MRL-compliant production are found to export more than countries with a low production level. The coefficients associated with GDP and expected unconditional complaint-production are positive. We also find that the multilateral resistance term of the exporting country (Remotindex_exp) significantly increases the volume of bilateral trade between African countries and OECD member countries. Indeed, according to Anderson and Van Wincoop (2003), exporting countries with high multilateral resistance terms face low import demand and low unit prices. Thus, an exporter is expected to increase its exports if competitor prices (including outward multilateral resistance terms) increase. The results also reveal that bilateral import demand is higher for destination countries with a high multilateral resistance index (Remotindex_imp). The coefficients associated with both terms are positive and significant.

TABLE 2.4 – Effect of MRLs on the likelihood to export and the export value

	Our Model			
	Pr(production>0)	ln(production value)	Pr(export>0)	ln(export value)
ln(producer prices) ($\bar{W}_{ij}$)	0.069*	0.191*		
	(0.040)	(0.114)		
ln(predicted mrl strigency index) (mrl_j)	-0.088*	-0.242*	-0.033	-0.183
	(0.047)	(0.133)	(0.037)	(0.447)
ln(perceived quality) $\left(\Theta_{ij}^{m}\right)$			0.065**	0.805**
			(0.028)	(0.338)
ln(expected unconditional complaint-production)			0.017	0.799***
			(0.011)	(0.138)
ln(GDP_imp) (E_j)			0.010	0.573***
			(0.012)	(0.155)
ln(Distw) ($Dist_{ij}$)			-0.113***	-1.362**
			(0.035)	(0.559)
Remotindex_exp $\left(\Psi_i\right)$			0.101***	0.556**
			(0.010)	(0.259)
Remotindex_imp $\left(P_j\right)$			0.048***	0.030
			(0.004)	(0.122)
1=Pair in colonial relationship post 1945 ($Col45_{ij}$)			0.528**	1.888*
			(0.208)	(1.091)
Dummy for ACP country exporting to EC/EU member (Acp_{ij})			-0.062	0.387
			(0.040)	(0.488)
Documents to import (number)($doctoimport_j$)			0.007	-0.158
			(0.016)	(0.184)
ln_timetoimport_days ($Importime_j$)			0.028	-0.156
			(0.057)	(0.687)
1=Common official or primary language ($Lang_{ij}$)			-0.038	
			(0.052)	
Constant				-17.38**
				(7.332)
IMR (Inverse Mills Ratio)				-0.171
				(0.937)
Observations			372	159
Prob > chi2			0.000	

Standard errors in parentheses * $p<.10$, ** $p<.05$, *** $p<.01$

2.6.3 Robustness Check Results

We check the robustness of these results by performing two alternative estimations and found that our results remain robust. First, we estimated a model following the approach of Xiong and Beghin (2014) by taking the MRL-compliance costs into bilateral trade costs without considering any relationship between production in exporting country and standards imposed by importing country. We used the total exports to proxy for standard-compliant production instead considering expected unconditional complaint-production that embodied the information related to the probability of producing and the observed quantities of production. The corresponding results are presented in table 2.5, columns (2-3) [26]. The second robustness check consists using alternative measures for multilateral resistance terms other than those suggested in (Yotov et al., 2016, p.43), especially we estimated the trade margins equations using computed exporter and importer fixed effects. The corresponding results are presented in table 2.5, columns (4-5).

26. In addition, we re-estimate the model by restricting the total export to the export toward only OECD countries. The results remain qualitatively identical. For example, the coefficient associated with total compliant-production increases from 0.758 to 0.896 and the net effect increases from 0.211 to 0.338 for intensive margin (trade value).

TABLE 2.5 – Robustness check results for the effect of MRLs on the likelihood to export and the export value

	Xiong and Beghin (2014)' approach		With predicted exporter-importer fixed effects	
	Pr(export>0)	ln(export value)	Pr(export>0)	ln(export value)
ln(Perceived quality)	0.059**	0.663**	0.067*	0.411
	(0.027)	(0.337)	(0.037)	(0.574)
ln(predicted mrl stringency index)	-0.032	-0.452	-0.089**	0.093
	(0.036)	(0.450)	(0.045)	(0.771)
*ln(total compliant-production**_exp)*	0.027***	0.758***		
	(0.009)	(0.142)		
ln(GDP_imp)	0.009	0.516***		
	(0.012)	(0.156)		
ln(Distw)	-0.100***	-1.824***	-0.198***	-0.564
	(0.035)	(0.533)	(0.037)	(1.205)
Remotindex_exp	0.082***	0.561**		
	(0.013)	(0.238)		
Remotindex_imp	0.048***	0.084		
	(0.004)	(0.122)		
1=Pair in colonial relationship post 1945	0.529***	2.662**	0.402**	0.849
	(0.204)	(1.109)	(0.191)	(2.056)
*Dummy for ACP country exporting to EC/EU member*r	-0.053	0.681	0.140***	0.495
	(0.039)	(0.488)	(0.044)	(0.934)
Documents to import (number)	0.009	-0.081		
	(0.016)	(0.186)		
ln_timetoimport_days	0.027	-0.425		
	(0.056)	(0.688)		
1=Common official or primary language	-0.023		0.043	
	(0.051)		(0.065)	
Exporter- fixed effects			0.051***	0.261
			(0.005)	(0.311)
Importer- fixed effects			0.040***	0.427
			(0.013)	(0.277)
Constant		-8.180		9.331
		(6.597)		(7.941)
IMR (Inverse Mills Ratio)		0.300		-1.789
		(0.936)		(2.841)
Net effect of MRLs for Pesticides*	0.027	0.211	0.504	-0.022
	[-0.060, 0.114]	[-0.876, 1.298]	[-0.134, 0.100]	[-0.823, 1.832]
Observations	372	159	372	159
Prob > chi2	0.000		0.000	

Standard errors in parentheses * p<.10, ** p<.05, *** p<.01
Square brackets refer to [95% Conf. Interval]

Note* : The net effects of MRLs for pesticides are computed as the sum of consumers' quality perception effect (perceived quality) and the effect of MRLs compliance costs (predicted mrl stringency index). The mean and the standard errors are calculated following the Delta method.

Note** : The total MRL-compliant production is proxied by total exports downloaded from UN COMTRADE/WITS.

2.6.4 The Net Effects of MRLs on Production and Bilateral Trade

Table 2.6 presents the results on the *net effects* of MRLs for pesticides on production and bilateral trade between African and OECD countries. This table shows that the net effects of MRLs for pesticides in force in OECD countries are significantly negative (-0.027%) for the likelihood of producing MRL-compliant mangoes and positive (0.953%) for the volume of expected unconditional standard-compliant mangoes production. In particular, if all OECD countries set their MRLs value for some moderate [27] toxic pesticides at their actual minimum MRLs value in OECD member countries, for instance at 0.05 ppm for carbendazin, 0.01 ppm for dimethoate and tebuconazole, then the average value of the index over all OECD countries will go up from current value of 1.414 to 1.480, which corresponds to an increase of 4.666%. Then, the net effect will be a decrease of 0.126% in the likelihood of producing MRL-compliant mangoes and an increase of 4.447% in the volume of expected unconditional standard-compliant mangoes production. However, if OECD member countries set their MRLs value for the same moderate toxic pesticides at their actual maximum MRLs value, that are 5 ppm for carbendazin, 2 ppm for dimethoate and 0.15 ppm for tebuconazole, then the average value of the index over all OECD countries will go down from 1.414 to 1.334, which corresponds to a decrease of 5.615%. Then, the net effect will be an increase of 0.152% in the likelihood of producing MRL-compliant mangoes and a decrease of 5.351% in the volume of expected unconditional standard-compliant mangoes production.

TABLE 2.6 – Net Effects of MRLs on the production and bilateral trade

	Our Model			
	Pr(production > 0)	ln(production)	Pr(export > 0)	ln(export)
Perceived quality			0.0645**	0.805**
			(0.028)	(0.338)
Predicted mrl stringency index	-0.088*	-0.242*	-0.033	-0.183
	(0.047)	(0.133)	(0.037)	(0.447)
Expected unconditional complaint-production			0.017	0.799***
			(0.011)	(0.138)
Producer prices	0.069*	1.309***		
	(0.040)	(0.403)		
Net effects of MRLs for Pesticides*	-0.027**	0.953**	0.048***	1.396***
	[-0.029, -0.026]	[0.937, 0.968]	[0.047, 0.049]	[1.375, 1.416]
Observations	372	372	372	159

Standard errors in parentheses * p<.10, ** p<.05, *** p<.01
Square brackets refer to [95% Conf. Interval]
Note* : The net effects of MRLs for pesticides on production is computed using the expressions defined in appendix E.
Equations (2.20) and (2.20) are used to calculate the net effect of MRLs on the two trade margins.
The K-R procedure is used to compute their mean values and standard error.

Figure 2.4 presents the distribution of the net effects of MRLs on the likelihood of exporting and the trade value. The mean of the net effect of MRLs on trade is significant and positive for both the likelihood of African countries exporting (0.048%) and the trade value (1.396%).

27. The European' Rapid alert system for food and feed (RASFF) members categorized pesticides as high, moderate and low toxic substances in their report edited in 2014. In this report, we thus chosen the substances (carbendazin, dimethoate and tebuconazole) that have been categorized as moderate toxic for our simulation schemes.

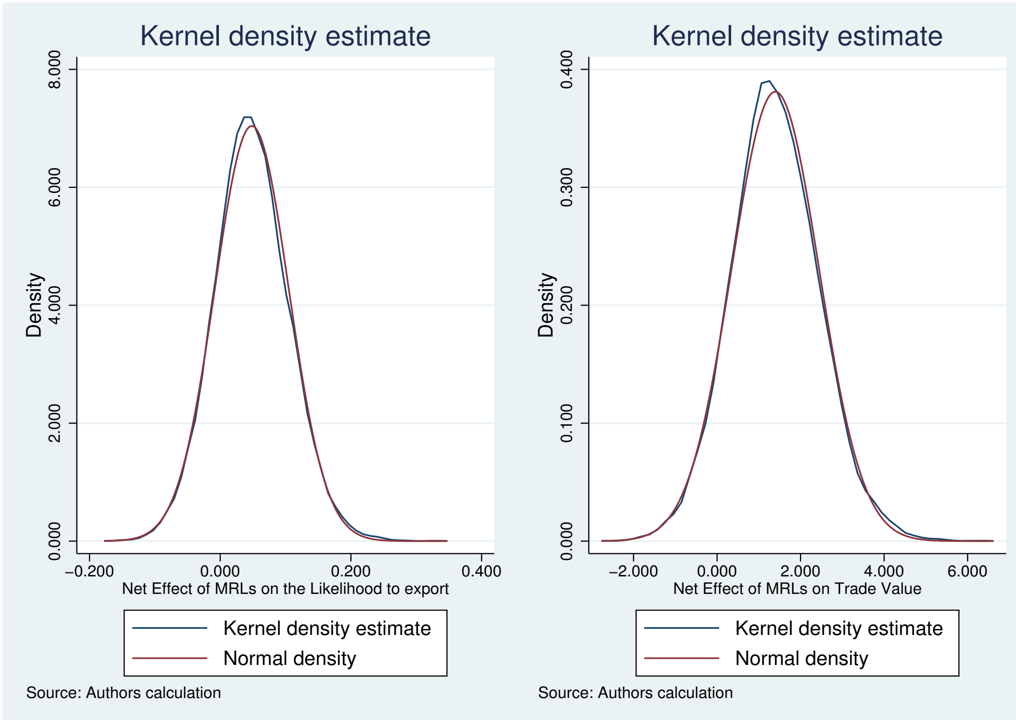

FIGURE 2.4 – Distribution of Net Effects of MRLs on Trade, Based on 10 000 replications

Given the estimated net effects of MRLs on the likelihood of importing and the imports value of OECD member countries from Africa, we analyzed the percent change in the average value of the stringency index over all OECD countries following a downward and upward harmonization for the three substances (carbendazin, dimethoate and tebuconazole). We find that if the average value of the index over all OECD countries increase by 4.666%, then the mean net effect will be an increase of 0.224% in the likelihood of OECD member countries to importing from African countries and an increase 6,514% in their imports value. However an average decrease in the mrl stringency index by 5.615% following a upward harmonization of MRLs values of the three moderate toxic substances in the OECD countries will reduce their likelihood of importing and their imports value from African by 0.270% and 7.838%, respectively.

Together, these results indicate that, at the average of our database, applied MRLs by OECD countries result in an increase of exporting countries welfare. However as mentioned before, at the country level it results in a negative impact on the extensive margin [28] or producing while the impact on intensive margin of production is positive.

Figure 2.5 presents the distribution of the percentage change in the net effects of MRLs on African mango exports over the unit percentage change in predicted mrl stringency scores for pesticides in different OECD member countries. The net effect of MRLs on trade value is slightly higher (greater than

28. This could be an issu for the distribution of the gain of trade within a country.

the sample mean, 1.396%) in Greece (1.526%), Israel (1.521%), Estonia (1.514%), Iceland (1.505%), Turkey and France (1.503%), Denmark (1.501%) and the Slovak Republic (1.500%). These countries are among the 25% highest MRL stringency countries in our sample. The net effect of MRLs on the likelihood of African countries exporting is slightly higher in Luxembourg and the United States (0.080%), Switzerland (0.079%) and Norway, Austria, Germany, Korea, Rep., Canada and the Netherlands (0.078%). These OECD member countries are characterized by lower MRL stringency scores, and each has an average net effect on the likelihood of African countries exporting, which is greater than the sample mean (0.077%). These results imply that African exporter countries that already export MRL-compliant mangoes to OECD member countries benefit more from higher OECD mrl stringency countries. In contrast, the net effect on the likelihood of exporting is higher in countries with lower OECD MRL stringency.

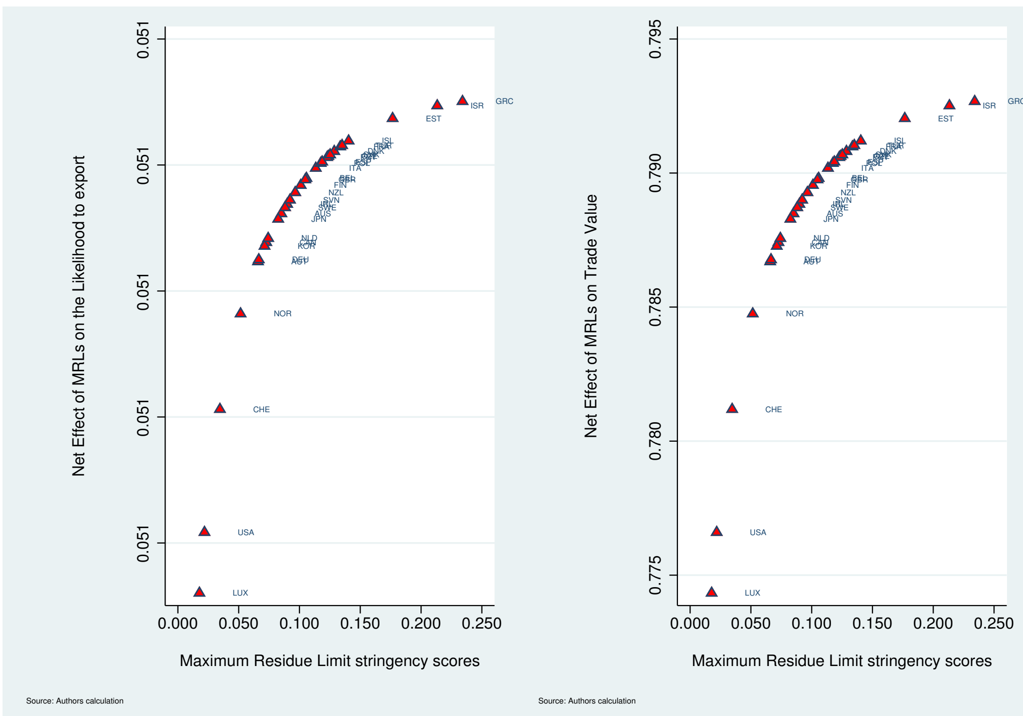

FIGURE 2.5 – Net Effects of MRLs on Trade Vs MRL stringency scores of OECD countries

2.7 Conclusion

The use of technical non-tariff measures such as MRLs for pesticides has increased in developed countries in recent decades. Several studies have investigated the economic impacts of heterogeneity using such measures on agricultural trade in developing countries. Most of the findings from these studies are divergent with respect to the direction, significance or magnitude of the effects of MRLs on trade, especially when market failures are considered. Our paper contributed theoretically and empirically to this debate. For the first time, we theoretically disentangle the effects of the MRLs for pesticides on production, export supply and import demand. The framework was then used to assess the empirical effects of MRL for pesticides on the production and trade of standard-compliant mangoes between African and OECD countries. In terms of net effects, the results show that the MRL for pesticides in force in OECD countries reduce the likelihood of African countries producing MRL-compliant mangoes and increase the volume of expected unconditional standard-compliant mangoes production. The latter result suggests that a perfect pass-trough prevails in high-quality mangoes values chain in African countries. However, we found that the MRLs for pesticides increase the demand of OECD countries for MRL-compliant mangoes imported from Africa. These results reveal that the MRLs for pesticides in force in OECD countries are barriers preventing African countries from producing high-quality mangoes. These barriers come in terms of higher production costs for upstream producers and a reduction in the likelihood of producing MRL-compliant mangoes. However, the presence of the MRLs for pesticide increases the expected unconditional standard-compliant production of mangoes and, if combining with an improving consumers' quality perceptions, they promote import demand in OECD countries.

The main policy implication of our results is that the tightening or imposition of strict MRLs for pesticides in developed countries may be trade promoting, while they severely impede production in developing countries and, especially in agricultural-food value chains characterized by incomplete price transmission between farmers and exporters. Our results highlighted that to evaluate the full effects of MRLs for pesticides on trade using standard sectoral trade models, one must take into account at least, the MRL-compliance cost on the production side because the tightening of MRLs for pesticides affects the propensity to produce and the volume of production and creates uncertainty regarding the probability of exporting as well as the volume available for exporting. Hence, the WTO might exercise restraint towards their members applying stringent (above CODEX's measures) SPS measures to developing countries' exports or provide technical and financial assistance to these countries to comply with SPS requirements. However, further research is needed to assess whether the net effect on the trade of mangoes remains valid when taking into account domestic markets that have lower standards. In addition, further applications to African countries' different agricultural products would allow a deeper understanding of the net effect of maximum residue limits for pesticides on the international trade of the agricultural sector.

Although this study focuses on mangoes for empirical investigation purpose, our theoretical and empirical approaches can be deployed to disentangle the effects of standards differences for pesticides on domestic production, export supply and import demand for all perishable agricultural products (e.g., green beans, oranges, bananas) exported by developing countries and targeted by developed countries' MRL standards. In addition, our results can be used by policymakers and future researchers to investigate the welfare effects of MRL standards. Indeed, the estimated elasticity of trade with respect to consumer perceived quality and the elasticity of production with respect to MRL-compliance costs can be used to calculate the welfare gain or loss of producers and exporters in origin countries as well as for consumers in destination countries, as in Disdier and Marette (2010). However, our main focus in this paper was simply to provide a theoretical framework and an empirical approach to investigate the production and trade effects of MRLs for pesticides. Finally, considering the whole set of production choices (other mangoes or products) available to the farmers could better explain the impact of MRL on trade and welfare of developing countries.

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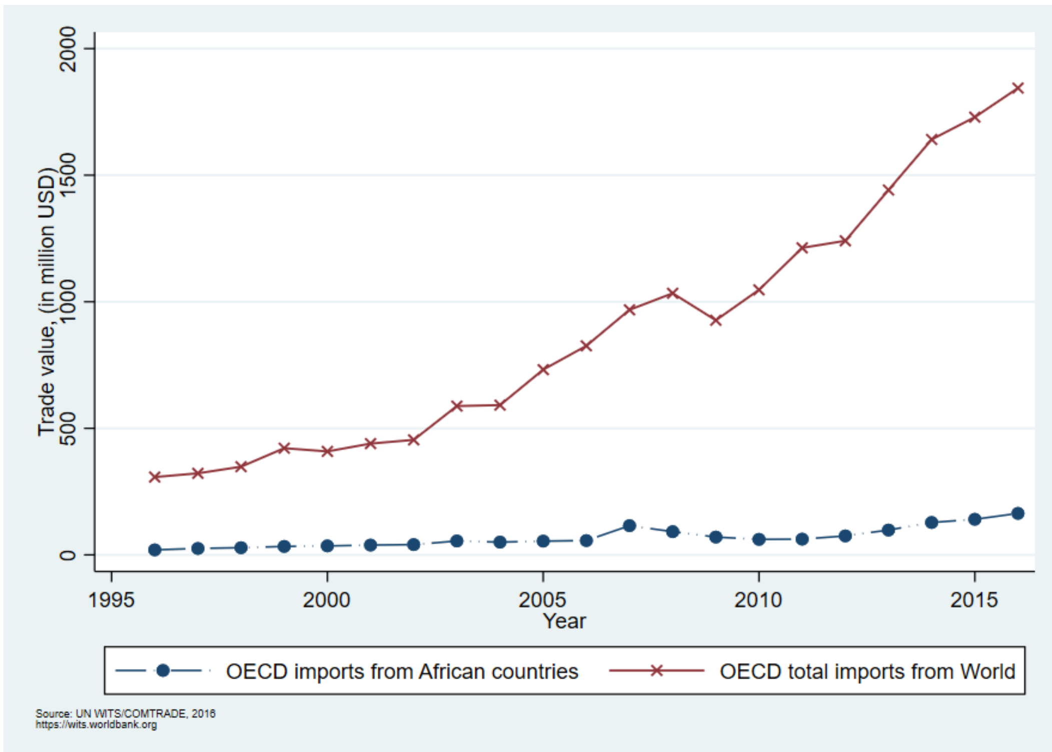
Appendix

Appendix A : Additional figures

FIGURE 2.6 – Trend of OECD imports of mangoes from Africa and World, 1996-2015



Appendix B : Additional tables

TABLE 2.7 – Test for equal means of unit values of export at UE market, 1996-2016

	Obs	Mean	Sd	Min	Max
Burundi (1000USD/Kg)	12	0.002	0.0005	0.002	0.003
Cameroon (1000USD/Kg)	18	0.003	0.001	0.001	0.004
Cote d'Ivoire (1000USD/Kg)	18	0.001	0.0005	0.001	0.003
Egypt (1000USD/Kg)	18	0.002	0.0004	0.001	0.003
Ghana (1000USD/Kg)	18	0.005	0.003	0.001	0.009
Mali (1000USD/Kg)	18	0.002	0.0004	0.001	0.007
H_0 : All means are the same					
	Hotelling T2 = 127.390				
	Hotelling F(5,7) = 16.210				
	Prob > F = 0.001				

TABLE 2.8 – Test for equal mean of unit values of export at Netherland market, 1996-2016

	Obs	Mean	Sd	Min	Max
Burkina (1000USD/Kg)	21	0.002	0.002	0.001	0.008
Cote d'Ivoire (1000USD/Kg)	21	0.001	0.0003	0.001	0.002
Senegal (1000USD/Kg)	21	0.001	0.0003	0.001	0.002
South Africa (1000USD/Kg)	21	0.003	0.003	0.001	0.012
H_0 : All means are the same					
	Hotelling T2 = 16.060				
	Hotelling F(3,18) = 4.820				
	Prob > F = 0.012				

TABLE 2.9 – Test for equal mean of unit values of export at French market, 1996-2016

	Obs	Mean	Sd	Min	Max
Burkina Faso (1000USD/Kg)	21	0.002	0.0005	0.001	0.003
Cameroon (1000USD/Kg)	21	0.003	0.001	0.001	0.006
Cote d'Ivoire (1000USD/Kg)	21	0.002	0.0005	0.001	0.003
Egypt (1000USD/Kg)	20	0.002	0.001	0.001	0.004
Mali (1000USD/Kg)	21	0.002	0.001	0.001	0.003
Senegal (1000USD/Kg)	21	0.002	0.0004	0.001	0.003
South Africa (1000USD/Kg)	21	0.004	0.003	0.001	0.010
H_0 : All means are the same					
	Hotelling T2 = 144.210				
	Hotelling F(6,14) = 17.340				
	Prob > F = 0.000				

TABLE 2.10 – Description of MRLs for pesticides, 2016

Country	Reference	Default MRLs	Number of country
Angola, Chile, Ghana, Israel, Kenya Libya, Malawi, Mozambique, Senegal Tanzania, Tunisia, Uganda et Zimbabwe	Codex	None	13
Marocco	Codex	0,010 ppm	1
New-Zeland	Codex	0,100 ppm	1
South Africa	Codex or UE	0,010 ppm	1
Egypt	1^{st} Codex 2^{nd} UE 3^{rd} USA	None	1
Algeria, European Union (25), Gambia, Iceland, Norway,Netherlands and United Kingdom	UE	0,010 ppm	7
Switzerland	UE	None	1
Japan, South Corea et Turkey	None	0,010 ppm	3
Canada	None	0,100 ppm	1
Australia	None	None	1
Mexico and USA	USA	None	2
Total			32

TABLE 2.11 – Estimates of strigency index of maximum residue limits for pesticides

Tobit		
	Africa and OECD	OECD
ln_appliedtariff	-0.661*	-0.710**
	(0.380)	(0.329)
ln_gdpcappa16	-0.294***	-0.071
	(0.060)	(0.082)
ln_pop16	-0.019	-0.014
	(0.021)	(0.011)
ln_rexchrate	0.017	0.042***
	(0.014)	(0.009)
elastprice	0.386	-0.033
	(0.447)	(0.261)
ln_rca15	0.014	0.025
	(0.031)	(0.019)
Political Stability and Absence of Violence/Terrorism	-0.095	-0.156***
	(0.059)	(0.040)
Government Effectiveness	-0.006	0.017
	(0.157)	(0.084)
Regulatory Quality	0.032	0.111
	(0.120)	(0.071)
liec	-0.081	
	(0.053)	
agrilaborlandratio	0.001	0.0002
	(0.002)	(0.001)
Constant	4.196***	0.959
	(0.845)	(0.901)
Observations	50	33
Pseudo R-squared	1.686	-0.623

Standard errors in parentheses * p<.10, ** p<.05, *** p<.01

TABLE 2.12 – List of producers and exporters of mangoes in Africa

exporter/producers			
Country	**Producer statut***		**Producer statut**
Algeria	No	Libya	No
Angola	No	Madagascar**	Yes
Benin	Yes	Malawi	Yes
Botswana	No	Mali**	Yes
Burkina Faso**	Yes	Mauritania	No
Burundi	No	Mauritius	No
Cameroon**	Yes	Morocco**	Yes
Cape Verde	Yes	Mozambique**	Yes
Central African Republic	Yes	Namibia	Yes
Chad	Yes	Niger	Yes
Comoros	No	Nigeria**	Yes
Congo, Dem. Rep.	Yes	Rwanda	Yes
Congo, Rep.	Yes	Sao Tome and Principe	No
Cote d'Ivoire**	Yes	Senegal	Yes
Djibouti	Yes	Seychelles	Yes
Egypt, Arab Rep.**	Yes	Sierra Leone	Yes
Equatorial Guinea	No	Somalia	Yes
Eritrea	No	South Africa**	Yes
Ethiopia(excludes Eritrea)	No	South Sudan	No
Gabon	No	Sudan	Yes
Gambia, The**	Yes	Swaziland	No
Ghana	Yes	Tanzania	Yes
Guinea	Yes	Togo	No
Guinea-Bissau	Yes	Tunisia	No
Kenya**	Yes	Uganda	No
Lesotho	No	Zambia	No
Liberia	No	Zimbabwe	Yes

* The producer statut is yes if country production data are available at FAOSTAT for years 2014, 2015 or 2016

Number of producer countries (Yes) = 35 and Number of no producer countries (No)= 19

** These are the countries (12) taken into account in our analysis.

TABLE 2.13 – List of importer countries of mangoes in OECD

Importer countries	
Australia	Korea, Rep.
Austria	*Latvia***
Belgium	Luxembourg
Canada	*Mexico***
*Chile***	Netherlands
Czech Republic	New Zealand
Denmark	Norway
Estonia	Poland
Finland	Portugal
France	Slovak Republic
Germany	Slovenia
Greece	Spain
*Hungary***	Sweden
Iceland	Switzerland
Ireland	Turkey
Israel	United Kingdom
Italy	United States
Japan	

** Excluded importer countries (04).These countries do not import mangoes from Africa

Appendix C : Net effect of MRLs on the likelihood of producing standard-compliant product

To derive the analytical expression of the net effect of MRLs on the likelihood of producing standard-compliant product, we exploit the decision-making process equation (2.5) which is derived from the non-zero profit condition. Given the profit function defined by equation (2.3), $\pi_i^{p*} > 0 \Rightarrow \frac{(\alpha-1)}{F}(\frac{W_i^{\alpha}}{\alpha\xi_i\tilde{C}_{ij}})^{\frac{1}{\alpha-1}} > 1$. By taking the logarithm of this expression and replacing ξ_i with its expression ($\xi_0\omega_i^{\alpha_L}r_i^{\alpha_K}$), we rewrite equation (2.5) as follows :

$$\begin{aligned} Prob\Big(I_{ij} = \quad 1|\bar{Z}_{ij}\Big) &= Prob\Bigg(ln(\xi_0) < (\alpha-1)\Big(\alpha_0 - ln(F)\Big) + \alpha ln(W_i) - \alpha_L ln(\omega_i) - \alpha_K ln(r_i) - ln(\tilde{C}_{ij})\Bigg) \\ &= \Phi\Bigg(\beta_0 + \beta_1 ln(W_i) + \beta_2 ln(\omega_i) + \beta_3 ln(r_i) + \beta_4 ln\Big(max[mrl_j - mrl_i, 0]\Big)\Bigg) \end{aligned} \tag{2.22}$$

where we assume the logarithm of productivity chocks (ξ_0) to be normally distributed in exporting countries, with $\Phi(.|.)$ the cumulative density function. Now, we derive the analytical expression of the net effect of MRLs on the likelihood of producing standard-compliant product by exploiting the equation (2.22) as follows :

$$\frac{\partial Pr\Big(\bar{X}_{ij}^{ob} > 0|\bar{Z}_{ij}\Big)}{\partial ln\Big(max[mrl_j - mrl_i, 0]\Big)} = \Big(\beta_1 + \beta_4\Big) \times \phi\Big(\bar{Z}_{ij}\beta\Big)\begin{cases} = 0 & \text{if} \quad \beta_1 = \beta_4 \\ > 0 & \text{if} \quad \beta_1 > \beta_4 \\ < 0 & \text{if} \quad \beta_1 < \beta_4 \end{cases} \tag{2.23}$$

where β_1 and β_4 are espected to be positive and negative, respectively. Equation (2.23) shows that the marginal net effect of the MRLs gap between exporting and importing countries on the producers' decision to produce standard-compliant products depends on the coefficient associated with the producer prices (β_1) and the MRLs gap parameter (β_4). Given that $\phi(.|.)$, a standard probability distribution function is always positive, it follows that the marginal net effect of the MRLs gap on the producer's decision is zero or positive if and only if the parameter (β_1) of producer prices is equal to or greater than the MRL-compliance costs parameter (β_4). However, if the parameter of producer prices is less than the MRL-compliance costs parameter, then marginal net effect of the MRL gap will be negative. As a result, the producers will likely produce standard-compliant products if there is at least a complete pass-through ($\beta_1 \geq \beta_4$). However, producers that less pass-through ($\beta_1 \leq \beta_4$) the standard-compliance costs to the unit price will exit high-quality or standard-compliant product markets.

Appendix D : Exporter's revenues maximization problem

Consider $\bar{X}_i$, the exportable quantity of mangoes available in an exporting country i, and then let X_{ij} be the optimal quantity to be exported to each market j among the set of destination markets Ω_i. Following Xiong and Beghin (2014), we derive the export supply function (X_{ij}) of country i to market j from exporter's revenues maximization problem defined as follows :

$$\begin{aligned} & max \sum_{j\in\Omega_i} W_{ij}X_{ij} \\ & S/C \\ & \left[\sum_{j\in\Omega_i}(T_{ij}X_{ij})^{\frac{\tau-1}{\tau}}\right]^{\frac{\tau}{\tau-1}} = \bar{X}_i \end{aligned} \tag{2.24}$$

where W_{ij} is the unit price of mangoes produced in country i and sold to consumers in country j. $T_{ij} > 1$ is the "iceberg" trade cost of exporting mangoes from country i to market j. The parameter $\tau < 0$ is the elasticity of transformation or the exporter's ability to substitute destination countries for each other when one becomes more stringent with respect to MRLs. Solving equation (2.24) yields the export supply function of country i to market j :

$$X_{ij} = T_{ij}^{\tau-1} W_{ij}^{-\tau} \Psi_i^{-1} \bar{X}_i \tag{2.25}$$

Based on several studies in trade literature that investigate the trade effect of SPS or TBT standards (Curzi et al., 2020; Medin, 2019; Xiong and Beghin, 2014), we specify the bilateral iceberg trade costs T_{ij} by including an additional variable that will capture the direct effect of compliance costs with MRL standards required for exporters in countries i.

$$T_{ij} = \quad \exp\Big(\beta_d ln(Dist_{ij}) - \beta_c Col45_{ij} - \beta_l Lang_{ij} + \lambda mrl_j\Big) \tag{2.26}$$

where $Dist_{ij}$ is the geographical distance between exporting and importing countries, $Col45_{ij}$ is a binary variable taking the value of 1 if there was a colonial relationship between the exporting and importing countries, and $Lang_{ij}$ is a common language variable taking the value of 1 if the exporting and importing countries share a common official language and zero otherwise. λ captures the effect of compliance with MRL standards on bilateral trade costs.

Appendix E : Empirical Expressions of the Net effect of MRLs on standard-compliant Production

The average partial net effects of MRLs for pesticides on the likelihood of producing and on both the conditional and unconditional expected MRL-compliant production of mangoes are computed using the following expressions :

$$\textit{Net effect of the MRLs on the likelihood of producing standard-compliant product} \equiv \frac{\partial Pr\left(\bar{X}_{ij}^{ob}>0|\bar{Z}_{ij}\right)}{\partial ln(mrl_j)} = \beta_1 \times \phi\left(\bar{Z}_{ij}\beta\right) + \beta_4 \times \phi\left(\bar{Z}_{ij}\beta\right) \quad (2.27)$$

$$\textit{Net effect of the MRLs on the conditional expected standard-compliant production} \equiv \frac{\partial ln\left(E(\bar{X}_{ij}^{ob}|\bar{X}_{ij}^{ob}>0,\bar{Z}_{ij})\right)}{\partial ln(mrl_j)} = \gamma_1 + \gamma_4 \quad (2.28)$$

$$\textit{Net effect of the MRLs on the unconditional expected standard-compliant production} \equiv \frac{\partial ln\left(E(\bar{X}_{ij}^{ob}|\bar{Z}_{ij})\right)}{\partial ln(mrl_j)} = \beta_1 \times \frac{\phi(\bar{Z}_{ij}\beta)}{\Phi(\bar{Z}_{ij}\beta)} + \beta_4 \times \frac{\phi(\bar{Z}_{ij}\beta)}{\Phi(\bar{Z}_{ij}\beta)} + \gamma_1 + \gamma_4 \quad (2.29)$$

$\bar{X}_{ij}^{ob}$ is the observed production of mangoes in country (*i*) that conforms to country (*j*)'s MRLs for pesticides.

Appendix F : Deriving the Net effect of MRLs on Trade

Net effect of MRLs on the volume of exports to a given destination :

$$\frac{\partial ln(V_{ij})}{\partial mrl_j} = \left[\frac{\partial ln(\Theta^m_{ij})}{\partial mrl_j} \times \frac{\partial ln(V_{ij})}{\partial ln(\Theta^m_{ij})}\right] + \left[\frac{\partial ln(T_{ij})}{\partial mrl_j} \times \frac{\partial ln(V_{ij})}{\partial ln(T_{ij})}\right] + \left[\frac{\partial ln(\bar{X}_i)}{\partial mrl_j} \times \frac{\partial ln(V_{ij})}{\partial ln(\bar{X}_i)}\right]$$
$$= \frac{1}{(\varepsilon-\tau)}\left[\beta_\theta \tau(1-\varepsilon) - \left(\lambda\varepsilon(1-\tau) + (\eta-1)\left[\frac{\varepsilon\gamma}{(\alpha-1)}\right]\right)\right] \leq\geq 0 \tag{2.30}$$

Net effect of MRLs on the likelihood of exporting to a given destination :

$$\frac{\partial Pr(V^*_{ij}=1)}{\partial mrl_j} = \left[\frac{\partial ln(\Theta^m_{ij})}{\partial mrl_j} \times \frac{\partial ln(Pr(V^*_{ij}=1))}{\partial ln(\Theta^m_{ij})}\right] + \left[\frac{\partial ln(T_{ij})}{\partial mrl_j} \times \frac{\partial ln(Pr(V^*_{ij}=1))}{\partial ln(T_{ij})}\right] + \left[\frac{\partial ln(\bar{X}_i)}{\partial mrl_j} \times \frac{\partial ln(Pr(V^*_{ij}=1))}{\partial ln(\bar{X}_i)}\right]$$
$$= \frac{1}{(\varepsilon-\tau)}\left[\beta_\theta \tau(1-\varepsilon) - \left(\lambda\varepsilon(1-\tau) + (\eta-1)\left[\frac{\varepsilon\gamma}{(\alpha-1)}\right]\right)\right] \leq\geq 0 \tag{2.31}$$

Appendix G : Estimating the Consumer's Perceived Quality

We infer the quality of mangoes from consumer CES import demand (import value) equation by following a two-step procedure.

— 1^{st} **step :** *Regress the logarithm of equation* (2.8) *for the consumer's CES demand*

$$lnM_{ijt} + \sigma^k lnW_{ijt} = FE_{jt} + FE_{it} + e_{ij} \tag{2.32}$$

where M_{ijt} indicates consumer demand for the variety of mango exported by country i into country j at time t. FE_{it} and FE_{jt} account for exporter-time-variant and importer-time-variant fixed effects, respectively. e_{ij} is the standard error term. W_{ij} is the consumer price (unit value) for the variety of mango imported from country i and sold in country j. The issue of endogeneity of consumers' prices is widely raised in the literature (Broda and Weinstein, 2006; Feenstra et al., 2018; Hallak and Schott, 2011; Piveteau and Smagghue, 2019) when estimating the consumers perceived quality through consumers' demand residuals, because prices are likely to be correlated to these residuals (quality). In addition, a fraction of prices may be present in the residuals due to measurement error because trade unit values are used to proxy these prices. A number of methods have been proposed in trade literature to deal with that endogeneity. To address this issue, we follow Piveteau and Smagghue (2019) by instrumenting the consumer price (unit value) using the trade-weighted Exchange rates ($\bar{ER}_{ij}$). In addition, as suggested by Hallak and Schott (2011) we use time series data from 2000 to 2018 and include importer-time-variant and exporter-time-variant fixed effects. The $\bar{ER}_{ij}$ is obtained by interacting destination-specific import shares with exchange rates (Local Currency per US Dollar) [29], $\bar{ER}_{ij} \equiv s_{ij}ER_i = \frac{m_{ij}}{\sum_j X_{ij}} ER_i$ with s_{ij} the share of importing country j's imports over exporting country i's total exports. To estimate equation (2.32) and infer consumers perceived quality on mangoes exported by each African countries, we use the Stata package ivreghdfe, which is an extended instrumental variable regressions command with multiple levels of fixed effects. We measure consumers' prices W_{ij} by using the CIF bilateral trade unit values

— 2^{nd} **step :** *Infer the quality from the residual of the estimated demand in equation* (2.32) Now, quality is estimated by taking the residual ($\widehat{e_{ij}}$) from equation (2.32) and dividing it by the destination market elasticity of substitution minus 1, so the quality of a variety of mango is $\theta^m_{ij} \equiv \frac{\widehat{e_{ij}}}{\sigma - 1}$. We measure the quality for $\sigma \approx 3$, which is close to the median estimate of 3.10 from (Broda and Weinstein, 2006, p.568) computed over some 10,000 HS import product categories. This value of σ is also close to the mean value of 3.28 for vegetable products estimated by (Piveteau and Smagghue, 2019, p.20) and to the median value of the micro-Armington elasticity of 3.22 estimated by (Feenstra et al., 2018, p.144) over a sample of 98 ten-digit import goods into the United States.

29. The Exchange rates data come from the International Monetary Funds (IFM) Database available at `https://data.imf.org/regular.aspx?key=61545862`.

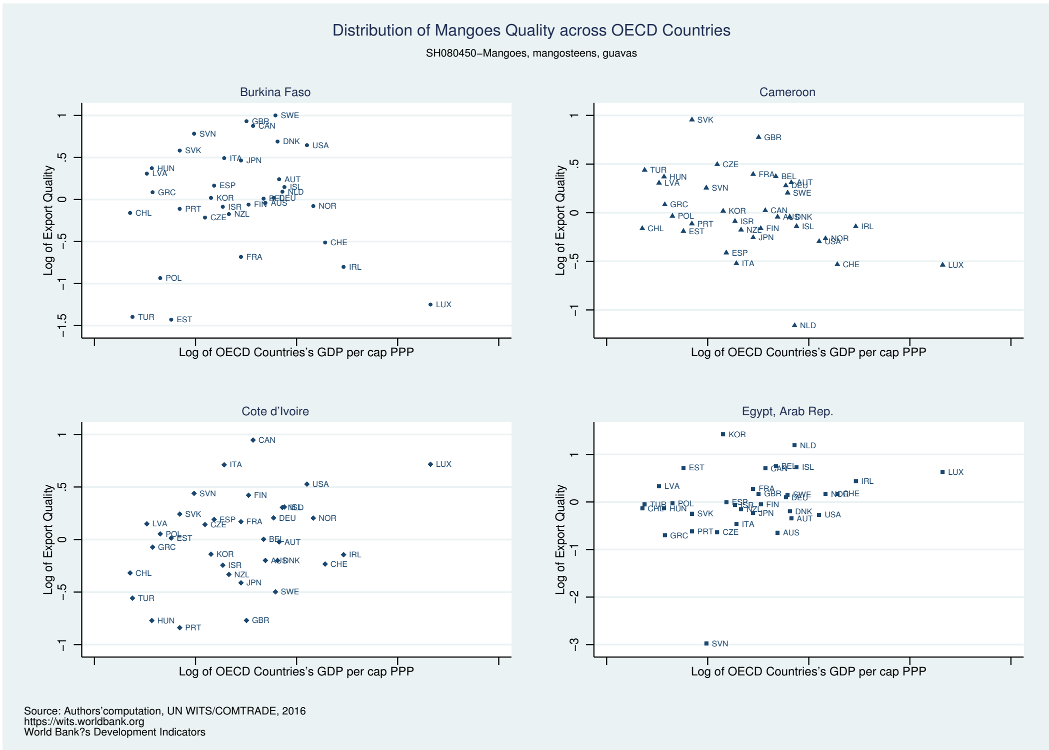


FIGURE 2.7 – Distribution of Mangoes Quality across OECD Countries, 2016

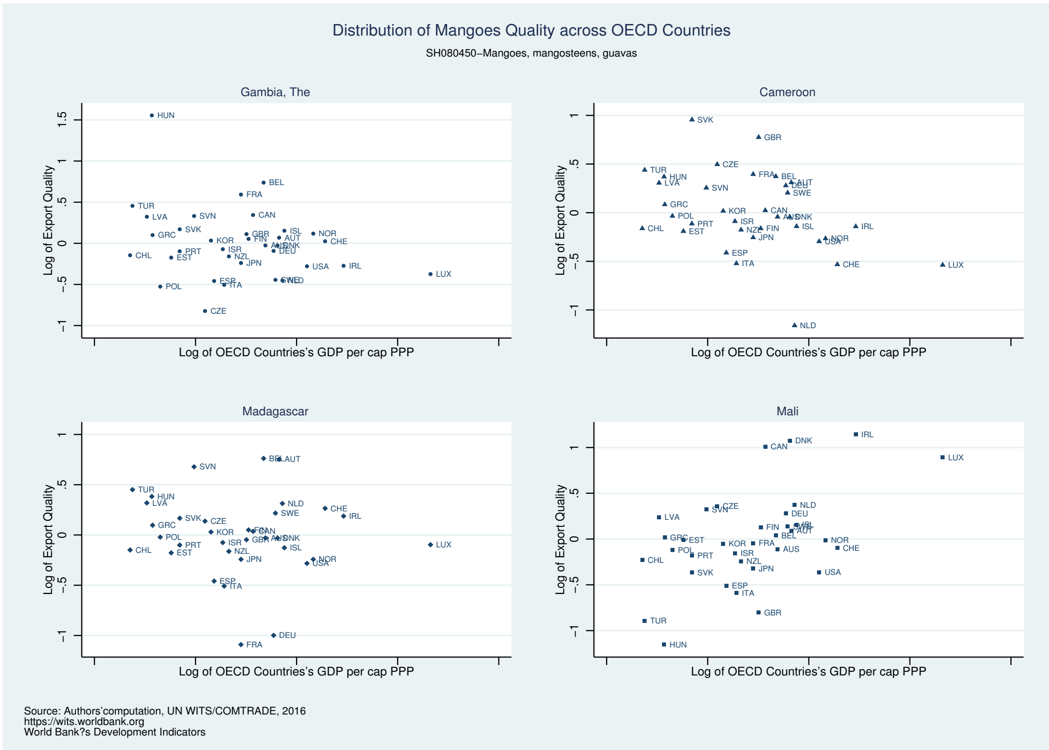


FIGURE 2.8 – Distribution of Mangoes Quality across OECD Countries, 2016

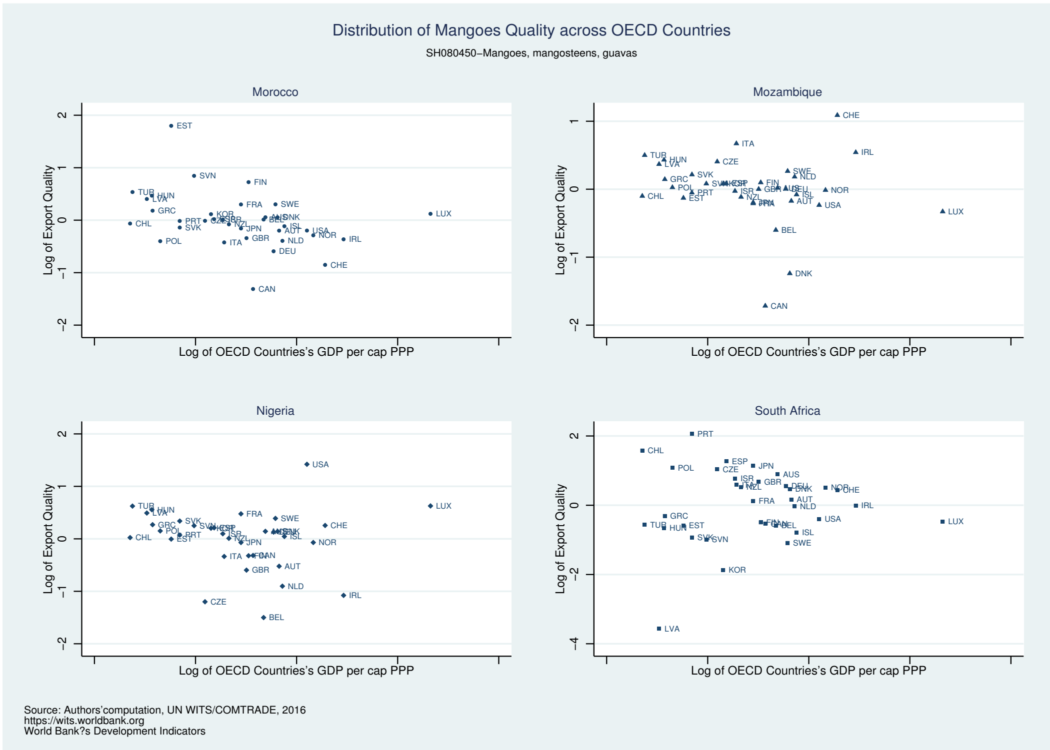


FIGURE 2.9 – Distribution of Mangoes Quality across OECD Countries, 2016

Appendix H : Data description and sources

In this appendix, we provide further details on the sources of non-normal data, namely, the price of capital variable, the wage and the producer prices.

The price of capital is measured by using the real interest rate obtained from World Bank Indicator Open Data [30]. The real interest rate is the lending interest rate adjusted for inflation as measured by the GDP deflator. The rate is calculated annually in terms of percentages. When the real rate of interest is high, that is, demand for credit is high, then money will, all other things being equal, move from consumption to savings. Conversely, when the real rate of interest is low, demand will move from savings to investment and consumption. Hence, the real interest rate provides information on the cost of capital in a given economy.

The producer prices are estimated using the average annual producer prices for the item "Mangoes, mangosteens, guavas" that we downloaded from the FAOSTAT website [31]. These prices received by farmers for primary crops are collected at the point of initial sale (prices paid at the farm gate). Annual data are provided from 1991, while monthly data are provided from January 2010 for 180 countries and 212 products

The wage variable measured by the average monthly earnings obtained from the International Labour Organization (ILOSTAT) portal [32]. Statistics of earnings presented in ILOSTAT refer to regular intervals employees' gross remuneration in cash and in kind paid to employees, including direct wages and salaries, remuneration for time not worked, bonuses and gratuities and housing and family allowances paid by the employer directly to the employee. ILOSTAT reports a harmonized series on average monthly earnings and monthly minimum wages [33].

30. https://data.worldbank.org/
31. http://www.fao.org/faostat
32. https://www.ilo.org/ilostat
33. https://ilostat.ilo.org/topics/wages/

Chapitre 3

European RASFF Border Rejections and African Countries' Reputation and Exports of Edible Vegetables and Fruits

3.1 Résumé

Le faible niveau et les nombreux flux commerciaux nuls observés entre les pays Africains et Européens sont attribuables au nombre croissant de refus d'importation dans un context de contrainte de conformité aux normes de sécurité sanitaire des aliments des pays du Système d'alerte rapide pour les denrées alimentaires et les aliments pour animaux (RASFF). Dans ce papier, nous évaluons l'effet des refus d'importation des pays Européens sur les exportations Africaines de fruits et légumes comestibles, au cours de la période 2008 à 2018. De façon plus spécifique, nous estimons l'effet moyen des rejets aux frontières des pays du réseau RASFF sur les marges extensive et intensive de commerce de fruits et légumes comestibles pour 45 pays africains. Nous utilisons les données sur les rejets aux frontières issues de la base de données en ligne du RASFF avec les données sur les exportations Africaines provenant de la base de données de WITS des Nations Unies. Nous estimons la version canonique de l'équation de gravité sectorielle d'Anderson et al. (2004) en utilisant l'estimateur du Pseudo poisson maximum de vraisemblance (PPML) de Silva et al.(2006) en combinaison avec l'approche robuste d'estimation à deux étapes avec inclusion de résidus (2SRI) de Terza et al.(2008). Nous constatons qu'une augmentation du nombre de refus d'importation par un pays du RASFF une fois dans l'année en cours entraîne une diminution du nombre de partenaires commerciaux en Europe pour les pays africains de 0,018% pour les légumes comestibles et de 0,143 % pour les fruits comestibles. En outre, nos résultats montrent qu'un refus d'importation supplémentaire diminue la valeur des exportations de légumes comestibles des pays africains de 0,045%. Cependant, nous constatons que les refus d'importation des pays du RASFF une fois dans l'année en cours entraînent une augmentation de la valeur des exportations de fruits comestibles des pays africains de 0,126%. Par ailleurs, nos résultats valident explicitement l'hypothèse d'endogénéité du nombre de refus d'importation et mettent en évidence les

effets directs et les effets de contagion des rejets aux frontières. Ce dernier résultat signifie qu'une augmentation du nombre de rejets à la frontière d'un produit donné (par exemple un fruit frais) au cours d'une année précédente entraîne une augmentation du nombre de rejets à la frontière pour ce produit et les produits voisins (par exemple un légume frais) au cours de l'année suivante.
Mots-clés : Afrique, Rejets aux frontières, Fruits et légumes comestibles, Système d'alerte rapide pour les denrées alimentaires et les aliments pour animaux, Commerce
Codes JEL : Q17, Q18, F13, F14

3.2 Abstract

The low level and frequent occurrences of zero trade flows observed between African and European countries are attributable to the increasing number of import refusals in the context of the constraint imposed by the requirement to comply with the food safety standards of the countries of the Rapid Alert System for Food and Feed (RASFF). In this paper, we assess the effects of European countries' import refusals on African exports of edible vegetables and fruits from 2008 to 2018. We specifically estimate the average effects of the RASFF countries' border rejections on the extensive and intensive margins of African countries exports of edible vegetables and fruits. We use the border rejections data from the RASFF online database and export data on 45 African countries from the UN WITS database. We estimate the canonical version of the sectoral gravity equation of Anderson and Van Wincoop (2004) using the Poisson pseudo maximum likelihood (PPML) estimator of Silva and Tenreyro (2006) in association with the robust two-stage residual inclusion (2SRI) approach of Terza et al. (2008). We find that a single increase in the number of import refusals by a RASFF country in the current year leads to a decrease in the number of trade partners in Europe for African countries by 0.018 percent for edible vegetables and 0.143 percent for edible fruits. In addition, our results show that one additional import refusal decreases the export value of African countries' edible vegetables by 0.045 percent. However, we find that RASFF countries' refusal to import once in the current year leads to an increase in the export value of African countries' edible fruit by 0.126 percent. Furthermore, our results explicitly validate the hypothesis of the endogeneity of the number of import refusals and highlight both the direct and spillover effects of border rejections. The latter result means that an increase in the number of border rejections for a given product (for instance, a fresh fruit) in a given year leads to an increase in the number of border rejections for a product and its neighboring products (for instance, a fresh vegetable) in the next year.

Keywords : Africa, Border Rejections, Edible Vegetables and Fruits, Rapid Alert System for Food and Feed, Trade

JEL codes : Q17, Q18, F13, F14

3.3 Introduction

Trade between African and European countries in fruit, vegetable and nut products increased from 2008 through 2018. However, over this period, many zero trade flows were observed between African countries and European member countries of the Rapid Alert System for Food and Feed (RASFF) [1]. For instance, during the period 2008-2018, the zero trade flows were 63.68% for edible vegetables and 52.56% for edible fruits (United Nations World Integrated Trade Solutions, UN WITS database [2]). Indeed, in recent years, the use by European Union (EU) member countries of stricter non-tariff measures (NTMs), such as measures related to sanitary and phytosanitary standards (SPSs) and technical barriers to trade (TBTs), has grown in the agrifood and agricultural sectors in an effort to reduce uncertainty over product quality and safety. Although these measures have explicitly no trade objective and are designed to avert sanitary and phytosanitary risks [3], they remain substantial barriers for many African countries in exporting into the EU market (Kareem et al., 2017; Otsuki et al., 2001; Shepherd and Wilson, 2013). Noncompliance with food quality and safety standards in force in the EU represents the main reason for the refusal of African countries' exports at the borders of European RASFF network countries and the main reason for numerous product recalls (alerts) in these markets. For example, RASFF (2014) reported that violations of maximum residue limits (MRLs) for pesticides, a particular SPS measure, constituted approximately 70% of EU border rejections of all African fruit and vegetable exports between 2008 and 2013. Because of noncompliance with EU food standards, Baylis et al. (2011) have also provided evidence that noncompliance with EU food standards were responsible for several bans on the importation of fish and fish products from Kenya and, by extension, Lake Victoria in the EU market in the late 1990s. In addition, we found from the RASFF database [4] that the number of products recalls from RASFF network countries' markets and the number of border rejections affecting African exports grew rapidly between 2008 and 2019. For example, we found persistent border rejections for some African countries' exports, with a notable example being Sudanese exports to Greece, from 2018 to 2019. Greece rejected 368 times the products classified in harmonized system (HS) category 1207 (other oil seeds and oleaginous fruits) exported by Sudan in 2018 and did so for 650 times in 2019.

The RASFF 2018 annual report (p.37) [5] shows that the majority of EU border rejections are related to mycotoxins (508 records), followed by pathogenic microorganisms (302 records), pesticide residues (154 records), and poor or insufficient controls (104 records). In the same report, it appears that the products more affected by EU border rejections are nuts, nut products and seeds (553 records), followed by fruits and vegetables (237 records), and fish and fish products (107 records). These data imply that EU border rejections are related to technical NTM conformity issues, and they concern products

1. The RASFF network includes 32 member states, which are the 28 EU member states, Switzerland, Norway, Liechtenstein and Iceland.
2. https://wits.worldbank.org
3. Sanitary risk refers to food-borne human illness and animal diseases, and phytosanitary risk refers to risks from plant pests and the transmission of disease.
4. The RASFF Database is available at https://webgate.ec.europa.eu/rasff-window/portal
5. The RASFF 2018 annual report is available at https://ec.europa.eu/food/safety/rasff_en

exported by African countries more than other countries. For example, in appendix A, figure 3.1 shows that the most commonly traded agricultural products between African and RASFF member countries are those classified in harmonized system (HS) category HS08 (fresh, chilled or frozen fruits), followed by HS03 (fresh, chilled or frozen fish and crustaceans), HS07 (fresh, chilled or frozen vegetables), and HS20 (preparations of vegetables, fruit and nuts). Figure 3.2 in appendix A indicates that these products are more affected by RASFF border rejections than other product groups for African countries, except for preparations of vegetables, fruit and nuts (HS20), which are less affected. This may be because the products classified in category HS20 are more processed, so they are less perishable and less likely to be rejected. In addition, figure 3.3 in appendix A shows that the trend in RASFF border rejections for products from African countries increased from 2008 to 2018. Figure 3.4 shows that the African country most affected by RASFF border rejections is Egypt, followed by Morocco, Nigeria, Sudan, Ghana, Mauritania, Tunisia, South Africa, Kenya, Ethiopia, Namibia and Gambia. Figure 3.5 indicates that these countries trade with RASFF member countries more than other African countries, with Morocco, South Africa, Kenya, Cote d'Ivoire and Egypt being the five largest African exporters. The noncompliance of African exporters with technical NTMs in force in RASFF member countries, resulting in border rejections of export shipments, may be due, on the one hand, to the higher compliance costs for African countries because they have deficient infrastructures and insufficient technical and storage capacities (Beestermöller et al., 2018; Kareem et al., 2017; Xiong and Beghin, 2012), and they often have limited access to certification bodies (Essaji, 2008). On the other hand, the border rejections or alert cases may also be due to the stringent quality and safety standards set by RASFF member countries, accompanied by stricter border inspections for countries with a lower probability of conforming with these standards. As a result, many African countries may fail to export to the RASFF market, and one may find a larger proportion of zeros in trade flows between African countries and these developed countries. In fact, complying with stringent EU standards entails higher compliance costs for African countries, which may discourage potential exporters in Africa from penetrating EU markets, drive away less productive exporters, and decrease both the probability of exporting and trade volume (Bao and Chen, 2013). Thus, the lower observed trade volume and the excessive zeros in trade flows between African and RASFF member countries may be attributed to stringent EU quality and safety standards and the EU's stricter border inspections for countries with less stringent standards and to the higher fixed and variable compliance costs for African exporters. However, this may also be due to data censoring issues.

The objective of this paper is to assess the effects of EU border rejections on African exports of edible vegetables and fruits during the period from 2008 through 2018. In particular, we estimate the average effects of the European RASFF network countries' border rejections on the extensive margin (number of trade partners) and intensive margin (trade value) of African exports of the two plant product categories by controlling for the possible endogeneity of the current number of border rejections and addressing the issue of zero trade flows. The choice of edible vegetables and fruits and European RASFF countries as partners is motivated by four main reasons. First, fruit and vegetable products play a significant role in export earnings and economic growth for many African countries. Indeed, these products constitute the main agricultural products traded between African and RASFF member countries. Second, the RASFF member countries are the largest importers of tropical fresh fruits and vegetables in which African countries have comparative advantages. Third, fresh fruit and vegetable products are more often subject to RASFF country border rejections than other product groups. Finally, these products attract stringent border controls due to their perishable nature and susceptibility to food safety risks. Hence, since African countries' exports of fruit and vegetable products depend heavily on RASFF member countries, it is important to determine the extent to which border rejections by the latter affect the exports of the former. Using border rejection data for European countries obtained from the RASFF online database and export data on 45 African countries from the UN WITS database for the period 2008-2018, we estimate the canonical version of the sectoral gravity equation of Anderson and Van Wincoop (2004) using the Poisson pseudo maximum likelihood (PPML) estimator of Silva and Tenreyro (2006) in association with the robust two-stage residual inclusion (2SRI) approach of Terza et al. (2008).

We depart from the literature in estimating the effects of border rejections on bilateral trade by explicitly validating and correctly addressing the issues of the *endogeneity* of border rejections and *zero trade flows* by jointly employing the 2SRI robust approach and the unbiased and consistent PPML estimator. Indeed, many previous studies (Baylis et al., 2011; Beestermöller et al., 2018; Grant and Anders, 2011; Kareem et al., 2017) have investigated the effects of border rejections on the exports of third countries without explicitly addressing the concern of the *endogeneity* of border rejections and appropriately addressing the issue of *zero trade flows*. The endogeneity of border rejections may arise from omitted variable bias that influences trade value and is correlated with the number of border rejections. For example, one might find that the unobserved quality of a product in the data can affect both the value of trade and the number of border rejections affecting this product. In addition, the endogeneity of border rejections arises as result of their simultaneity with trade value because we find that the number of import refusals is highly and positively correlated with trade value. For instance, figure 3.3 in appendix A shows that African countries that are more affected by RASFF border rejections trade more with RASFF member countries than do other countries. To address the issues of endogeneity and zero trade flows, previous studies have generally adopted traditional instrumental variable (IV)-based approaches with a simple ordinary least squares (OLS) method. Terza et al. (2008) show that the use of the two well-known traditional IV-based approaches, two-stage least squares (2SLS) and two-stage predictor substitution (2SPS), may sometimes be appropriate for addressing the concern of endogeneity in linear regression models, but 2SLS and 2SPS are both inconsistent in the case of nonlinear regression models, such as a structural gravity trade model. Furthermore, the use of OLS is problematic because this approach requires log-transforming the dependent trade variable and dropping the zero trade flows. Hence, the clear drawback of OLS is that this approach cannot take into account the information contained in the zero trade flows. The problem with zero trade flows becomes especially pronounced in the context of border rejections. Following our empirical strategy, we explicitly validate the hypothesis of the endogeneity of the number of import refusals and highlight both the direct and spillover effects of border rejections. The latter result means that an increase in the number of border rejections for a given product (for instance, a fresh fruit) in a given year leads to an increase in the number of border rejections for a product and its neighboring products (for instance, a fresh vegetable) in the next year. We also find that a single increase in the number of import refusals by an RASFF country in the current year leads to a decrease in the number of trade partners in Europe for African countries by 0.018 percent for edible vegetables and 0.143 percent for edible fruits. In addition, our results show that one additional import refusal decreases the export value of African countries' edible vegetables by 0.045 percent. However, we find that a single import refusal by RASFF countries in the current year leads to an increase in the export value of African countries' edible fruits by 0.126 percent.

The estimation strategy deployed in the literature to estimate the effects of border rejections on the exports of third countries is, in general, the standard inconsistent and biased OLS method. For example, Beestermöller et al. (2018) used a two-step procedure and an OLS method at each step to assess both the direct and spillover effects of RASFF border rejections on Chinese exporters. They did not take into account the endogeneity of border rejections. Baylis et al. (2011) deployed an OLS method to estimate a gravity equation to assess the trade diversion and deflection effects of EU import refusals of fishery and seafood products. Although they seem to find unbiased and consistent estimates with this approach by deleting zero trade values, there is a potential for selection bias, and there remains the issue of controlling for possible spillover effects between related fishery and seafood products classified in different HS 6-digit product categories in their database. Grant and Anders (2011) followed the same approach and method as Baylis et al. (2011) to estimate the magnitudes of trade deflection resulting from United States Food and Drug Administration (US FDA) import refusals of fishery and seafood products. Although these authors seem to obtain unbiased and consistent estimates by segmenting their data into four cross-sections, there remains the issue of controlling for possible spillover effects between related fish and seafood products classified in different HS 4-digit product categories in their database.

The remainder of this paper is organized as follows. In section 3.4, we define and explain what drives a country's reputation for a product and the spillover effects of reputation. Section 3.5 presents our theoretical trade models and estimation strategy. In section 3.6, we describe our data. We present and discuss the empirical results in section 3.7. In the final section, we draw conclusions.

3.4 A Country's Reputation for a Product and the Spillover Effects of Reputation

The reputation of a country for a particular product is defined as its ability to produce and export this product in conformity with the quality and safety standards of the country in which that reputation is held (Dimitrova et al., 2017). The quality and safety standards include sanitary and phytosanitary risk mitigation measures, such as TBT and SPS measures. Hence, the reputation of a country for a particular exported product may depend not only on the investments the country has made to meet

SPS and TBT requirements related to this product but also on the likelihood that this country will successfully pass through strict border controls. An exporting country may be considered to exhibit a good/bad reputation for a specific product in a given importing country if this country succeeds/fails one or several times to pass this product through the border of the importing country. The highlighted main reason for noncompliance by developing countries is the higher investment cost required to meet the stringent standards set by developed countries because developing countries face deficient infrastructures and insufficient technical and storage capacities (Beestermöller et al., 2018). However, several recent studies (Baylis et al., 2009, 2011; Jouanjean et al., 2015; Beestermöller et al., 2018) on import refusals indicate that inspections at the borders by customs officers are not random, and hence neither is the decision to reject a product. Indeed, identifying unsafe products may be too costly (in terms of money and time), so customs officers focus their controls on a particular country, firm or product to minimize the probability of a noncompliant good entering the importing country or to maximize the likelihood of identifying a fraudulent shipment. The particularity is related to the higher sanitary and/or phytosanitary risks that may be intrinsically associated with specific products (e.g., perishable products) or related to certain countries or firms that have frequently experienced border rejections. In general, this risk is established on the basis of a preexisting alert, information from other countries' inspections, or past refusals affecting that country, firm or product. For example, (Baylis et al., 2009; Jouanjean et al., 2015) show that the probability of rejecting a given product depends on the past reputation of this product, the past reputation of similar products and the past reputation of neighboring countries that export the same product. This mechanism is known in the literature as the *"direct reputation for a product and reputation spillover effect of related products"*. The implication of this mechanism is that the exporting country's reputation for a particular exported product (measured by the number of its shipments rejected at the border) in a given importing country is endogenous. Hence, to estimate an unbiased and consistent effect of an exporting country's reputation for a particular product on bilateral trade, we must account for such endogeneity. We do so by instrumenting the number of current import refusals affecting a particular exporting country i and product k using the lagged border rejection of this product ($\text{Refusal}^k_{\text{ijt}-1}$) and the lagged border rejection of related products r ($\text{Refusal}^r_{\text{ijt}-1}$). The econometric model is defined as follows :

$$\begin{aligned}\text{Refusal}^k_{\text{ijt}} =& \theta_0 + \underbrace{\theta_1 \text{Refusal}^k_{\text{ijt}-1}}_{\text{Rejection History}} + \underbrace{\theta_2 \text{Refusal}^r_{\text{ijt-1}}}_{\text{Rejection History in Related Products}} \\ &+ \underbrace{\theta_3 \omega^{\text{k}}_{\text{ijt-1}}}_{\text{Lagged Market Share}} + \theta_4 \ln DIST_{ijt} + \theta_5 \text{CINY}_{ij} + \varepsilon^k_{ijt}\end{aligned} \tag{3.1}$$

where i, j, k and t indicate exporter, importer, product, and year, respectively. $Refusal^k_{ijt}$ ($Refusal^k_{ijt-1}$) denotes the number of import refusals affecting product k exporting from origin country i to importing country j in year *t*(*t-1*). $Refusal^r_{ijt-1}$ denotes the number of import refusals affecting related product r other than product k exporting from origin country i to importing country j in year *t-1*. ω^k_{ijt-1} measures the market share of exporting country i over the total imports of importing country j of product k

from the world in year *t-1*. $\ln D\text{IST}_{ijt}$ is the logarithm of the distance between the origin country i and the importing country j at time t. CINY_{ij} is a dummy variable taking value 1 if origin country i and importing country j have been in colonial relationship and 0 otherwise. As the number of import refusals is a count model, we use the Poisson model to estimate equation (3.1) and compute Anscombe (1948)'s residuals that will be included in the trade model as an additional variable to control for endogeneity.

3.5 The Trade Models

In this section, we present the theoretical frameworks that we follow to analyze the effects of the European RASFF network countries' border rejections on the extensive and intensive margins of African exports of edible fruits and vegetables.

3.5.1 Intensive margin

As a foundation for our analysis of the intensive margin, we use the gravity model of trade that predicts that the international trade between two countries is directly proportional to the product of their sizes and inversely proportional to the trade frictions between them. We use the canonical version of the Anderson and Van Wincoop (2004) sectoral gravity equation :

$$X_{ijt}^{k} = \frac{Q_{it}^{k} E_{jt}^{k}}{Q_{t}^{k}} \left(\frac{\tau_{ijt}^{k}}{P_{it}^{k} \Pi_{jt}^{k}} \right)^{1-\sigma^{k}} \tag{3.2}$$

where X_{ijt}^{k} is the export value of product k from origin country i to importing country j at time t. Q_{t}^{k} is the value of global production of product k at time t. τ_{ijt}^{k} is the iceberg bilateral trade cost between origin country i and importing country j at time t. E_{jt}^{k} is the amount of income allocated to the consumption of product k in importing country j at time t. Q_{it}^{k} is the production value of product k in origin country i at time t. Π_{jt}^{k} and P_{it}^{k} are the unobservable inward and outward multilateral resistance terms, respectively. These terms are theoretically constructed, and they capture the incidence of trade costs on the consumers in importing country j and on the producers in origin country i. $\sigma^{k} > 1$ is a parameter capturing the elasticity of substitution between varieties (origins) of product k.

To capture the effect of reputation for a particular plant product on African exports of this product to European RASFF network countries, we extend the standard specification of the bilateral trade cost by including an additional variable ($Refusal_{ijt}^{k}$) that measures the number of import refusals affecting product k exporting from origin country i to importing country j in year t. Specifically, we specify the iceberg bilateral trade costs (τ_{ijt}^{k}) as follows :

$$(\tau_{ijt}^{k})^{1-\sigma^{k}} = \exp\left(\gamma_{d} \ln D\text{IST}_{ijt} + \gamma_{c}\text{CINY}_{ij} + \gamma_{br}\text{Refusal}_{ijt}^{k}\right) \tag{3.3}$$

where $\ln D\text{IST}_{ijt}$ is the logarithm of the distance between origin country i and importing country j at time t. CINY_{ij} is a dummy variable taking value 1 if origin country i and importing country j have been in colonial relationship and 0 otherwise. We do not take into account the tariffs and the contiguity variables because, on the one hand, EU tariffs do not vary across EU member countries and, on the other hand, African countries do not share a common border with EU countries. In addition, we do not include the variable common language LANG_{ij} because it appears to be collinear with the colonial relationship variable CINY_{ij} in our data set. As defined above, for an exporting country i, a specific product k and a given importing country j at time t, the variable ($Refusal^k_{ijt}$) measures the number of import refusals affecting product k, which indicates the reputation for this specific product k at time t.

We obtain the econometric model for the intensive margin by plugging equation (3.3) into the structural sectoral gravity equation (equation (3.2)) and then augmenting this equation with an error term as follows :

$$
\begin{aligned}
X^k_{ijt} = \quad & \exp\Bigg(ln(Q^k_{jt}) + ln(E^k_{it}) - ln(Q^k_t) - (1-\sigma^k)ln(P^k_{it}) - (1-\sigma^k)ln(\Pi^k_{jt}) \\
& + \gamma_d \ln D\text{IST}_{ijt} + \gamma_c \text{CINY}_{ij} + \gamma_{br}\text{Refusal}^k_{ijt} \Bigg) \times \vartheta^k_{ijt}
\end{aligned}
\tag{3.4}
$$

where ϑ^k_{ijt} is a random error term. To control for the unobservable multilateral resistance terms, we follow Anderson and Yotov (2010) and Yotov et al. (2016) by using importer-time and exporter-time fixed effects to account for country-time-specific effects. Specifically, we use fe^k_{jt} to denote the set of importer-time fixed effects that will account for the inward multilateral resistance term Π^k_{jt} and fe^k_{it} to denote the set of exporter-time fixed effects that will control for the outward multilateral resistance term P^k_{it}. In addition, the exporter-time and importer-time fixed effects will absorb the exporter's output (Q^k_{it}) and importer's expenditure (E^k_{jt}) and all other possible observable and unobservable importer-time- or exporter-time-specific characteristics. The final econometric model is now completed by substituting the multilateral resistance terms (Π^k_{jt} and P^k_{it}) for the importer-time and exporter-time fixed effects (fe^k_{jt} and fe^k_{it}).

$$
X^k_{ijt} = \exp\left(\alpha_0 + \gamma_d \ln D\text{IST}_{ji} + \gamma_c \text{CINY}_{ij} + \gamma_{br}\text{Refusal}^k_{ijt} + fe^k_{it} + fe^k_{jt} \right) \times \vartheta^k_{ijt} \tag{3.5}
$$

Consistent with the structural gravity equation (3.2), the parameters of equation (3.5) are defined as follows : $\alpha_0 = \text{Q}^k_t$. Since we use the number of import refusals as the measure of a country's reputation for a product, *we expect that γ_{br} should be negative*. It captures the average effect of reputation for a particular product on African exports of this product to the RASFF market.

3.5.2 Extensive margin

Beyond the intensive margin, we pay particular attention to the extensive margin in explaining the observed trade patterns between African and RASFF member countries. Indeed, because of the information shared through the RASFF tool, one import refusal in a given European country will affect the reputation of the rejected country and then clearly decrease the probability that this exporting country will enter into the other RASFF countries. As a result, both the trade volume and the number of trade partners in Europe for African countries will be affected after a border rejection. A wide variety of definitions have been proposed for the extensive margin in theoretical (Melitz, 2003; Chaney, 2008; Helpman et al., 2008) and empirical (Hillberry and Hummels (2008); Eaton et al. (2004); Berthou and Fontagné (2008); Hillberry and McDaniel (2002); Hummels and Klenow (2005); Dennis and Shepherd (2007) and Helpman et al. (2008)) frameworks. According to these frameworks, among the universe (N_i^k) of firms operating in a given sector k and exporting country i, only firms that exhibit a productivity level greater than a threshold value can export into a given importing country j. Firms with a low productivity level will not be able to sell in foreign markets, while firms that reach the threshold productivity will be indifferent between selling in domestic and foreign markets. The threshold productivity is the one that equalizes the variable export profits to the fixed export costs.

Given that we are interested in capturing the spillover effect of reputation, it follows that we are interested not only in the probability of an exporting country entering a market but also in its ability to expand the market. Therefore, we define our extensive margin as the number of trade partners in Europe for African countries. We begin with the ratio (D_{ijt}^k) of Helpman et al. (2008) defined as the variable export profits over the fixed export costs, expressed as follows :

$$D_{ijt}^k = \frac{(1-\alpha^k)(\Pi_{jt}^k \frac{\alpha^k}{c_i^k \tau_{ijt}^k})^{\sigma^k - 1} E_{jt}^k a_L^{1-\sigma^k}}{c_i^k f_{ij}^k} \tag{3.6}$$

where D_{ijt}^k is greater than one for all of the exporting firms that will find it profitable to export to country j. This ratio is lower than one for firms that will not earn enough from exporting to country j to cover the fixed export costs ($c_i^k f_{ij}^k$). The indifferent firms will have a ratio equal to one. α^k is a parameter that determines the elasticity of substitution ($\sigma^k > 1$) across varieties of product k, with $\sigma^k = \frac{1}{1-\alpha^k}$. Π_{jt}^k is the unobservable inward multilateral resistance term. E_{jt}^k is the amount of income allocated to the consumption of product k in importing country j at time t. τ_{ijt}^k is the iceberg bilateral trade cost between origin country i and importing country j at time t. c_i^k measures the marginal cost in exporting country i, and f_{ij}^k indicates the fixed export cost coefficient. a_L is the lower bound of the distribution of productivity across firms in exporting country i.

As in Helpman et al. (2008), we define the fixed export costs (f_{ij}^k) as a function of the fixed trade barriers imposed by the importing country on all exporters ($\phi_{IM,j}^k$), the fixed export costs common across all export destinations ($\phi_{EX,i}^k$), and any observed additional country-pair-specific fixed trade costs (ϕ_{ij}^k). Given these factors, the fixed export costs (f_{ij}^k) can be expressed as follows :

$$f_{ij}^{k} = \exp\left(\phi_{EX,i}^{k} + \phi_{IM,j}^{k} + \zeta\phi_{ij}^{k} - \bar{\eta}_{ij}^{k}\right) \tag{3.7}$$

Using the specification of the iceberg bilateral trade costs (τ_{ijt}^{k}) in equation (3.3) together with the fixed export costs (equation (3.7)), we define a latent variable $T_{ijt}^{k} \equiv ln(D_{ijt}^{k})$ as follows :

$$T_{ijt}^{k} = \gamma_0 + fe_{it}^{k} + fe_{jt}^{k} + \gamma_d \ln D\text{IST}_{ijt} + \gamma_c \text{CINY}_{ij} + \gamma_{br}\text{Refusal}_{ijt}^{k} + \eta_{ijt}^{k} = \psi\gamma + \eta_{ijt}^{k} \tag{3.8}$$

where $\eta_{ijt}^{k} \sim \mathcal{N}(0,1)$. $fe_{it}^{k} = -\sigma^{k} ln(c_i^{k}) - \phi_{EX,i}^{k}$ represents exporter-product fixed effects and $fe_{jt}^{k} = (\sigma^{k}-1)ln(\Pi_{jt}^{k}) + ln(E_j^{k}) - \phi_{IM,j}^{k}$ indicates importer-product fixed effects. ψ is the set of explanatory variables that determines the latent variable T_{ijt}^{k} and γ, the associated parameters to be estimated.

To obtain the number of trade partners, we define an indicator variable $d_{ijt}^{k} = 1$ if $D_{ijt}^{k} > 1$ or $T_{ijt}^{k} > 0$, with $d_{ijt}^{k} \sim \mathcal{B}\Big(p = Pr(d_{ijt}^{k} = 1) \equiv Pr(T_{ijt}^{k} > 0)\Big)$

Next, let Ω_i^{k} be the universe of possible importing countries of product k originating from country i. Then, let us define $EM_{it}^{k} \leq \Omega_i^{k}$ as the observed number of trade partners of exporting country i at time t. It follows that these observed trade partners (j) are those for which the latent variable (T_{ijt}^{k}) is greater than zero ($T_{ijt}^{k} > 0$ or $D_{ijt}^{k} > 1$) or the indicator variable (d_{ijt}^{k}) is equal to one ($d_{ijt}^{k} = 1$). For the remaining number ($\Omega_i^{k} - EM_i^{k}$) of trade partners, the latent variable will be lower than zero ($T_{ijt}^{k} < 0$ or $D_{ijt}^{k} < 1$), and then the indicator variable (d_{ijt}^{k}) will be equal to zero ($d_{ijt}^{k} = 0$).

Given the definitions and assumptions on the indicator variable d_{ijt}^{k} and the latent variable T_{ijt}^{k}, we now define the extensive margin as follows :

$$\begin{aligned} EM_{it}^{k} = \quad & \textstyle\sum_{j=1}^{\Omega_i^{k}} (d_{ijt}^{k} | D_{ijt}^{k} > 1) \equiv \sum_{j=1}^{\Omega_i^{k}} (d_{ijt}^{k} | T_{ijt}^{k} > 0) \\ & = \Omega_i^{k} \times \left[1 - \textstyle\prod_{j=1}^{\Omega_i^{k}} \Big(1 - \Phi(\psi\gamma)\Big)\right] \end{aligned} \tag{3.9}$$

where $\prod$ is the product operator and $\Phi(.)$ is the normal cumulative density function (cdf). Given that our extensive margin EM_{it}^{k} is a count variable by definition, we specify equation (3.9) as a Poisson model.

3.5.3 Estimation Strategy

To estimate equation (3.5) for the intensive margin and equation (3.9) for the extensive margin, we first control for the endogeneity of the number of import refusals and then address the issue of zero trade flows. We follow the 2SRI approach of Terza et al. (2008) to address the issue of the *endogeneity* of border rejections (Refusal_{ijt}^{k}) and take into account the *zero trade flows* by using the PPML estimator of Silva and Tenreyro (2006). Indeed, Terza et al. (2008) show that the use of the two well-known traditional IV-based approaches, 2SLS and 2SPS, may sometimes be appropriate to address the concern of endogeneity in linear regression models, but these two methods are both inconsistent in the case of nonlinear regression models, such as a structural gravity trade model. Silva and Tenreyro (2006) propose the PPML estimator to estimate the structural gravity equation in levels rather than translating it into a logarithmic form that requires dropping the zero trade observations. The PPML estimator is more robust than standard OLS because it controls for heteroskedasticity and exploits the information contained in zero trade flows.

As suggested by Terza et al. (2008), to implement the 2SRI estimation procedure, in the first stage, we estimate the reduced-form equation, which is the number of import refusals defined by equation (3.1), with a Poisson model and then compute the residuals. In the second stage, we include the computed residuals of border rejections as additional regressors in the trade equations (3.5) and (3.9). We use the residuals of Anscombe (1948) because the normality assumption for the use of the control function method is not satisfied. Indeed, the number of import refusals is a count variable that follows a Poisson distribution instead of a normal distribution. The Anscombe approach transforms a non-normally distributed variable into one that follows a Gaussian distribution (Anscombe, 1948).

3.6 Data

We combine 32 European individual country' border rejection data from the RASFF online database [6] with country-level HS 2-digit product export data on 45 African countries from the UN WITS database [7] for the period 2008–2018. The RASFF, initiated by the European Commission in 1979, is a tool that enables its 32 member countries (28 EU Member States, Norway, Liechtenstein, Iceland and Switzerland) to share information related to food safety risks and actions that have been taken to avert these risks. When a member country detects a food safety risk with a given import shipment at its border, the following possible actions are taken and shared in terms of notification with other members through the RASFF platform : *detain, return, reject or destroy the product, etc*. A notification shared through the RASFF provides details on the hazard type, name, category and origin of products, date (daily), action taken, etc. However, the description and classification of products in the RASFF database are not the same as described and classified in the HS product description and classification.

One of our contributions in this paper is that we developed a replicable program in the Stata software [8], which is available upon request, to match the RASFF data with the UN WITS HS 6-digit trade data. Indeed, to identify and classify a product in the RASFF border rejection database into an HS 6-digit product category, we need to treat verbal description records in a variable named *subject* (e.g., "*pyridalyl (0.05 mg/kg - ppm) in chilled strawberries from Egypt*") and aggregated information contai-

6. `https://webgate.ec.europa.eu/rasff-window/portal`
7. `https://wits.worldbank.org`
8. We thank Ms. Cécile Le-Roy, a data management officer at the French National Institute of Research for Agriculture (INRA) in Nantes, for her helpful contributions in elaborating the replicable program in Stata.

ned in a variable named *product category* (e.g., "*fruits and vegetables*"). Our Stata program uses the *split* function to split (separators are commas and space)s the variable *subject* and applies the looping commands (*foreach and forvalues loops*) with the *regexm* function to search for key words related to *product name* (e.g., strawberries) and *product state* (e.g., fresh, chilled, frozen, dried, powder, juice, cooked, preserved, or desiccated) to obtain an HS description (e.g., chilled strawberries) of products targeted by a notification. For each notification, the program assigns an HS 6-digit product code by exploiting the information related to the *name* and *state* of the product identified through the variable *subject* and the information from *product category*. For the assignment, we used the 1992 version of the HS product description and classification. We identified an HS 6-digit product code for 99.97% of notifications. We then matched the codified notification data with our UN WITS HS 6-digit trade data. Due to the frequent occurrences of zero trade flows and border rejections at disaggregated level, we aggregate all border rejections and exports by exporter-importer-year at the HS 2-digit level. We used the export data between African and RASFF countries in edible fruits (HS 08) and vegetables (HS 07) for the period 2008-2018.

Table 3.1 provides summary statistics for trade, border rejections and some gravity variables. The table shows that the annual average bilateral trade value is higher for edible fruits (4.304 million US dollars with a standard deviation of 32.818), followed by edible vegetables (1.818 million US dollars with a standard deviation of 19.949). Figure 3.6 shows that the trend in trade between African and RASFF countries increased from 2008 to 2018. However, in table 3.1, we find that there are still many zero trade flows between them. For instance, the zero trade observations represent 63.68% for edible vegetables and 52.56% for edible fruits and nuts. The average market share of African countries over the total imports of European countries is very low, 0.1% for edible vegetables and 0.2% for edible fruits and nuts.

Table 3.1 shows that the edible vegetables are more affected by RASFF border rejections than other product categories. On average, edible vegetables originating from African countries have been rejected by RASFF member countries more than once (1.241 times) per year, and edible fruits and nuts have been refused more than once (0.199 times) per year. Figure 3.3 in appendix A shows that the trend in RASFF border rejections affecting African countries increased from 2008 to 2018. Figure 3.4 in appendix A shows that the African country that is most affected by RASFF border rejections is Egypt, followed by Morocco, Nigeria, Sudan, Ghana, Mauritania, Tunisia, South Africa, Kenya, Ethiopia, Namibia and Gambia. Figure 3.5 in appendix A indicates that these countries trade more with RASFF member countries than other countries, with Morocco, South Africa, Kenya, Cote d'Ivoire and Egypt being the five largest African exporters.

Finally, we use two traditional gravity variables from the CEPII database [9] as control variables for the other trade costs. These variables include the population-weighted distance between exporting and importing countries and a dummy variable indicating a past colonial relationship between exporting and

9. CEPII is the Centre d'Etudes Prospectives et d'Informations Internationales. The CEPII database is available at `http://www.cepii.fr`.

TABLE 3.1 – Summary statistics

Continous variables	Obs	Mean	Std. Dev.	Min	Max
Trade value of edible vegetables (in 1000 USD)	11842	1817.872	19949.256	0	685725.33
Trade value of edible fruits and nuts (in 1000 USD)	11563	4303.946	32817.669	0	850877.71
Number of trade partners in Europe for edible vegetables (in number)	11842	11.259	8.486	0	31
Number of trade partners in Europe for fruits and nuts (in number)	11563	14.705	8.797	0	31
Number of border rejections of edible vegetables (in number)	11842	.032	1.241	0	123
Number of border rejections of edible fruits and nuts (in number)	11563	.013	.199	0	11
Market share for edible vegetables (in percent)	11842	.001	.009	0	.243
Market share for edible fruits and nuts (in percent)	11563	.002	.008	0	.157
Log of Distance	11842	8.604	0.463	5.993	9.353
Binary variables	**Obs**	**Dummy**	**Frequency (%)**		
Binary trade of edible vegetables	11842	0 1	63.68 36.32		
Binary trade of edible fruits and nuts	11563	0 1	52.56 47.44		
Pair in colonial relationship post 1945	11842	0 1	97.15 2.85		

importing countries. The weighted distance between African and European countries is, on average, 5,453.430 km. The pairs of countries that had a colonial relationship after 1945 represent 2.85%.

3.7 Results and Discussions

This section presents the results of the effects of European RASFF border rejections on the exports of edible vegetables and fruits from African countries. As we instrument the number of current import refusals affecting a particular exporting country i and product k, we first present these results in table 3.2. Our results highlight both the direct and spillover effects of border rejections. Indeed, we find that the border rejections of one of the two plant product categories (edible vegetables (HS 07) and edible fruits and nuts (HS 08)) one year before positively and significantly affect the current number of import refusals of both categories. Specifically, table 3.2 shows that an increase in import refusals affecting edible vegetables once in the previous year increases the number of current import refusals of edible vegetables and edible fruits and nuts by 0.033 and 0.062 percent, respectively. Similarly, we find that an increase in import refusals affecting edible fruits once in the previous year increases the number of current import refusals of edible fruits and nuts and edible vegetables by 0.356 and 0.452 percent, respectively. Our results show that an increase in African countries' export shares of edible vegetables and fruits over the total imports of the RASFF countries in the previous year substantially increases the number of current import refusals of these products, by 5.620 and 30.24 percent, respectively. As expected, we find that the distance between the African and RASFF member countries decreases the number of current import refusals for both plant product categories. African countries that had previously been in colonial relationships with RASFF member countries are more likely to experience import refusals for edible vegetables.

TABLE 3.2 – Border Rejection Estimation Results

	Poisson model	
	HS 07 : Edible vegetables	HS 08 : Edible fruits and nut
Constant	3.642***	5.603***
	(0.785)	(0.045)
Log distance (lnDIST_ijt)	-0.947***	-1.534***
	(0.094)	(0.099)
Colony (CINY_ij)	3.628***	-3.028
	(0.123)	(1.985)
Lagged Border rejections for product HS07	*0.033****	*0.062****
	(0.002)	*(0.018)*
Lagged Border rejections for product HS08	*0.452****	*0.356****
	(0.029)	*(0.029)*
Lagged Market share for product HS07	5.620***	
	(1.179)	
Lagged Market share for product HS08		30.24***
		(3.153)
Observations	11842	11563

Standard errors in parentheses : * p<.10 ; ** p<.05 ; *** p<.01

Next, we present in table 3.3 the results of the average effects of European RASFF border rejections on the two export margins of African countries of edible vegetables and fruits. First, our results explicitly validate the hypothesis of the endogeneity of the number of import refusals. However, we do not find evidence for such endogeneity in the intensive margin for edible fruits and nuts. Indeed, we find that the computed Anscombe residuals of border rejections significantly and positively affect the extensive margins of both edible vegetables and fruits and the intensive margins of edible vegetables. The effect is not significant for the intensive margin for edible fruits and nuts.

TABLE 3.3 – Effects of RASFF Border Rejections on African Exports of Edible Fruits and Vegetables

	Number of trade partners in Europe (in number)		Trade value (in 1000 USD)	
	Poisson model		PPML	
	HS 07 : Edible vegetables	HS 08 : Edible fruits and nut	HS 07 : Edible vegetables	HS 08 : Edible fruits and nut
Constant	5.254*** (0.049)	5.603*** (0.045)	19.230*** (1.201)	18.710*** (0.937)
Log distance (lnDIST_ijt)	-0.326*** (0.006)	-0.338*** (0.006)	-1.223*** (0.152)	-0.961*** (0.106)
Colony (CINY_ij)	-0.147*** (0.021)	-0.168*** (0.017)	1.334*** (0.104)	0.881*** (0.069)
Border rejection for product HS07	*-0.0183**** *(0.004)*		*-0.045**** *(0.017)*	
Border rejection for product HS08		*-0.143**** *(0.019)*		*0.126**** *(0.042)*
Lagged Market share for product HS07	5.474*** (0.178)		11.690*** (0.705)	
Lagged Market share for product HS08		14.290*** (0.195)		17.310*** (1.011)
Ansombe Residuals of Border rejection for product HS07	0.069*** (0.007)		0.122*** (0.028)	
Ansombe Residuals of Border rejection for product HS08		0.160*** (0.012)		-0.018 (0.040)
Observations	11842	11563	11842	11563
Adjusted R-squared			0.966	0.952
Exporter-Year fixed effects	-	-	YES	YES
Importer-Year fixed effects	-	-	YES	YES

Standard errors in parentheses : * p<.10 ; ** p<.05 ; *** p<.01

Note : We combine 32 European individual country' border rejection data from the RASFF online database with country-level HS 2-digit product export data on 45 African countries from the UN WITS database. We first codified the RASFF countries' border rejection notifications at HS 6-digit level, and then matched the codified notification data with African country-level export data. Due to the frequent occurrences of zero trade flows and border rejections at disaggregated level, we aggregate all border rejections and exports by exporter-importer-year at the HS 2-digit level. We used the export data between African and RASFF countries in edible fruits (HS 08) and vegetables (HS 07) for the period 2008-2018.

As expected, we find that the current number of border rejections significantly and negatively affects the extensive margins of both edible vegetables and fruits and the intensive margin of edible vegetables. These results signify that an increase in the number of current RASFF country border rejections affecting edible vegetables and fruits decreases the number of trade partners in Europe for African exporting countries and decreases their export value of edible vegetables. For example, the average effect of border rejections on the extensive margin is - 0.018 (p-value < 0.01) for edible vegetables and - 0.143 (p-value < 0.01) for edible fruits and nuts. These results mean that an increase in import refusals once in the current year decreases the number of trade partners in Europe for African exporting countries by 0.018 percent for edible vegetables and 0.143 percent for edible fruits and nuts. Similarly, an increase in import refusals once in the current year decreases the export value of edible vegetables in African countries by 0.045 percent. In contrast, we find an unexpected effect for edible fruits and nuts. Indeed, we find that an increase in import refusals once in the current year increases the export value of edible fruits and nuts by African countries by 0.126 percent. One possible explanation for this result may be that African exporters tend to concentrate their exports to some EU importing countries when they experience border rejections in other EU countries. This hypothesis is supported by the higher negative effect of edible fruit and nut import refusals on the number of trade partners in Europe for African exporting countries. Although our results are quantitatively different from those found in previous studies (Baylis et al., 2011; Beestermöller et al., 2018; Grant and Anders, 2011) because of the products considered for analysis, they remain qualitatively identical. Indeed, similar to our results, Beestermöller et al. (2018) find that the RASFF countries' border rejections decrease the exports of Chinese exporters. Baylis et al. (2011) indicate that EU import refusals decrease the imports of fishery and seafood products into EU member countries. Grant and Anders (2011) find that US FDA import refusals decrease the imports of fishery and seafood products into the US.

Consistent with the standard estimates of the gravity model, we find that the distance between the exporter and importer significantly decreases the two export margins of African countries in both of the plant product categories. Specifically, a one percent increase in bilateral distance decreases the number of trade partners in Europe for African exporting countries by 0.326 percent for edible vegetables and by 0.338 percent for edible fruits and nuts. The effect of distance on the export value of edible vegetables and edible fruits is -1.223 and -0.961 percent, respectively. As expected, we also find that African countries that had previously been in a colonial relationship with RASFF member countries export more than those that had not. However, the existence of a past colonial relationship does not favor partner diversification.

3.8 Conclusion

The increasing number of import refusals and the high number of zero trade flows observed between African countries and European member states, which are the largest world importers of tropical edible fruits and vegetables, both highlight the issue of compliance with EU food quality and safety regulations for many African countries. In this paper, we assessed the effects of EU import refusals on the exports by African countries of edible vegetables and fruits during the period from 2008 through 2018. In particular, we estimate the average effects of the RASFF countries' border rejections on the extensive and intensive margins of African countries' exports of edible fruits and vegetables. Using European countries' border rejection data from the RASFF online database and country-level export data for 45 African countries from UN WITS database, we found that an increase in the number of import refusals in the RASFF countries once in the current year leads to a decrease in the number of trade partners in Europe for African countries by 0.018 percent for edible vegetables and by 0.143 percent for edible fruits and nuts. In addition, our results show that import refusals decrease the export value of African countries' edible vegetables by 0.045 percent. However, we found that the RASFF countries' refusal to import once in the current year leads to an increase in the export value of African countries' edible fruits by 0.126 percent. Furthermore, our results explicitly validated the endogeneity of the number of import refusals and highlighted both the direct and spillover effects of border rejections, which means that an increase in the number of border rejections for a given product (for instance, a fresh fruit) in the previous year leads to an increase in the number of border rejections for a product and related products (for instance, a fresh vegetable) in the current year.

When we consider the main reasons (the presence of mycotoxins and pesticide residues, the poor or insufficient controls, etc.) for EU border rejections, which are mentioned in the RASFF annual reports for 2014 and 2018, our results imply that African countries must invest in improving their infrastructure and technical and storage capacities. These investments may help to reduce the cost of complying with quality and safety standards in force in EU member countries and improve the quality of African countries' exports. Efforts may also be made to improve African exporters' access to mutual certification bodies for edible vegetables and fruits and nuts. There is also a need to harmonize the EU quality and safety standards with those set in international frameworks, such as the CODEX Alimentarius.

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Appendix

Appendix A : Additional figures

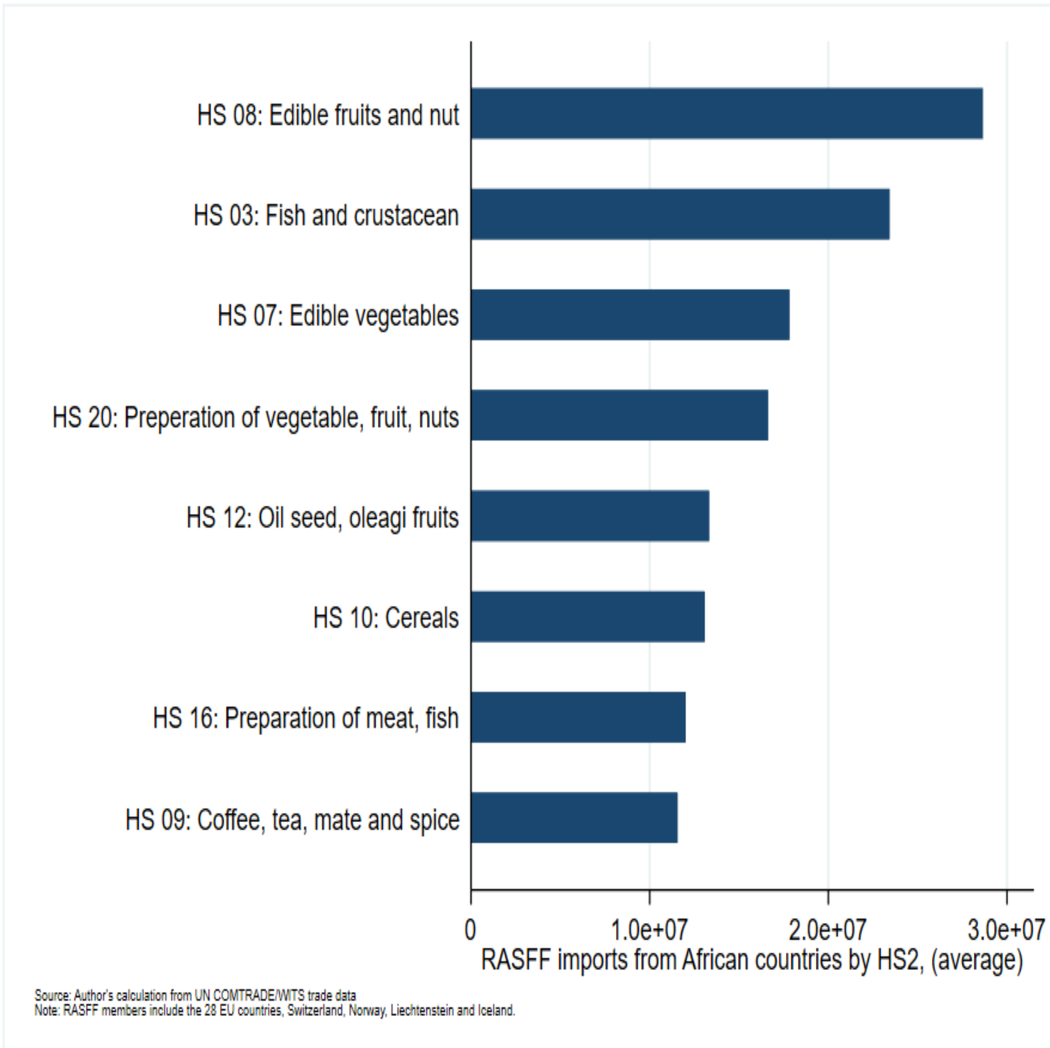

FIGURE 3.1 – RASFF imports from Africa by HS2, 2008-18

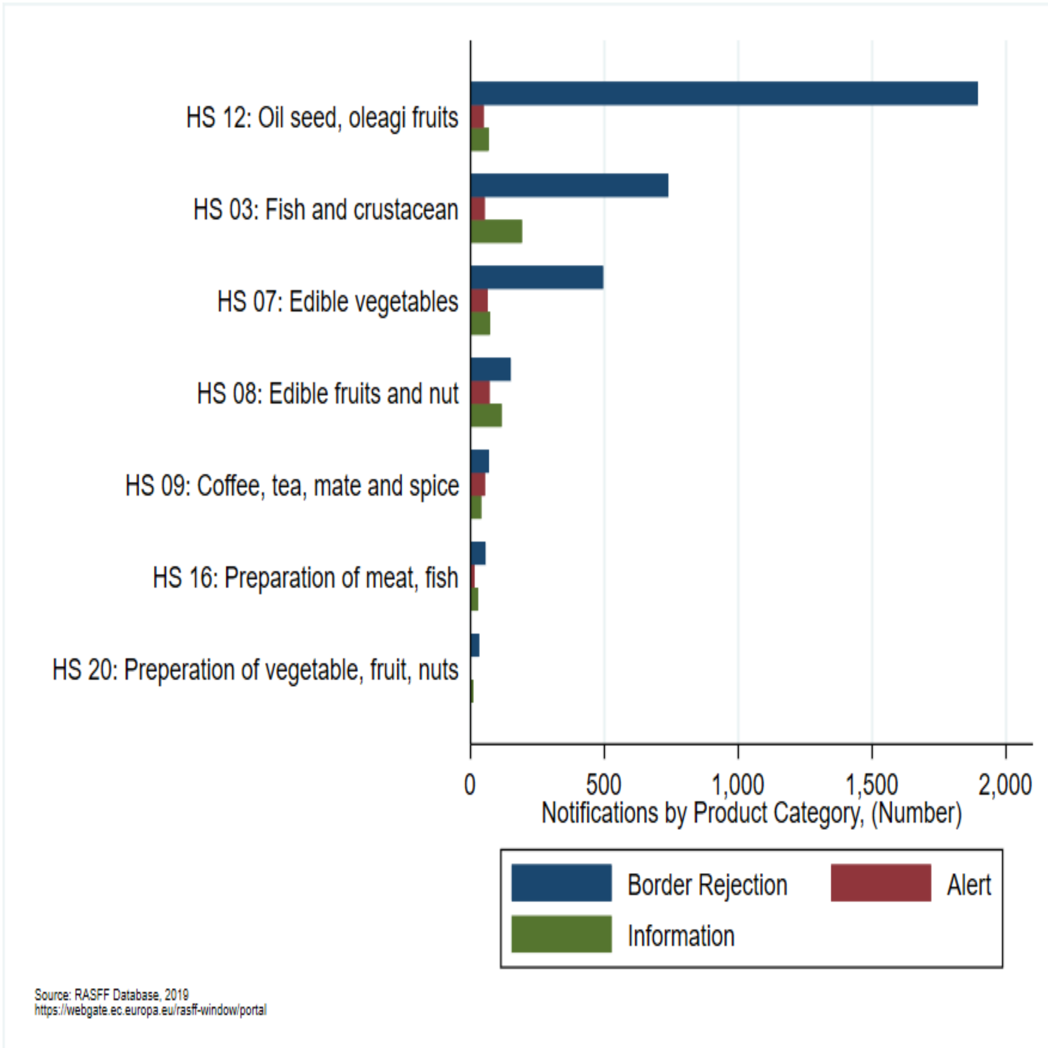

FIGURE 3.2 – Notifications by Product Category, 2008-2019

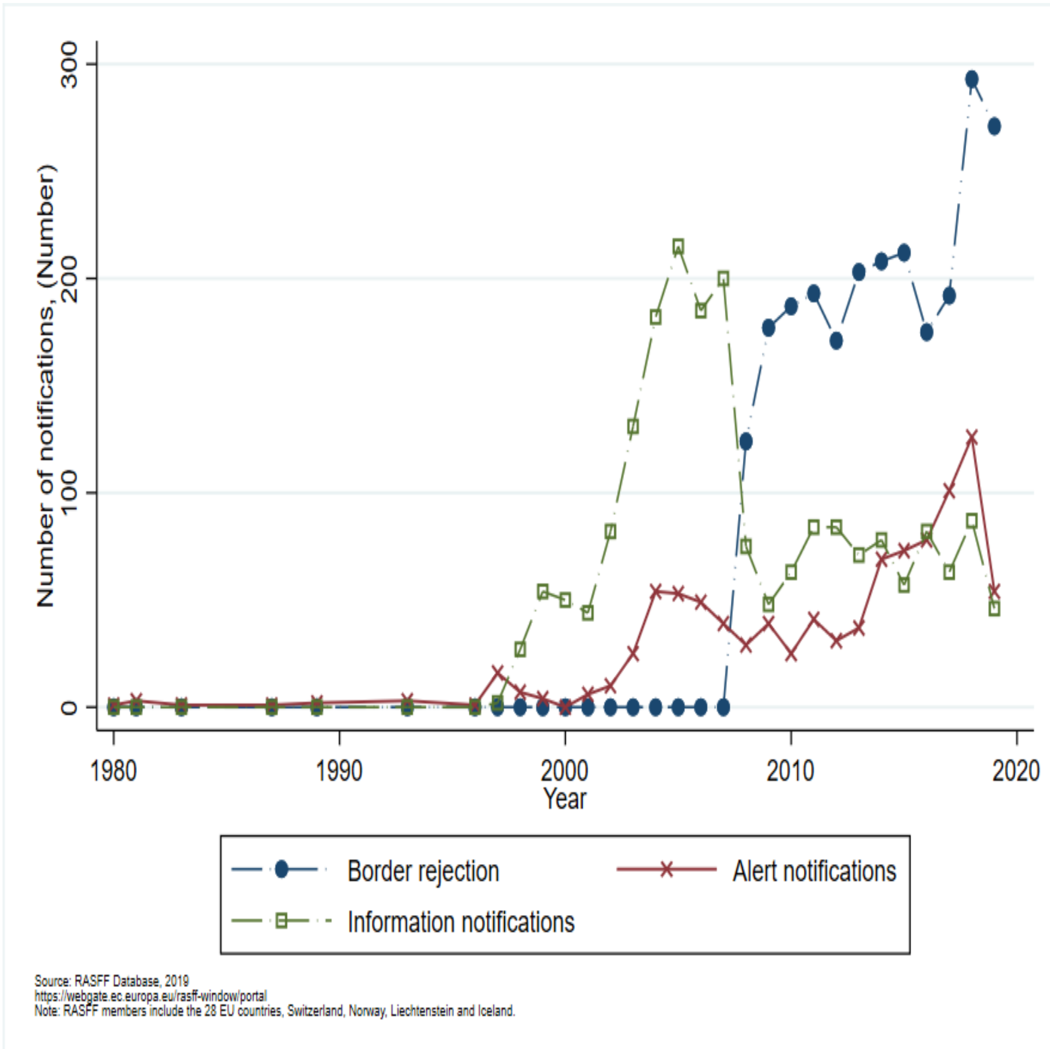

FIGURE 3.3 – Evolution of RASFF notifications affecting Africa

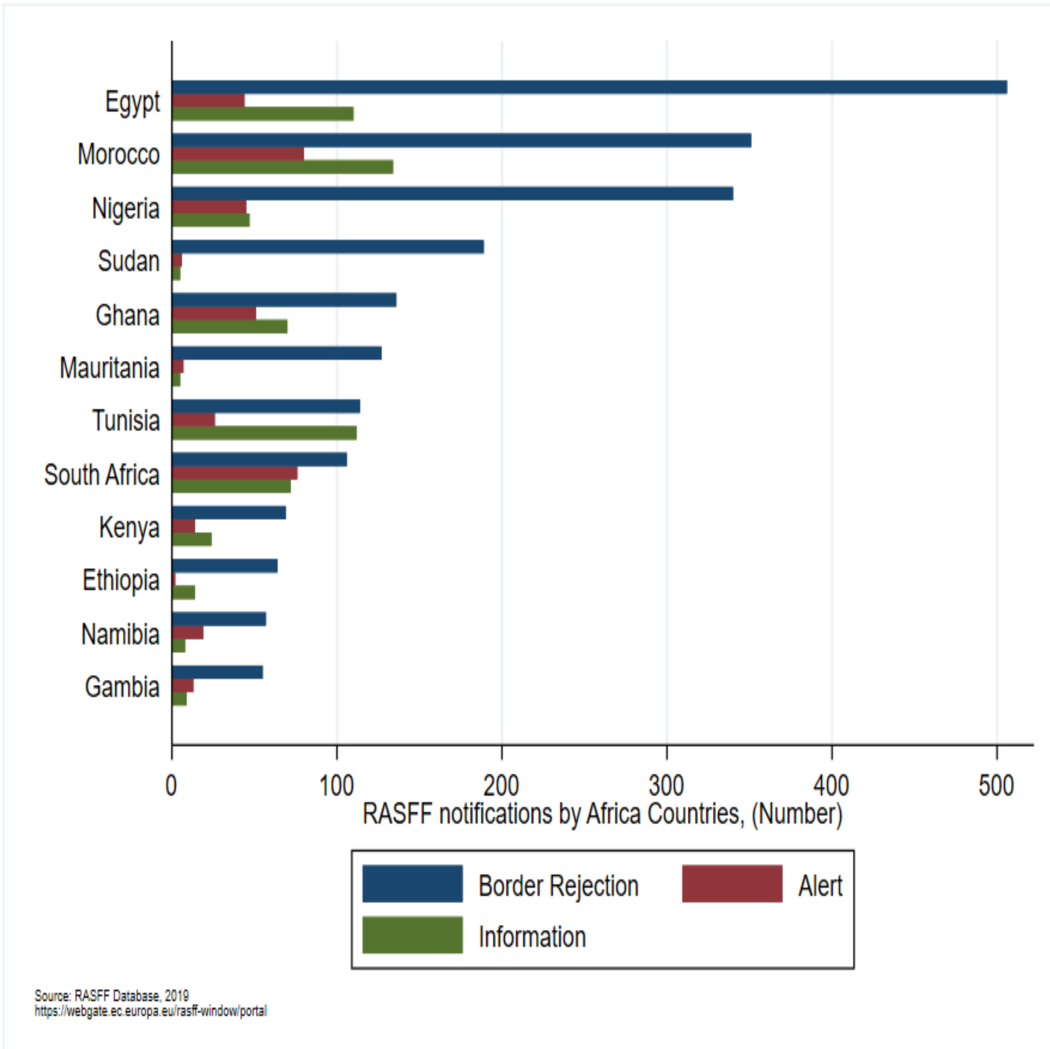

FIGURE 3.4 – RASFF notifications by African Countries, 2008-2019

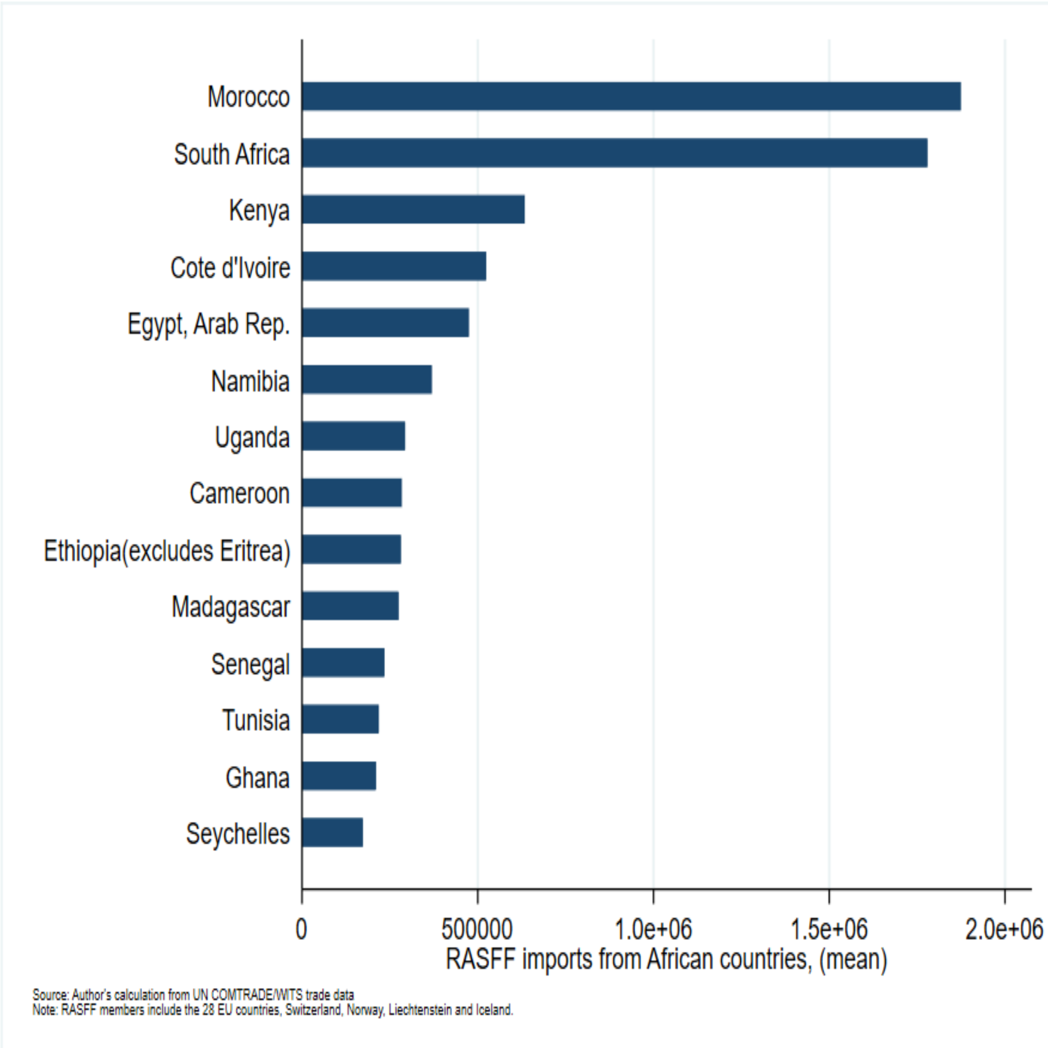

FIGURE 3.5 – RASFF imports by African country, 2008-18

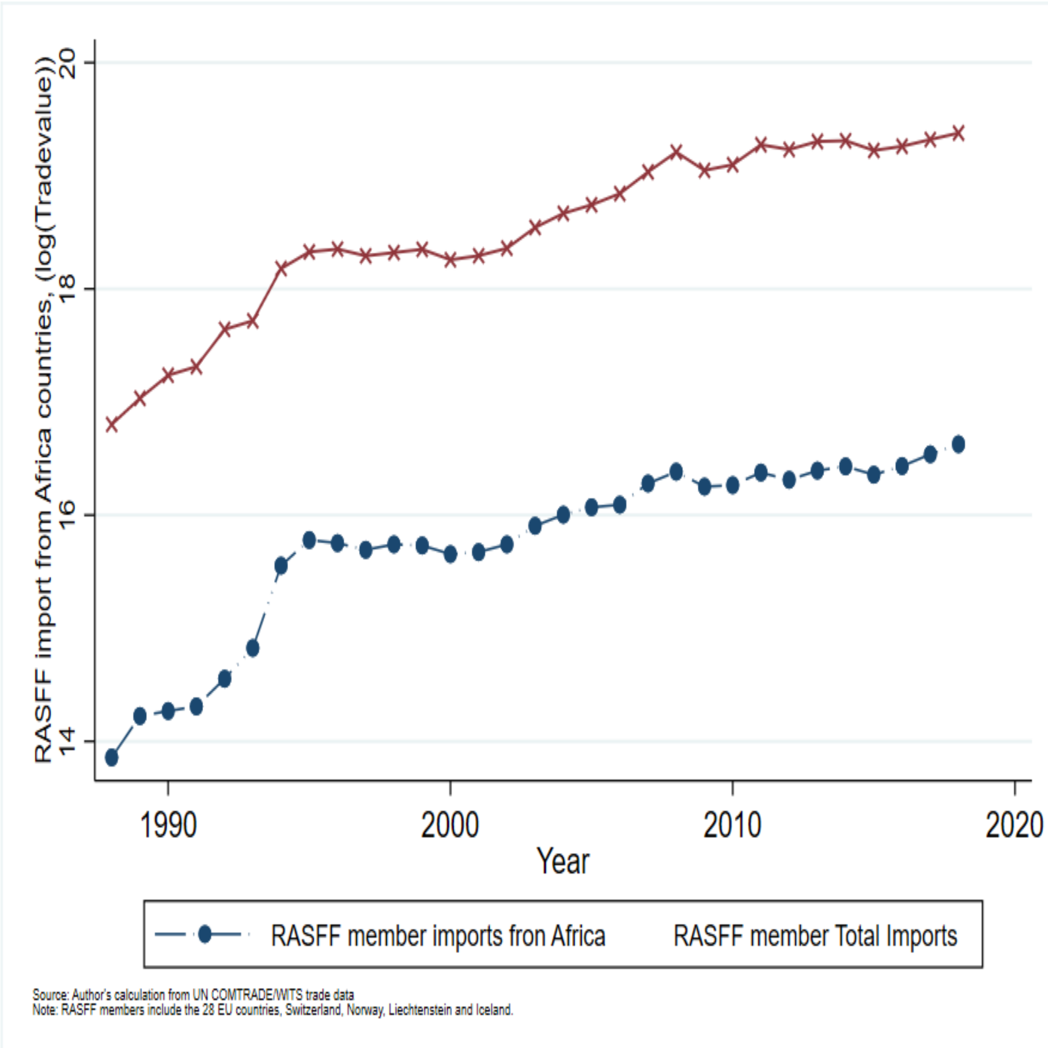

FIGURE 3.6 – Evolution of RASFF imports from African countries

Appendix B : Additional tables

TABLE 3.4 – List of exporting and importing countries

Exporters		Importers	
Algeria	Madagascar	Austria	Slovak Republic
Angola	Malawi	Belgium	Slovenia
Benin	Mali	Bulgaria	Spain
Botswana	Mauritania	Croatia	Sweden
Burkina Faso	Mauritius	Cyprus	Switzerland
Burundi	Morocco	Czech Republic	United Kingdom
Cameroon	Mozambique	Denmark	
Cape Verde	Namibia	Estonia	
Central African Republic	Niger	Finland	
Comoros	Nigeria	France	
Congo, Rep.	Rwanda	Germany	
Cote d'Ivoire	Sao Tome and Principe	Greece	
Djibouti	Senegal	Hungary	
Egypt, Arab Rep.	Seychelles	Iceland	
Ethiopia(excludes Eritrea)	Sierra Leone	Ireland	
Gabon	South Africa	Italy	
Gambia, The	Sudan	Latvia	
Ghana	Swaziland	Lithuania	
Guinea	Tanzania	Luxembourg	
Kenya	Togo	Malta	
Lesotho	Tunisia	Netherlands	
Uganda	Zambia	Norway	
Zimbabwe		Poland	
		Portugal	
		Romania	
		Slovak Republic	

TABLE 3.5 – List of products

HS Code	Description	Number
	HS-07 : Edible vegetables	
HS0701	Potato	-
HS0702	Tomato	-
HS0703	Bulb onion ; green onion ; bulb shallot, garlic ; leek,	-
HS0704	Cabblage ; cauliflower ; kohlrabi ; kale	-
HS0705	Lettuce(head) ; lettuce(leaf) ; chicory(tops) ; chicory(root) ;	-
HS0706	Carrot ; turnip(top) ; turnip(root),	-
HS0707	Cucumber ; gerkhin(west indian)	-
HS0708	Bean(haricot)	-
HS0709	Artichoke(globe) ; asparagus ; celery ; mushrooms ; truffles ; spinach	-
HS0714	Casava(manioc) ; arrowroot ; artichoke ; sweet potato ;	-
	HS-08 : Edible fruits and nut ; peel of citrus fruit or melon	
HS0801	Coconuts ; brazilnut ; cashewnut ;	-
HS0802	Almond ; hazelnut ; walnut ; chestnut ; pistachio ;	-
HS0803	Banana ; plantain ;	-
HS0804	Avocado ; date ; fig ; guava ; pineapples ; mango ; mangosteen	-
HS0805	Orange ; mandarin ; clementine ; lemon ; lime ; grapefruit ;	-
HS0806	Grape	-
HS0807	Watermelon ; papaya	-
HS0808	Apple ; pears ; quince	-
HS0809	Appricot ; cherry(black) ; peach ; nectarine ; plum prune ;	-
HS0810	Strawberry ; raspberry ; blackberry ; mulberry ; loganberry ; currant (black) ; currant (red/white) ; gooseberry ; cranberry	-
Total		**-**

Conclusion

L'objectif de cette thèse était d'analyser les implications économiques des MTNT en vigueur dans les pays développés sur le commerce international de produits agroalimentaires des pays Africains. De façon plus spécifique, nous avons traité trois questions principales. La première, plus générale, etait de mesurer et d'identifier les déterminants de l'effet net de l'ensemble des mesures techniques non tarifaires en vigueur dans les pays de l'OCDE sur les exportations Africaines de produits végétaux. La deuxième question, plus spécifique, cherchait à savoir quels sont les effets de la conformité aux LMR de pesticides sur la production, l'offre d'exportation et la demande d'importation d'un produit précis. Finalement, la troisième question a consisté à déterminer quel est l'impact des rejets de produits à la frontière des pays Européens du reseau RASFF sur les exportations Africaines de produits végétaux.

Nos résulats ont contribué à la littérature de façon théorique, méthodologique et empirique sur les implications des mesures techniques non tarifaires sur les échanges bilatéraux de produits agroalimentaires. Nous avons montré que l'effet net des MTNT sur le commerce bilatéral agrégé dépend non seulement de l'élasticité de substitution et de l'élasticité du coût marginal par rapport aux MTNT, mais aussi du paramètre de forme de la distribution des coûts marginaux qui dépend de la technologie. En plus, nous avons constaté que pour une élasticité de substitution donnée, seules les entreprises ou les pays caractérisés par un coût marginal inférieur à un coût marginal seuil et une productivité supérieure à un niveau de productivité seuil connaîtront un effet net positif du commerce vers une destination donnée. Dans le second essai, nous avons démêlé théoriquement et empiriquement les effets des LMR pour les pesticides sur la production, l'offre d'exportation et la demande d'importation. Nos résultats ont montré que les effets des LMR sur la production sont négatifs tandis que leurs effets nets sur le commerce bilatéral peuvent être positifs, nuls ou négatifs selon que l'effet de la qualité perçue par les consommateurs sur la demande d'importation est supérieur, égal ou inférieur à l'effet du coût de mise en conformité sur l'offre d'exportation. Dans le dernier essai, nous avons évalué les effets des refus d'importation des pays du RASFF sur les exportations africaines de fruits et légumes comestibles. Nos résultats ont montré qu'augmentation du nombre de refus d'importation par un pays du RASFF une fois dans l'année en cours entraîne une diminution du nombre de partenaires commerciaux en Europe pour les pays africains. En outre, nos résultats montrent qu'un refus d'importation supplémentaire diminue la valeur des exportations de légumes comestibles des pays africains. Cependant, nous constatons que les refus d'importation des pays du RASFF une fois dans l'année en cours entraînent une augmentation de la valeur des exportations de fruits comestibles des pays africains. Par ailleurs, nos résultats valident explicitement l'hypothèse d'endogénéité du nombre de refus d'importation et mettent en évidence les effets directs et les effets de contagion des rejets aux frontières. Ce dernier résultat signifie qu'une augmentation du nombre de rejets à la frontière d'un produit donné au cours d'une année précédente entraîne une augmentation du nombre de rejets à la frontière pour ce produit et les produits voisins au cours de l'année suivante.

Ensemble, les resultats de cette thèse permettent de souligner que les MNT en vigueur dans les pays membres de l'OCDE constituent des obstacles pour les exportateurs africains de produits végétaux. Ensuite, les résultats indiquent que le renforcement ou l'imposition de LMR strictes pour les pesticides dans les pays développés favorisent les échanges commerciaux alors qu'ils entravent fortement la production dans les pays africains. Finalement, le problème de conformité des produits aux normes de qualité et de sécurité sanitaire des aliments de l'UE, se traduisant par les coûts élevés de mise en conformité et le nombre croissant de refus d'importations en provenance des pays africains, réduit le nombre de partenaires et les flux commerciaux entre les pays africains et les membres européens du réseau RASFF.