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ARTICLE

The Issues of Zero Values in Trade Data and Modelling

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ARTICLE INFO

Article history
Received: 11 March 2019
Accepted: 17 March 2019
Published Online: 31 March 2019

Keywords:
Trade statistics
Gravity modeling
Theoretical framework
Zero trade

ABSTRACT

International trade provides a channel with which the interaction, integration and partnership of countries can be attained and/or established. Despite the relevance of trade to national, regional and global economies, the documentation of these economic activities is sometimes inadequate such that it brings to question the validity of the generated data. Empirical scholars often find it difficult to analyze trade statistics with zero-trade values, especially in terms of finding the natural logarithm. Researchers often deal with the zero trade statistics by employing the truncation method or censoring method. However, this has consequences for empirical analysis and policy formulation because there is information in the zero-value trade that will be lost if they are truncated from the dataset. Hence, the main challenge in the literature is the issue of the most appropriate and efficient empirical strategy for solving the problem of zero-trade values among available options. This has led to controversy in the literature with several proofs and reproofs, actions and reaction as well as counter-reaction. It is on this basis that this paper is situated to review the raging controversy on the solution to the consideration of zero values in trade statistics as applicable to positive trade analysis and/or modelling.

1. Introduction

International trade has been a veritable avenue with which countries can interact and integrate. It provides a channel for bilateral, regional and multilateral trade relationships among countries such that it has the propensity to reduce unemployment and poverty as well as propel economic growth. It could also be the mechanism with which country can attain sustainable development goals. Despite the importance of trade to national, regional and global economies, the documentation and reporting of this economic activity are sometimes inadequate and porous/spurious such that it brings to question the validity of the generated statistic. One of the problems is the documentation/reporting of the activities that constitute the aggregate trade data and/or statistics. While most trade statistics are given/provided in aggregate, however, the aggregation of the economic activities that constituted trade is sometimes complicated. Besides, the issue of double counting and value addition surface, which if not properly identified, handled and documented could lead to the porosity and/or spuriousity of the generated trade statistics.

Beyond this, the aggregate trade statistics are often prone and/or ravage with a lot zero values and this is often

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DOI: https://doi.org/10.30564/mmpp.v1i1.749

pervasive in disaggregated product's data. Many a time, the provider/producer of the trade statistics/data often do not report and/or include the zero values in the dataset that arise due to the temporary absence of exporter/importers in the market or because of low-value trade or owing to both demand and supply constraints. Thus, the data producers usually drop-off the zero values and near-zero values due to the disappearing of some trading partners. This is done because the values of the trade are too small to report and thereby are negligible. Furthermore, empirical scholars often find it difficult to analyze trade statistics with zero-trade values, especially in terms of finding the natural logarithm. These scholars often deal with the zeroes trade statistics by employing the truncation method where the zero trade observations are deleted completely from the trade matrix, or censoring method where the zeros are substituted by a small positive constant, an arbitrarily small value. However, [1, 2, 3, 4] posit that these methods are arbitrary, are without any strong theoretical or empirical justification and can distort the results significantly, leading to inconsistent findings. In addition, [5] posits that if the zeros are not random, deleting can lead to loss of information; while including arbitrary constants to the zero observations are tantamount to deliberately introducing measurement error which can lead to selection bias.

However, this has implication and consequences for trade analysis, policy formulation, and implementation because there is information in the zero-value trade that will be lost if they are neglected and truncated from the dataset. Technically, it leads to selection bias that could affect the outcome of the analysis done afterwards. Trade scholars have acknowledged the importance of zero trade statistics to policy making and sustainable development. The 'New' New Trade Theory asserts the importance of the zero-trade value in the context of the probability of trading. The theory postulates that the selection bias that arises due to the truncation of zero trade values could lead to loss of information in the data. Besides, [6] (hereafter known as HMR) have comprehensively investigated this issue in the light of its implication on trade policy. HMR shows that non-consideration of zero trade means the neglection of the probability of trading (extensive margin of trade) which can be very relevant for the trading partners.

Thus, having presented the issue surrounding trade statistics, the challenge in the literature is how to consider the zero-trade values in the empirical strategies of trade analyses. Because earlier trade models did not consider this issue, this initially made it a challenge in positive trade analyses. However, there are some scholars that have provided solutions to the issue, which gave credence to the fact that the consideration of zero value trade in positive trade analyses and strategies is no longer a problem. The main challenge in the literature is the issue of the most appropriate and efficient empirical strategy for solving the problem of zero-trade values among available options. This has led to controversy in the literature with several proofs and reproofs, actions and reaction as well as counter-reaction. It is on this basis that this paper is situated to review the raging controversy on the solution to the consideration of zero values in trade statistics as applicable to positive trade analysis and/or modelling.

2. The Motivation

The characteristics of trade statistics go beyond the presentation of the direction of trade, terms and balance of trade, countries' import/export base and major traded products; it is also input in scientific trade analyses and empirical strategies. The zero trade statistics might seem not informative in normative trade analysis sense but are highly considered in positive trade analysis because of the embedded information that could be essential for policymakers, and thereby the government. To this end, the empirical issue in this regard is the best empirical strategy in the presence of zero trade statistics, which is the basis for this paper; to review the issues on the appropriate empirical strategy when zero values are present in trade statistics. This paper reviews the debate with respect to the contributions of scholars to the frontier of knowledge in the area.

This paper departs from the work of [7] that examines different ways by which the gravity models could be specified and provided a workhorse or toolkit for gravity modelling in trade in goods and beyond. Specifically, this study focuses on the review of the issue surrounding the scientific use of zero trade statistics for an informed and evidence-based trade policy. Similar to [7] was the evaluation of the appropriate gravity model specification by [8] that identified three common mistakes in gravity modelling in the literature, in which they gave each mistake a 'medal'. [9] reviews the modelling of non-tariff barriers with gravity models and the computed general equilibrium model (CGE) as well as the different conclusions in the literature. The focus of his paper was not to investigate issues arising from the inclusion of zero value in empirical trade analysis.

[10] theoretically derived gravity equation from Heckscher – Ohlin (H-O) and the Increasing Returns to Scale (IRS) trade theories. They concluded that only a few productions are perfectly specialized as a result of the differences in factor endowments and that the increasing returns to scale cause perfect product specialization and the gravity equation, while the extent of imperfection in pro-

 DOI: https://doi.org/10.30564/mmpp.v1i1.749

duction across countries gives support for the HO and IRS models. Basically, the paper evaluated and derived the gravity model from these theories, while also determining the reason behind the variation in international production patterns and trade volume. However, this is not the focus of our study, which reviews the issue of zero trade empirical strategy in the literature. A theoretical contribution was made recently by [11] when he explains the roles of economic size and distance in a gravity model. He confirms the fact that the size distribution of the firms is empirically well approximated by [12] law and finds a piece of new evidence that larger firms export over longer distances than smaller ones. His explanation for the role of economic size is not new but confirms existing facts, however, innovation was brought in through the role of distance in a gravity model. He asserted that if the distribution of firm size is Pareto, and if the average distance squared of a firm's exports is an increasing power function of its size, then the distance elasticity of trade is constant and equals -1 in the special case of Zipf's law. This article gave a theoretical validation to the coefficient and sign of distance in the gravity model but did not consider zero trade and other specification issues as we have done in this survey. [13] show the extent to which some of the issues raised 50-year ago by Tinbergen have been the step stones of research agenda over the years. The paper also discusses how many of the empirical and theoretical contributions that followed [14] has dealt with the old problems, among which are the issue of zero trade specification and estimation that the study reviews in one of the sub-sections. However, among the studies reviewed, recent studies such as [15, 6] etc., were not considered and their contributions to the discussion on the specification of gravity models in the presence of zero trade were not included. This might be due to the coverage period of the paper, but our paper has put these studies into consideration for review. More so, our paper actually focuses on the specification and estimation issues in trade gravity modelling, particularly the raging debate right from the thought-provoking work of [16] on the best estimator of the gravity model in the presence of zero trade. The conclusion of [13] was that Heckman two-step procedure and count data modelling were the two main strategies for dealing with the zero trade, however, some criticisms have been levelled against the estimator (see [16, 6, 15]), which our paper considered and reviewed.

[17] examine the state of the art in gravity modelling, especially that relates to the non-tariff measures. The paper reviewed gravity models estimation techniques such as the Heckman, Poisson, Negative Binomial and the Zero-Inflated models as a possible solution to the estimation problems in the log-normal gravity equation. They concluded that the Zero-Inflated Negative Binomial Poisson Maximum Likelihood (ZINBPML) regression supersedes other estimators, especially Heckman procedure. However, the study did not consider the feasible generalized least square (FGLS) as proposed by [15], the Gamma Pseudo Maximum Likelihood (GPML) of [18] and [19] non – linear least square. Besides, there are other gravity model estimators like the Tobit model as used by [20, 21, 22] that need to be adequately considered before making the conclusion. More so, the choice of ZINBPML needs to be evaluated in the presence of model misspecification as argued by [23], which makes it inconsistent. All these arguments and counter-arguments in the literature are reviewed, which is our focus in this study, to bring to the fore the ongoing debate and current research on the estimation of zero trade statistics in gravity models.

Similarly, [24] surveyed gravity literature with respect to the specifications and estimation techniques. He proceeded to test for the most appropriate estimator using trade data for 80 countries that accounted for 80% of world trade. The conclusion of the study gave credence to the efficacy of Heckman sample selection model among other estimators. The difference in his study and this present comprehensive review of the literature on zero trade estimation is that his study excluded the Negative Binomial Pseudo Maximum Likelihood and the Zero-Inflated Models among the most recently used gravity model with zeros estimators as was considered in our paper. Note that this study does not perform any empirical estimation to compare and select the best estimator. The identification of the most appropriate estimator is not the focus of the paper, but to review the recent development in the zero-trade statistics gravity model literature, in terms of the specification and estimation of the models. This will enable users and prospective users of these empirical strategies to know the pros and cons of the estimators and provide them with estimation options that they can choose from in line with their research questions and the available trade data.

3. The Context

More appropriate empirical techniques are increasingly employed to deal with the estimation challenges posed by the logarithm transformation and zero trade flows issues in the context of gravity trade literature. The models proposed by [25, 5, 6] have all been used to deal with the problem associated with zero value trade flows. For instance, the Tobit model was employed by [22, 26] to deal with the problem of zero trade statistics which resulted either because the actual trade flows are not observable or due to measurement errors from rounding. However, several

DOI: https://doi.org/10.30564/mmpp.v1i1.749

studies, notable among them is [3] have argued that the appropriateness of using the Tobit model to estimate zero valued trade flows in a gravity model depends on whether rounding up of trade flows is important or whether the desired trade could be negative. They posit that the desired trade cannot be negative since the zeros do not reflect unobservable trade flows; therefore, one cannot censor trade flows from below it. Likewise, sample selection models were developed by [5, 6] H to deal with selection bias resulting from the non-random elimination of zeros from the trade matrix. The sample selection models have also been criticized because it is difficult to satisfy the exclusion restriction. Further, [27, 28] show that [6] model does not control for heteroscedasticity which is usually pervasive in most trade data, consequently casting doubts on the validity of inferences drawn from the model.

More so, the influential paper by [16] suggest that nonlinear estimators, precisely the Poisson pseudo maximum likelihood (PPML) should be used to deal with the zero trade observations as it provides unbiased and consistent estimates that are robust to the presence of heteroscedasticity in the data and naturally take care of the zero observations of the dependent variable. This influential work of [16] has generated a lot of debates in the literature. The debate centred on the appropriateness of the PPML as the best estimator of the gravity model in the presence of zero trade, as advocated by [16]. This assertion was contested and faulted, in which alternative estimation techniques have been proposed to accommodate zero trade values in the data [c.f. 4, 15, 6, 21]. In the effort of these studies to identify the best performing estimator, alternative estimation techniques were compared, however, they obtained divergent outcomes. This has further led to a rise in the debate in the literature about which of the different alternative estimators performs best. For instance, [16] propose the usage of the PPML as against the usual OLS technique, with the justification that it is consistent in the presence of heteroscedasticity and deals naturally with the zero trade flows. However, [15] found that, although the PPML is less affected by heteroscedastic compared to other estimators, nevertheless, the PPML estimator proposed by Santos Silva and Tenreyro (2006) is not always the best estimator as its estimates are outperformed by both the OLS and FGLS estimates in out of sample forecast.

In response to this, [29] posit that although the other estimators might outperform the PPML in some cases, however, the PPML should be a benchmark against which other alternative estimators be compared due to its identified advantages. Study by [4] has also challenged that of [16] with the fact that PPML is vulnerable to the problem of over-dispersion in the dependent variable and excessive zeros and propose the use of the Negative Binomial Pseudo Maximum Likelihood (NBPML) to correct for the over-dispersion in the dependent variable. In addition, they also found PPML and NBPML to be inconsistent in the presence of excessive zero trade observations and propose the usage of the Zero-inflated models which are Zero-inflated Pseudo Maximum Likelihood technique (ZIPML) and Zero-inflated Binomial Pseudo Maximum Likelihood technique (NIBPML) as they are noted to be consistent in the presence of excessive zeros. A similar result has been found by [15, 21], with the latter claiming that the Heckman model is appropriate for dealing with this issue. Therefore, these raging arguments and counter-arguments in the literature are the focus of this paper to bring to the fore the recent development in the empirical strategies of zero trade statistics.

4. The New 'New' Trade Theory

The theoretical framework for the consideration of imperfect competition and increasing returns to scale in international trade is traced to [30] which formed the basis for the new trade theory. However, after more than two decades, a new theoretical framework emerges that incorporated trade costs and firm heterogeneous behaviour – zero trade statistics into the empirical strategies. The studies of [31, 32, 6] are deemed to be influential here.

A new theoretical framework that was spearheaded by [32, 33] introduced a methodological issue that is associated with the presence and behaviour of heterogeneous firms operating in the international markets. Firm heterogeneity arises since not all existing firms in country exports; only a minority of these firms participate in the international market [33, 34]. Furthermore, not all exporting firms export to all the countries in the world; they are only active in just a subset of countries and may choose not to sell specific products to specific markets (or their inability to do so). The reason for the heterogeneity in firm behaviour is because fixed costs are market specific and higher for international trade than for domestic markets. Thus, only the most productive firms can cover these costs, and firms' inability to exports may be due to the high cost involved. Consequently, the bilateral trade flows matrix will not be full as many cells will have zero entries. This case is seen at the aggregated level of bilateral trade flows statistics but more often and obvious in greater proportion at the product disaggregation level such as the HS6 and HS8 product classification.

The prevalence of zero bilateral trade flows has important implication for trade empirical strategy such as the modelling of the gravity equation - as zero trade between several country-pairs might signal a selection bias prob-

 DOI: https://doi.org/10.30564/mmpp.v1i1.749

lem. In addition, the observed zeros might contain important information about the countries (such as why they are not trading) which should be exploited for efficient estimation. Thus, more recent waves of theoretical contribution relate to incorporating the firm heterogeneity into the empirical strategy, hence the development of an influx of estimation techniques that would take care of the zero trade statistics. Standard gravity model usually neglects the issue of the prevalence of zero bilateral trade flows and predict theory consistent with only positive bilateral trade flows. However, [6, 35, 36] derived the theoretical gravity equation which highlights the presences of zero trade statistics and gives theoretical interpretations for them. The new 'new' trade theory of international trade with firm heterogeneity that is spear-headed by [31] is usually adopted in giving the gravity equation theoretical basis.

[6] argue that "by disregarding countries that do not trade with each other, these studies give up important information contained in the data", and that symmetric relationship imposed by the standard gravity model biases the estimates as it is inconsistent with the data. To correct for this bias, [6] provides a theoretical gravity equation that incorporates firm heterogeneity and positive asymmetric and was thus, able to predict both positive and zero trade flows between country-pairs. Given firm-level heterogeneity, they assume products are differentiated and firms are faced with both fixed and variable costs of exporting. Firms vary by productivity, such that only the more productive firms find it profitable to export; with the profitability of exports varying by destination. Since not all firms found it profitable, this gives rise to positive and zero trade flows across country-pairs. Furthermore, this difference in productivity gives rise to asymmetric positive trade flows in both directions for some pairs of countries. This positive asymmetric trade and zero bilateral trade flows then determine the extensive margin of trade flows (number of prospective firms). Moreover, given that firms in country 'j' are not productive enough to enable them profitable to export to country i, this implies that there will be zero trade flows from country j to i for some pairs of countries. This generates a model of firm heterogeneity that predicts zero trade flow from countries j to i but positive exports from country i to j for some pairs of countries, and zero bilateral trade flows between countries in both directions.

Sequent to [6] some scholars have empirically incorporated firm heterogeneity [11, 34, 37]. For instance, [38] derives an industry level gravity equation using a model that assumes firm level heterogeneous productivity across firms and fixed costs of exporting. [37] however, argued that apart from variations in trade costs across industries, industry-specific elasticities of substitution are also important in capturing the cross-industry variations. Thus, they derive a model that allows for both industries specific bilateral trade costs and industry-specific elasticities of substitution. Employing the monopolistic competition framework used in [32] that allows for only heterogeneous cross-country trade costs, they also included heterogeneous elasticities of substitution across industries in the model and generate a micro-founded gravity equation of bilateral trade flows that controls for cross-industry heterogeneity but nets out multilateral resistance terms.

5. The Contending Issues

Early empirical studies rely on the economic framework of cross-sectional gravity model analysis for the trade statistics [40, 41, 42, 43, 44]. For such cross-sectional analysis, the ordinary least square (OLS) estimation technique or pooled OLS technique is normally employed. However, the traditional cross-sectional approach is affected by severe misspecification problems and thus, previous estimates are likely to be unreliable [45]. This is because, the traditional cross-sectional gravity model usually includes time-invariant variables (e.g. distance, common language, historical and cultural dummies, border effects), but the model suffers from misspecification problems as it fails to account for country-specific time-invariant unobservable effects. This unobservable country-specific time-invariant determinants of trade are therefore captured by the error term. These unobserved variables are likely to be correlated with observed regressors and since OLS technique is usually used, this renders the least square estimator to be inconsistent, which makes one of its classical assumptions invalid. In addition, OLS does not control for heterogeneity among the individual countries, which has the potential of resulting in estimation bias as the estimated parameters may vary depending on the countries considered. Therefore, estimating cross-sectional formulation without the inclusion of these country-specific unobservable effects gives a biased estimate of the intended effects on trade. This renders the conclusions on cross sectional-based trade statistics estimates problematic (ibid).

Thus, over the last decade, there has been an increasing use of panel trade data statistics in gravity modelling and in the panel econometric [46, 47, 48, 49, 50, 51]. The panel specification is much more adequate, as the extra time series data points give more degree of freedom, results in more accurate estimates. A unique advantage of panel data is that the panel framework allows the modelling of the evolvement of variables through time and space, which helps in controlling for omitted variables in form of unobserved heterogeneity, which if not accounted for can cause

  DOI: https://doi.org/10.30564/mmpp.v1i1.749

omitted variable bias [52]. In addition, with panel data, the time-invariant unobserved trade effects can easily be modelled by including country-specific effects such as countries and time dummies and thus avoiding the consistency issue mentioned above.

With the availability of panel trade data analysis, the two common techniques used in fitting the data are the fixed effects and random effect estimation techniques, where the choice between the two hinges on their a priori assumptions. The fixed effect assumes that the unobserved heterogeneity is correlated with the error term. In contrast, the random effect assumes that the unobserved heterogeneity is strictly exogenous i.e. it does not impose any correlation between the unobserved heterogeneity (individual effects) and the regressors. Under the null hypothesis of zero correlation, the random effect model is efficient; both models are consistent, but the random model is more consistent. If, however, the null hypothesis is rejected, the fixed effect is consistent and the random effect is neither consistent nor efficient. There are, however, some drawbacks in the fixed effect model in the sense that all time-invariant explanatory variables (are deemed to be perfectly collinear with the fixed effects) would be dropped from the model. Consequently, the fixed effect model eliminates some important theoretically relevant variables from the trade gravity model which is distance, common language, common borders, and the effects of these variables cannot be established. In addition, studies have also applied the OLS technique to panel data. However, pooled OLS can only give precise estimators and test statistics with more power if the relationship between the dependent variable and the regressors remain constant over time.

Early gravity model empirical strategy was to estimate the model by least squares, where the model is usually log linearized as a common practice. Their position is that the validity of a log-linear trade gravity model hinges on the homoscedastic assumption, as the error term must be statistically independent of the regressors. However, in recent times, [16] have identified flaws with this practice. Their position is that due to the nature of trade statistics that are intrinsic to heteroscedasticity and pervasive zero trade observations, log-linearizing the gravity equation and then applying OLS is problematic.

First, problems arise in logarithmic transformation due to heteroscedasticity, which is usually present in trade data. As noted by [16] in their influential paper, the common practice of log-linearizing the gravity equation and then estimating using OLS is inappropriate because, the expected values of the log-linearized error term will depend on the covariates of the regression, and hence, OLS will be inconsistent even if all observations of the dependent variables are strictly positive. This is because the logarithmic transformation of the gravity model changes the property of the error term. In other words, OLS will produce consistent estimates as long as the error term (ε_{ij}) of the log-linear specification $(\ln \varepsilon_{ij})$ is a linear function of the regressors, i.e., if $E[\ln(\varepsilon_{ijt} \mid x_{ijt})] = 0$, which is the homoscedasticity assumption. However, logarithmic transformation generates estimates of $E(\ln \varepsilon_{ij})$ and not $\ln E(\varepsilon_{ij})$, but where $\ln E(\varepsilon_{ijt} \mid x_{ijt}) = 0; E(\ln \varepsilon_{ijt} \mid x_{ijt}) \neq 0$, which is the well-known Jensen's inequality.

Consequently, due to Jansen's inequality, the error term (ε_{ijt}) is not equal to the log of the error term $(\ln \varepsilon_{ij})$ as the error terms in the log-linear specification of the gravity equation are not statistically independent of the regressors but are rather heteroskedastic, leading to inconsistent estimates of the elasticity coefficients. Given this Jansen's inequality, [16] argue that the log-linear transformation of the gravity model is intrinsic to heteroscedasticity. Thus, applying OLS results in biased and inefficient estimates. They argue that even though, economists have long known about Jensen's inequality and that the concavity of the logarithm function could create a download bias when employing OLS, this important drawback has, however, been overlooked in bilateral trade studies. They confirm their argument as they found evidence of the presence of heteroscedasticity and inconsistency in the normal log-linear representation of the gravity model; which renders the estimates of elasticity obtained from least squares estimation technique to be both inefficient and inconsistent.

Second and more importantly is the presence of zero trade statistics in the trade matrix and the appropriate estimation technique. While the Newtonian gravity theory from which the gravity model of trade was derived allows for very small gravitational force, but not zero force, however, in trade, there are frequent occurrences of zero-valued bilateral trade flows. The practice of estimating the log-linear gravity model in the presence of such zero trade flows implies both theoretical and methodological problems; especially in cases where the presence of such zero values are excessive. In estimating the gravity model, the gravity model is log-linearized and estimated using these linear regression techniques. However, given the predominance of zero trade statistics in the trade matrix, particularly at the more disaggregated level, where zero trade statistics can account for about 50% of trade flows, the logarithm transformation of the dependent variable is therefore problematic. This is so because the logarithm of zero is indeterminate or not feasible.

The common practice in the literature employed to deal with the problem of zero statistics in the data is the truncation and censoring methods and thereafter applying linear estimation techniques. In the case of truncation method, the zero-valued trade flows are dropped completely from the trade matrix, whereas, the censoring method involves substituting the zeros by a small positive arbitrary value. These methods are, however, arbitrary and are without any strong theoretical or empirical justification and can distort the results significantly, leading to inconsistent estimates [1, 2, , 3, 4, 53]. In addition, [1] show that the results are sensitive to (small) differences in the constant substituted, which can cause serious distortion in the results. [2] noted that deleting these zero values led to loss of information as important information on the zero trade levels is left out of the model and this can generate biased results if the zero trade flows are not randomly distributed; while [5, 6] posit that omitting these zero trade statistics can result in sample selection bias. The loss of information is said to reduce efficiency and omission of data produces biased estimates [54, 53]. In addition, [54] noted that deleting the zero trade observations prevents the possibility of exploring the extensive margin of trade – the creation of new bilateral trade relations. This implies that the estimates are conditioned on a trade that already took place – the intensive margin of trade. They concur that ignoring zeros limits the economic interpretation of the model as nothing can be said on the implication for a new trade.

Likewise, [3] kicked against truncating and censoring trade data by arguing that, zero trade observations may provide important information for understanding the bilateral trade patterns and therefore should not be eliminated a priori. Disregarding the zeros trade flows can bias the results if they do not randomly occur. This is because zero trade flows provided information about the probability to engage in bilateral trade. thus, if distance, low levels of GDP, the lack of historical or cultural links, etcetera, make trade to be non-profitable, thereby reducing trade or bringing about no trade, then eliminating zero flows from the analysis is tantamount to sample selection bias and applying OLS will lead to underestimating of the gravity equation coefficients (downward bias).

Therefore, in recent years, attention has been on the appropriateness of the estimation technique especially those relating to the problems of zero trade costs and logarithmic transformation of the gravity equation, and the constant emphasis on the inappropriateness of linear estimators in taking care of these two problems. Consequently, more appropriate estimation techniques are being increasingly employed to deal with these two issues in the context of gravity trade literature. The Tobit and Probit models, truncated regression, Poisson and modified Poisson models, Nonlinear Least Square (NLS), Feasible Generalized Least Square (FGLS) and the [6] approach have all been used to deal with the problem associated with log-normal formulation and the excessive zero trade statistics.

Early studies have relied on the Tobit model to deal with zero trade problems. For instance, the Tobit model has been employed by [55, 20] to deal with the problem of zero-valued trade flows that resulted either because the actual trade flows are not observable or due to measurement errors from rounding. The Tobit estimator is applied to fit dataset when outcome/data are only observable over some range. It is applied in cases of measurement errors (e.g rounding up) or when actual outcomes cannot seem to reflect the desired outcomes. The Tobit censoring method involves rounding (censoring) part of the observation to zero or rounding up the zero trade flows below some positive value.

Nevertheless, [3] have debated on the appropriateness of using the Tobit model to fit zero valued trade flows in a gravity model. However, the fitness of the Tobit model will depend on whether the desired trade could be negative or whether rounding up of trade flows is important. Their argument is that in the gravity model, the zero trade flows cannot be censored at zero as the desired trade cannot be negative in the gravity equation; this can only occur if the GDP of one or country pair is equal to zero which is unlikely in real life. They further argue that censoring at a positive value is not also appropriate. The intuition is that the UN COMTRADE data reports trade values, even for very small values (up to $1), indicating that rounding to zeros is not an important cause of zero observation as most zeros are caused by economic reasons such as lack of profitability. This implies that zero trade flows are likely to occur from binary decision-making about the profitability of engaging in trade, and not from rounding up (censoring), thus the model might not be appropriate for taking care of zero trade flows. In addition, [56, 55] noted that the Tobit estimator involves an artificial censoring of positive albeit small trade values, however, the trade flow is subject to measurement errors, and they may have a high influence on the regression results.

Furthermore, [21] Martin and Pham (2008) show that, although both truncated OLS and censored Tobit model lead to bias results but the censored method generally produced much worse results in comparison to the truncated method and suggested that [57] Eaton and Tamura (1994) threshold Tobit model gives the lowest bias and outperform all other estimators in a simulation exercise. However, in contrast, in a simulation exercise, [58] found the Tobit model of [57] has a large bias, which increases with sample

DOI: https://doi.org/10.30564/mmpp.v1i1.749

size, which also confirms its inconsistency as an estimator.

Attention has also been shifted to the use of the Poisson and the modified Poisson specifications of the gravity model. [16, 58] used the Poisson Pseudo Maximum Likelihood (PPML) method to deal with the zero-valued trade flow and the logarithm transformation. According to them, in the presence of zero-valued observations and due to the logarithm transformation of the gravity equation, OLS (both truncated and censored OLS) are inconsistent and have very a large bias which does not vanish as the sample size increase which confirms that they are inconsistent [58]. However, the PPML estimates the gravity equation in levels instead of taking its logarithms and this is said to avoid the problem posed by using OLS under logarithm transformation. According to them, this model is appropriate: first, the Poisson model takes account of observed heterogeneity. Second, the fixed effects PPML estimation technique gives a natural way to deal with zero-valued trade flows because of its multiplicative form. Third, the method also avoids the under-prediction of large trade volumes and flows by generating estimates of trade flows and not the log of the trade flows. In their 2006 influential paper, they find the PPML estimator, which need not be log-linearized, to be the best performing estimator that naturally deal with zero trade flows, consistent and gives the lowest bias among the other estimators. They, therefore, suggest it as the new workhorse for the estimation of the typical constant elasticity models, such as the gravity model.

However, their influential paper has however generated some controversies in the literature [59, 21, 4]. For instance, [4] identified some important limitations of the PPML model. They noted that the model is vulnerable to the problem of over-dispersion in the dependent variable and excess zero trade flows. They posit that the model only takes account of observed heterogeneity and not unobserved ones and this is an important limitation of the PPML model. While an important condition of the PPML is the assumption of equidispersion (the conditional variance is equal to the conditional mean) in the dependent variable, however, due to the presence of unobserved heterogeneity which is not accounted for in the model, there is an overdispersion in the trade flows (dependent variable). The overdispersion is said to generate consistent but inefficient estimates of trade flow [4, 60].

Contrary to [4] who noted that the model is vulnerable to the problem of over-dispersion in the dependent variable and excess zero trade flows, which generate consistent but inefficient trade estimates, [58] find that PPML is consistent and generally well-behaved even in the presence of over-dispersion in the dependent variable (i.e. when the conditional variance is not equal to the conditional mean). Also, the predominance of a large proportion of zeros statistics does not affect its performance. In addition, [61] find that the PPML performs quite well under over-dispersion, and show that the PPML is well-behaved under bimodally distributed trade data.

Nonetheless, attempts have also been made to correct for the over-dispersion in the dependent variable and the vulnerability of the PPML to excessive zero trade flows using other estimation techniques apart from the PPML. These are the Negative Binomial Pseudo Maximum Likelihood (NBPML) and the Zero-inflated models which are Zero-inflated Pseudo Maximum Likelihood technique (ZIPML) and Zero-inflated Binomial Pseudo Maximum Likelihood technique (NIBPML) (Burger et al. 2009). They posit that the NBPML corrects for the over-dispersion, the estimator incorporates unobserved heterogeneity into the conditional mean and thus, takes care of unobserved heterogeneity. However, an important drawback of the NBPML and PPML relates to the excessive number of zero in the observation which means that the number of zero flows is greater than what the models predict where excessive zeros in trade statistics is said to be derived from the 'non-Poisson' of the model [62] (Johnson and Kotz, 1969). Thus, [4] posit that even though the Poisson model and the NBPML model can technically handle zero flows, both models are however not well suited to handle cases where the number of observed zero trade flows is greater than the number of zeros predicted by the model.

They posit that the zero-inflated models (ZIPPML and ZINBPML) perform better and correct for excess zeros and over-dispersion in the dependent variable. They also noted that zero-inflated models have an added advantage as they theoretically well suited in modeling the origin of zero counts because the models account for two different types of zero trade flows, which are countries that have never trade (the non-Poisson group), implying a data that strictly have zero counts; and countries that presently do not trade but potentially could, i.e. those that have a non-zero probability of having non-zero counts (the Poisson group). Thus, these models make allowances for the possibility to separate the probability to trade from trade volume as it provides additional information on the causes of the probability of the different kinds of zero-valued flows. Given these, [61] argued that the choice of the model to use will depend on whether the sample has excessive zero trade flow or not. However, [4] posit that the Poisson model and the NBPML model are not well suited to handle cases where the number of observed zero valued trade flows is greater than the number of zeros predicted by the model.

DOI: https://doi.org/10.30564/mmpp.v1i1.749

Contrary to [4, 23] however, find that the PPML is consistent even when zeros are excessive. They also show that both ZIPPML and ZINBPML are inconsistent if the underlying assumptions of the distribution of model are violated, i.e. if the models are misspecified. They instead recommend the use of zero-inflated Poisson Quasi-Likelihood (PQL) estimator which was shown to be consistent in the presence of excessive zeros and it is unaffected by unobserved heterogeneity and found to be robust to misspecification as it consistently estimate the regression coefficients irrespective of the true distribution of the counts while ZIPPML and ZINBPPML demonstrate considerable bias in medium sample. They also noted that the PQL can be less efficient compared to zero-inflated estimators if the zero-inflated model is correctly specified.

Similar to [4, 15] also find out that the PPML estimator proposed by Santos Silva and Tenreyro (2006) is not always the best estimator as its estimates are outperformed by both the OLS and FGLS estimates in out of sample forecast. In addition, the PPML assumption regarding the pattern of heteroscedasticity is rejected by the data in most cases. However, [29] responded by justifying the use of PPML as the best estimator in the context of the gravity model but also acknowledged that PPML estimator can be outperformed by other estimators in some cases.

Furthermore, [59] also find the PPML to be outperformed by both the OLS and FGLS estimates in out of sample forecast and deduced that it is not always the best estimator. They find that PPML assumption regarding the pattern of heteroscedasticity is rejected by the data in most cases. The study opined that even in the presence of an unknown form of heteroscedasticity, FGLS can still be applied, because as FGLS is an efficient estimator within the class of least squared estimators, but the variance of the disturbances should then be re-estimated to correct for heteroscedasticity errors. They pointed out that FGLS is well suited to estimating parameters in the presence of heteroscedasticity, so, the comparison of the best performing estimator should be between FGLS and the class of generalized linear models (GLM) such as the Non-linear least square (NLS), Gamma Poisson Maximum Likelihood (GPML), and PPML.

[15] compares the performance of different estimators via a Monte Carlo simulation exercise and find that although PPML to be less affected by heteroscedasticity compared to FGLS, NLS and GPML, nonetheless, its performance is found to be similar both in terms of bias and standard errors to the performance of the FGLS estimator. Particularly for small sample size; with the lowest bias and standard errors found in the GPML in the simulations which have non-zero values in the dependent variable. Further empirical analysis using three different real datasets reveal that the choice of the performance of the model is sensitive to the sample size; for small sample size, FGLS could be the perfect way to deal with the heteroscedasticity problem, while the PPML will be appropriate when the sample size is large and there is measurement error in the dependent variable. However, for a large sample size, PPML bias is found to decrease in large sample size while FGLS bias is found to remain almost constant. In addition, the PPML standard error falls considerably, but it remains twice the FGLS standard errors. Conclusively, [15] find that the choice of the best estimator is dependent on the specific dataset, and there is no generally best estimator for these three datasets; thus, the appropriate estimator for any application is data specific, which could be determined using a few models' selection tests.

[21] have also challenge [16] findings and posit that, although the PPML estimator is less subject to bias resulting from heteroscedasticity problem, however, it is not robust to the joint problems of zero trade flows and heteroscedasticity. Based on this, they conclude that the estimator could be appropriate for other multiplicative models which have relatively few zero observations. They proposed that the [57] threshold Tobit model perform better than the PPML and other estimators considered as it recorded the smallest bias in a simulation exercise.

The Monte Carlo simulation done by [15] has also generated some debates. Although the authors find that the PPML can deal with zero trade flows, interestingly, their simulation is done in order to determine the best performing model was without any zeros, except where the dependent variable was contaminated with measurement errors. This has made some studies to question the performance of the PPML in cases where there are excessive zeros in the dependent variable [15, 21]. [21] therefore used a data generation process different from that used by [16] which include a high proportion of zero values and show PPML to be highly vulnerable to bias in the presence of high percentage of zero values in the dependent variable. A similar result has been found by [15]. However, these results have been challenged by [58].

In response to these studies, [58] argued that both simulations were done by [59, 21] reveal no information on the performance of the PPML model of constant elasticity model as the data used in their simulation exercises are not generated by a constant elasticity model. [58] however, further investigate the performance of the PPML estimator when the dependent variable has a large percentage of zeros and when the data generating process is given by a constant elasticity model (both of which are typical in trade data used in gravity modelling). Similar to their

DOI: https://doi.org/10.30564/mmpp.v1i1.749

2006 findings, they also find the PPML estimator to be consistent and generally well-behaved in the presence of a high proportion of zeros, and to be more robust to departures from the heteroscedasticity assumption (over-dispersion); as its performance is not affected even with the over-dispersion in the dependent variable and the presence of excessive zero values.

Among the class of the generalized linear models, the Gamma Pseudo Maximum Likelihood (GPML) technique has also been used in taking care of the zero trade values and the associated problem of the logarithm transformation [18]. Like the log-linear model, the GMPL is said to be a more efficient estimator under the assumption that the conditional variance is a function of higher powers of the conditional mean, as it gives more weights to the conditional mean. [58] found that the GPML is consistent and well behaved under Monte Carlo simulation in the presence of excessive zero values whose data generation process follows the constant elasticity model. However, it is found to have a larger bias than the PPML, suggesting that the PPML is the best performing estimator [58]. In addition, [15] noted that the GPML may also suffer from substantial loss of precision, particularly, if the variance function is misspecified or if the log-scale residuals have high kurtosis.

Another class of the generalized linear model is the nonlinear least square (NLS) technique, which has also been used in the trade literature [19] or used in comparison with other non-linear estimators [16, 24, 15]. [16] however show that although both GPML and NLS can take care of these two problems, the PPML is still the preferred estimator as the NLS technique assigns more weight to noisier observations, which reduces the efficiency of the estimator. This is because, while PPML gives the same weights to all observations, and assumes that the conditional variance is proportional to the conditional mean, however, GPLM and NLS give more weights to observations with large mean. This is because the curvatures of the conditional mean are more pronounced here, which are also general observations with a large variance, implying nosier observations. In addition, ibid noted that the estimator can also be very inefficient because it generally ignores the heteroscedasticity in the data.

[5] sample selection model has also been frequently used in trade literature. Noting that the standard practice of excluding zero bilateral trade statistics can potentially give rise to sample selection bias, especially if the eliminated zeros are not randomly done, and estimating non-randomly selected sample is a specification error and can potentially bias the results. Heckman, therefore, developed a model that corrects for this sample selection bias which is a two-step statistical approach in which the model is estimated under the normality assumption. The first step of the Heckman model involves estimating an equation (Probit regression) for the probability of exporting at the firm level based on the decisions of the firms and then using it in estimating the volume of trade. [5] correction model allows one to correct for selection bias in non-randomly selected samples and has also been frequently used in the gravity model literature to correct for problems relating to zero-valued trade flows [3, 63]. [3] noted that the sample selection model uses the information provided by the zero-valued trade observations; thus, providing information on the underlying decision process regarding the zero trade flows, while arbitrary truncating and censoring are ad-hoc crude methods and they do not give accurate results compared to the sample selection model. They argued that unlike truncated OLS, without sound theoretical background, the samples election model is theoretically sound and offers an econometrically elegant solution to estimate the gravity equation that includes zero trade flows.

Further, in a methodological paper, [6] (thereafter HMR), noted that the estimation of bilateral trade flows using the gravity equation is not only subjected to sample selection bias (if the non-zero exports do not occur randomly), but that estimates may also be vulnerable to omitted variable bias if the number of exporting firms within an industry (extensive margin of trade) is not accounted for. The idea is that due to trade costs, firms differ in productivity (firm heterogeneity) and only firms with productivity level beyond a threshold end up exporting.

HMR, therefore, extended [5] procedure by controlling for both sample selection bias and firm heterogeneity bias and solve the zero problems by also developing a two-step estimation procedure which exploits the non-random presence of zero trade flows in the aggregate bilateral trade data. The aim of the HMR two-step procedure is to correct both the sample selection bias resulting from eliminating zero trade flows when estimating the logarithmic form of the gravity equation and the bias caused by unobserved firm heterogeneity that results from an omitted variable, which also measures the effect of the number of exporting firms (extensive margin). The first step involves estimating an equation (Probit regression) for the probability of exporting at the firm level based on the decisions of the firms and then using it in estimating the effects on the extensive margin of trade (the decision to export from country i to j). The second step is a gravity equation estimated in its logarithm form and involves using the predicted probabilities obtained in the first step to estimate the effects on the intensive margin of trade (the number of

 DOI: https://doi.org/10.30564/mmpp.v1i1.749

exporting firms from country i to j).

[6] posit that the excluded variable must not be correlated with the error term of the second stage equation but must be correlated with trade volume (the dependent variable). In addition, the excluded variable must have influenced trade through fixed trade cost and not through variable trade cost because of the latter impact on the extent of trade volume, and as such, is not uncorrelated with the second stage equation. However, [4] noted that one important drawback of the [5, 6] models is that, it is difficult to satisfy the exclusion restriction as the instrumental variable is most often difficult to find. Examples of exclusion variables used in the literature are common religion and common language variables [6]; governance indicators of regulatory quality [64]; historical frequency of positive trade between country pairs [3, 65, 66]. However, both [3, 65] include the excluded variable in both equations and impose the normality of the error term in the two equations – an identification condition implying a zero covariance between both equations.

Notwithstanding the advantages of the HMR, some other limitations have been identified regarding its application. Both the [5] and the HMR trade flow equations are usually transformed to the logarithmic form before estimated and might cause biased coefficient [67, 16]. In addition, [27, 28] also show that HMR does not control for heteroscedasticity which is usually pervasive in most trade data. For instance, [27] show that the assumption of homoscedasticity error term for all country pairs by the HMR results in serious misspecification as HMR does not control for heteroscedasticity, consequently casting doubts on the validity of inferences drawn from the model. They also pointed out that in contrast to models which can be made robust to the presence of heteroscedasticity, the consistency of the HMR model is only possible under the 'unrealistic' homoscedasticity assumption, which they identified as the most important drawback of the model as it is too strong to make it applicable or practicable to trade data in which heteroscedasticity is pervasive. They, therefore, posit that the presence of heteroscedasticity in the data preclude the estimation of any model that purports to identify the effects of the covariates in the intensive and

Table 1. The Zero Trade and Logarithmic Transformation in Gravity Modelling – A Summary of the Debate

Model/Estimator	Scholar	Characteristics/Merit	Criticism/Demerit	Response to Critics
Tobit	[20, 55, 21]	-To deal with the zero-trade problem due to unobservable trade flows or measurement error from rounding up. -Applied to fit dataset that is only observable over some range. -Applicable there is the difference between actual outcomes and desired outcomes.	-[3] opined that zero trade occurs due to binary decision making on the profitability of trade and not from censoring that the model posited, which makes it inappropriate to take care of the zero trade. -[56] argued that the estimator is liable to measurement errors, which will impact on the result due to the artificial censoring of positive small trade values. -In response to the position of [21, 58] find the threshold Tobit model to have a large bias that rise with sample size, which makes it an inconsistency estimator in a simulation exercise.	-[21] suggested the use of [57] threshold Tobit model that gives the lowest bias and outperform all other estimators in a simulation exercise.
Poisson Pseudo Maximum Likelihood (PPML)	[16, 29, 27, 58, 23].	-It is used to deal with the zero trade and logarithm transformation. -The gravity equation is specified at levels in order to avoid the problem that arose using OLS under logarithm transformation. -It takes into consideration observed heterogeneity; zero trade dealt with through the multiplicative form of the fixed effects in PPML and avoid under-prediction of large trade volume by generating estimates of trade flows rather than the log of trade flows. -Gives the lowest bias among estimators. -Proponents suggest the estimator as the workhorse for the gravity model.	-[21] argued that the model is vulnerable to over-dispersion in the dependent variable and excess zero flows. This only takes care of observed heterogeneity and unobserved ones. -The assumption of equidispersion in the dependent variable leads to overdispersion due to unobserved heterogeneity. -The overdispersion generates consistent but inefficient estimates of trade flows [21, 60, 15] opined that PPML is not always the best estimator as its estimates are outperformed by both OLS and FGLS estimates in out of sample forecast, so, it is not always the best estimator. -The PPML assumption regarding the pattern of heteroscedasticity is rejected by the data in most cases [15]. -[21] argue that PPML is not robust to the joint problems of zero trade and heteroscedasticity.	-[58] opined that despite the identified overdispersion and excessive zero trade problems, PPML is consistent and generally well-behaved in the presence of overdispersion in the dependent variable and large zero trade will not affect its performance. -[61] argued that PPML performs quite well under overdispersion, and show that the PPML is well-behaved under bimodally distributed trade data. -[29] responded by justifying the use of PPML as the best estimator in the gravity model but acknowledged that PPML estimator can be outperformed by other estimators in some cases. -PPML is consistent in the presence of excessive trade zero [23]. -[58] responded to the critics of PPML arguing that the studies of the critics of PPML did not generate its data through a constant elasticity model, with which their study did. -Also, [58] re-investigate the performance of PPML in the presence of large zero trade data in a constant elasticity model. The results show that PPML estimator is consistent, well-behaved with large zero trade and not affected by overdispersion in the dependent variable.

DOI: https://doi.org/10.30564/mmpp.v1i1.749

Negative Binomial Pseudo Maximum Likelihood (NBPML) and Zero-Inflated Models e.g. Zero-Inflated Pseudo Maximum Likelihood (ZIPML) technique, Zero-Inflated Binomial Pseudo Maximum Likelihood (ZINBPML).	[21]	-To correct for the overdispersion in the dependent variable and the vulnerability of the PPML to excessive trade zero. -It incorporates unobserved heterogeneity into the conditional means and thus, takes care of unobserved heterogeneity.	-One of the drawbacks of NBPML and PPML is the excessive number of zero trade that is derived from the non-Poisson of the model [62]. -[60] argued that these estimation techniques cannot handle excessive zero. -[23] posit that both ZIPML and ZINBPML are inconsistent if the models are misspecified.	-[21] opined that even though the Poisson model and NBPML model can technically handle zero trade, however, both are not well positioned in the case where the number of observed zeros trade value is greater than the number of zero predicted by the model. -- The Zero-Inflated Models perform better as they corrected excessive zeros and overdispersion in the dependent variables. The models theoretically well situated in Poisson and non-Poisson estimation.
Zero-Inflated Poisson Quasi-Likelihood (ZINPQL)	[23]	-Consistent in the presence of excessive zero trade. -Unaffected by unobserved heterogeneity. -It is robust to misspecification as it consistently estimates the regression coefficients irrespective of the true distribution of the counts, while ZIPML and ZINBPML demonstrate considerable bias in the medium sample.	-ZINPQL can be less efficient compared to zero-inflated estimators when the zero-inflated models are correctly specified.	
FGLS and other generalized least square (GLM) e.g. Gamma Pseudo Maximum Likelihood (GPML), Non-Linear Least Square (NLS).	[59, 15] - FGLS, [18] – GPML, [19] –NLS.	-FGLS can be applied in the presence of an unknown form of heteroscedasticity. -It is an efficient estimator among the class of least square estimators. -The variance of the disturbances needs to be re-estimated to correct for heteroscedasticity errors. -The comparison of the best estimators should be between FGLS and other generalized least models (GLMs) such as; Non-linear least square (NLS), Gamma Poisson Maximum Likelihood (GPML) and PPML. -Gamma Pseudo Maximum Likelihood (GPML) techniques are more efficient under the assumption that the conditional variance depends on the higher power of the conditional mean, thus, given more weight to conditional mean. -NLS assigns more weight to noisier observations. -NLS is consistent in the modelling of zero. -NLS gives more weight to observations with large variance.	-[29] debunked the claim of FGLS proponents and provided justification for the PPML estimator in the context of the log-linear gravity model. -[58] found GMPL to be consistent and well-behaved under Monte Carlo simulation with excessive zero trade values in a constant elasticity model but has a larger bias than the PPML. -[15] argued that the GMPL may suffer from substantial loss of precision whenever the variance function is misspecified or when the log-scale residuals have high kurtosis. -NLS efficiency is reduced due to its allocation of more weight to noisier observation [16]. Also, NLS is inefficient because it generally ignores heteroscedasticity in the data.	[15] argued that the choice of the best estimator is a function of the dataset and there is no absolute best estimator for all typology of the dataset. Thus, the most appropriate estimator is data specific and could be determined by model selection tests.
Heckman Selection Model	[5, 3, 63].	-This model corrects for sample selection bias and specification error when zero trade does not occur randomly. -It is a two-step approach under the normality assumption: first, estimation of the probability of trade at the firm levels (probit regression), finally, using the first approach to estimate the volume of trade. -It has a theoretically sound method and offers an econometrically elegant solution. -Providing an avenue of using information from zero trade observation.	-[21]argued that in both Heckman and HMR models, it is difficult to satisfy the exclusion restriction because the instrumental variable is often difficult to find. -- The transformation of these models into logarithmic form before estimation might cause biased coefficient [67, 16]. -[28, 27]posited that these models did not control for heteroscedasticity that is pervasive in trade data.-	[3], 65 included the excluded variables and imposed the normality of the error term.
Extensive and Intensive Trade Margins Model	[6]	-It extended the Heckman model by controlling for both sample selection bias and firm heteroscedasticity. -It solves the zero-trade problem with a two-step estimation procedure. -It measures the effects of the number of exporting firms and volume of trade. -First, it estimates the probit regression for the probability of trading at the firm's levels (extensive margin). -Using the first stage estimation result to estimate the intensive trade margin. -It assumes homoscedasticity.		

Source: Author's Computation

extensive margins, at least with the current econometric technology [27].

In sum, as noted in the review, each technique has its pros and cons and the 'workhorse' or best performing model for the estimation of the gravity equation in the presence of zero trade statistics remains unclear as the consensus on a commonly accepted solution has not yet been reached. Therefore, given the pros and cons of each estimator, the determination of the best performing estimator when zero trade statistics are frequent remains an empirical issue.

6. Concluding Remarks

Trade statistics have become necessary in the development planning of countries, especially as it relates to trade policy and strategy that will fortify trade relations, integration, arrangements and/or agreements. The collation and reporting of these statistics are important to policy-making and planning that cut across national, regional and international. The appropriateness and inclusiveness of these statistics often propel a comprehensive strategy that considers both the competitive and less competitive firms, large and small firms as well as other heterogeneity in the trade sector. Consideration of only positive trade statistics by many of the sources and/or provider of trade statistics means that the heterogeneity of the firms is not considered, which would lead to loss of vital information in the analysis of the trade sector. To this end, this study evaluates trade statistics in the presence of zero trade values and the controversy with regard to the appropriate empirical strategy that can account for these zero trade values.

The empirical strategy of the gravity models has often been used to scientifically consider zero trade statistics in trade and trade policy analyses. The theoretical framework underpinning the empirical strategy of the gravity model is no longer in doubt among international economists. The gravity model is very useful in modelling bilateral, regional, plurilateral and multilateral economic relations. The equation can arise from a wide range of trade models; the standard, new and 'new' new trade theories. These theoretical options in the application of the models and specification of the equation would depend on the preferred set of assumptions and models. Differences are noticed in the underlying assumptions and models in gravity modelling, which could be due to the various specifications in the empirical studies. These often resulted in different outcomes and inferences for these studies.

Thus, this review, although do not claim to have exhausted all theoretical and empirical studies, has shown that the current emphasis in the theoretical literature is to ensure that empirical applications of gravity models is well rooted in its theoretical ground and that it can be linked to any one of the available and appropriate theoretical frameworks. The bottom line of this review is that each technique in the debate has its pros and cons as enunciated in this paper. Thus, the best performing estimator for the consideration of zero trade statistics in gravity models still remains an empirical issue as the consensus on a commonly accepted solution has not yet been reached. Therefore, given these merits and demerit of each estimator, the empirical analysis of the zero trade statistics in the gravity model should be based on the nature and consistency of the data as well as the structure of the observation.

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DOI: https://doi.org/10.30564/mmpp.v1i1.749