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Price transmission Analysis and Associated Policy in Sub-Saharan Africa's Agricultural Markets: What Does the Literature Say?

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Abstract

Price transmission studies have become increasingly important in sub-Sahara Africa (SSA) over the last two decades because of their application in assessing the impact of market reforms policies embarked upon by the region's governments between the mid 1980s and early 1990s. In this study, a meta-database obtained from 43 price transmission studies published between 1978 and 2011, is used to provide an overall assessment of the potential impact of selected, study-specific attributes on estimated price transmission coefficients and in identifying episodes of asymmetric price transmission in SSA agricultural markets. Despite the large dispersion of estimated price transmission coefficients of about 0.002- 0.99, the mean coefficient of 0.34 is an overall evidence that the extent of price transmission in SSA is comparatively low. The impacts of the study-specific attributes on the price transmission coefficients, and on the likelihood of the primary studies to report asymmetric price transmission however differ consistently across the attributes, and provide in general evidence on the critical role such attributes may play in determining price transmission results and their implications for policy formulation.

Key words: meta-analysis, price transmission, asymmetry, Sub-Saharan Africa

JEL Classification: C01, L11, Q13

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1. Introduction

Empirical studies on Price transmission measure the degree to which commodity prices at geographically separated markets or at different levels of the value chain share common long-run price information. Traditional analyses of price relationships began over 60 years ago, with the blueprint popularly called the Enke-Samuelson-Takayama-Judge (ESTJ) equilibrium model for price transmission (Enke, 1951; Samuelson, 1952; and Takayama and Judge, 1971).

Price transmission and integration analysis of agricultural markets received considerable attention in the past 50 years. This is because; price transmission studies have demonstrated both practical and theoretical relevanec viz.:

1) Backing neo-classical economic theory of price determination, resource allocation and output mix decisions by economic actors;

2) Proving that the absence of price transmission between markets trading with each other implies gaps in economic theory and results is less than Pareto efficiency in resource allocation and economic welfare (Peltzman, 2000 in Meyer and von Cramon-Taubadel, 2004);

3) Providing countries with liberalised domestic markets with knowledge on how world price signals are transmitted to domestic markets, serving as a platform for policies which ensure distributional balance in staple food commodities in the domestic scene, and a tool for assessing market efficiency resulting from the role of profit-seeking arbitrageurs (Goletti and Babu, 1994 in Abdulai, 2007); and

4) Supplying the evidence needed to understand the impact of policy changes on the performance of agricultural markets. This evidence aids negotiations in the ongoing WTO Doha Round, the economic partnership agreements (EPA), and other bi- or multilateral agreements in developing countries in the face of the recent global economic and food price crises.

Jones (1972) premiered price transmission and market integration analysis in sub-Sahara Africa (SSA) using correlation coefficient analysis to estimate the extent of price transmission between geographically separated retail markets in Nigeria. Following Jones (1972), progress in price transmission and market integration studies in SSA slacked, with only nine reported studies out of 61 studies published before 2000 (van Campenhout, 2007). These studies include Ejiga (1977) on Nigerian cowpea; Loveridge (1991) on Rwandan beans markets; Teklu *et al.,* (1991) on sorghum and cattle markets in Sudan; Webb et al (1992) on Ethiopian grain markets; Alderman (1993) on Ghanaian maize markets; Golletti and Babu (1994) on Malawian maize markets; Dercon (1995) on Ethiopian teff markets; and Lutz *et al.,* (1995) on maize markets in Benin.

The initial dearth of empirical studies in price transmission in SSA was attributed to inadequate availability of relevant and complete data and models to comprehensively explore price transmission analysis[2]. Over the last decade however, price transmission and market integration studies in SSA have proliferated due to the availability of numerous, extensive time series data and sophisticated models. More than 70% of quite recent price transmission analyses in SSA were commissioned to assess the responsiveness of domestic prices to government market policy reforms embarked upon between the mid 1980s and early 1990s, or to examine improvements in key price transmission determinants like transportation and market institutions, infrastructure and information, and fiscal and monetary policy changes on market performance in various countries in SSA. Presently, most SSA's studies turn to focus on the effects of the 2007/2008 global food price and economic crises on market performance.

The various price transmission studies conducted in SSA are based on different econometric models and datasets, and so their findings are often heterogeneous, highlighting several possible factors driving price transmission under different contexts and attempt to suggest relevant, context-specific policy strategies that may be needed to boost price transmission, and market integration and efficiency.

The consequence is that despite the overall usefulness of the results of price transmission and market integration, the high diversity in the findings, and the ensuing

[2] All the studies listed above used three linear, simple static models viz. correlation coefficients, Ravallion, Timmer and Co integration for their analyses of price transmission.

conclusions and policy implications drawn from them represent a critical weakness. Particularly, formulating holistic market reforms and future WTO and EPA agreements for SSA as a single economic block based on the different estimates may mislead the region's policy makers is responding to emerging bi- and multi-lateral international trade policies under the WTO, EPAs and regional economic blocks.

This is why our study combines qualitative and quantitative survey to obtain data from 43 studies on price transmission based on a number of agricultural products across markets in 20 different countries of SSA. The objective is to determine the factors influencing price transmission as measured by price adjustment coefficients in SSA. In addition, we assess what cause price asymmetric in SSA's agricultural commodity markets.

By combining the different evidence on price transmission in the different countries, we obtain a unified picture of the extent of, underlying factors causing and the broad policy measures required for improving price transmission between agricultural markets within SSA as a whole and between SSA's agricultural markets and their counterparts in SSA's major trading partner countries. In addition, by covering the whole of the SSA region and including several critical study attributes and variables, our analysis is unique as it goes beyond the usual simple static review of the literature, to undertake an extensive meta-analysis, and thus providing a unified, quantitative assessment of the extent of, underlying factors causing and the policy strategies for improving analysis of price transmission in SSA.

The next section undertakes a brief review of the empirical models employed in price transmission analysis, while section 3 provides detailed description of an over view on meta-analysis as a concept, the meta-dataset used for the analysis and the empirical model used for the meta-regression. Sections 4 and 5 present the findings and conclusions from the analysis.

2. Models for Estimating price transmission and Market Integration

As noted in section one, the analysis of price transmission spatially or vertically has attracted much attention over the last five decades and likewise several analytical models for estimation. This section undertakes a review of the main econometric models used for price transmission analysis over the years. The following review begins from the simple linear correlation and regression models, through co-integration- and error correction-based to recent regime-switching models. Details on the various models may be found in the price transmission literature.

2.1. *Static Correlation and Regression Models*

Premier Price transmission and market integration analysis used standard static models viz. bivariate correlation and regression models, to test for the law of one price (LOP). Bivariate correlation models (BCM) measure the extent of market integration by examining the co-movement of price series at fixed transfer costs. For instance, if P_t^i and P_t^j are two contemporaneous price series in markets i and j connected by trade for a homogenous commodity, the correlation coefficient, r, is obtained by:

$$r = \frac{\sum_{k=1}^{n}\left[(P_t^i - \bar{P}^i)(P_t^j - \bar{P}^j)\right]}{\sqrt{\sum_{k=1}^{n}(P_t^i - \bar{P}^i)^2 \sum_{k=1}^{n}(P_t^j - \bar{P}^j)^2}} \qquad (1)$$

where $\overline{P^i}$ and $\overline{P^j}$ are the mean values of P_t^i and P_t^j respectively.

The bivariate regression models (BRM) of price transmission and market integration are commonly specified as:

$$P_t^i = \beta_0 + \beta_1 P_t^j + \beta_2 T_t + \beta_3 R_t + \varepsilon_t \qquad (2)$$

Where P_t^i and P_t^j may either be in their first-difference or logarithms form, T_t is transaction cost, R_t denotes other factors influencing prices. The β_is are the coefficients to be estimated. Even though the static models are easy to estimate using only price data, their assumption of stationary price behaviour and fixed transactions costs make them underestimate the extent of market integration (Barrett, 1996; Baulch 1997).

2.2. Dynamic Models

Dynamic market integration models recognize and specify lead/lag relationships in price transmission to account for the dynamic nature of prices and transaction costs.

Unlike the static approaches that merely investigate whether markets are integrated or segmented, the dynamic methods check in addition the extent of integration by estimating speeds of price adjustment. A review of three of the dynamic models used in market integration analysis is given below.

Granger Causality Tests

Granger (1969) causality test provides evidence of whether price transmission is occurring between two markets, and in which direction. P_t^i is said to granger-causes P_t^j if both current and lagged values of P_t^i improves the accuracy of forecasting P_t^j (Judge et la, 1988). Typical Granger causality models are specified as in (3).

$$P_t^i = \sum_{K=1}^{n} a_k P_{t-1}^j + \sum_{K=1}^{n} b_k P_{t-1}^i + \varepsilon_{1t}$$
$$P_t^i = \sum_{K=1}^{m} c_k P_{t-1}^j + \sum_{K=1}^{m} d_k P_{t-1}^i + \varepsilon_{2t} \qquad (3)$$

Ravallion and Timmer Models of Market Integration

Ravallion's (1986) model specifies a radial framework of numerous rural markets linked to a central market. The test for market integration determines whether the price of a commodity in a given producer market is influenced by its price in a central market. The variant of the Ravallion's model commonly used in price transmission analysis is:

$$P_{it} = \sum_{j=1}^{n} a_{ij} P_{it-j} + \sum_{j=0}^{n} b_{ij} P_{1t-j} + c_i X_{it} + \varepsilon_{it} \quad \forall i = 2,\ 3,\ \ldots,\ N \qquad (4)$$

where a_{ij}, b_{ij}, and c_i are the parameter estimates, and j (j = 1, 2 … n) is the lag lengths.

Timmer's (1987) model assumed that the central market price is predetermined relative to the local market prices and made two modifications to the Ravallion model by using the logarithm of the prices and a single lag rather than the six lags used by Ravallion. Timmer specification is:

$$P_t^i = c_0 (P_t^1 - P_{t-1}^1) + (c_0 + c_{1i}) P_{t-1}^1 + c_{11} P_{t-1}^i + \gamma X_{it} + \varepsilon_{it} \qquad (5)$$

Here the author assume γ = 0, then $c_0 + c_{1i}$ and c_{11} are the contributions of the central and local market price history respectively to current prices.

2.3 Co-integration Models

The co-integration of a pair of markets means that the dynamics of the price relationships in the markets converge in the long run towards the law of one price (LOP). If two price series, P_t^i and P_t^j, in two spatially separated markets contain stochastic trends and are integrated of the same order, say I (d), the markets are said to be co integrated if there is a linear relationship - P_t^i + βP_t^j □ I (0), between the price series. The two commonly employed approaches to co-integration analysis are Engel and Granger (1987) used for bivariate analyses and the Johansen (1990) variance autoregressive (VAR) approach used in multivariate analyses. The first step in employing any of the two approaches is testing unit roots in the price series individually under a null hypothesis of unit roots using the Dickey-Fuller (DF), augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and/or a host of other procedures.

2.4. Switching Regime Regression Models (SRM)

Usually, prices are related nonlinearly, contrary to the assumption in much of the premier price transmission literature that linear price relationships exist. The realisation that price relationships may be nonlinear due to transactions costs motivated the introduction of a class of models collectively called switching regime models (SRM). Four classes of SRM are widely used in the literature for price transmission analysis – the error correction models (ECM), threshold autoregressive (TAR) models; parity bound models (PBM) and Markov-switching models (MSM).

The Error Correction Models (ECM)

The ECM is an extension of the co-integration model. If P_t^i and P_t^j are co-integrated, then the equilibrium relationship between them can be specified as: $P_t^c - \beta_1 P_t^s - \beta_0 = \varepsilon_t$. And if ε_t, the error term, is assumed to follow an autoregressive (AR) process, then $\varepsilon_t = \alpha\varepsilon_{t-1} + e_t$. This means the equilibrium relationship between P_t^i and P_t^j can be expressed as:

$$P_t^c - \beta_1 P_t^s - \beta_0 = \alpha\varepsilon_{t-1} + e_t \quad (6)$$

The above equation implies that the long run relationship (co-integration) between P_t^i and P_t^j is a function of the autoregressive process ε_{t-1}, where ε_{t-1} is the deviation from long run equilibrium, and called the error correction term (ECT), while α measures the response of P_t^i and P_t^j to deviation from equilibrium. The ECM has been extended to asymmetric error correction (EC), vector EC and switching vector EC models.

Threshold Autoregressive (TAR) Models

The TAR models explicitly recognize the influences of transactions costs faced by traders on spatial market integration and account for them without necessarily using actual transactions costs data. The idea is that, inter-market price differentials must exceed thresholds bands arising from transactions costs, before provoking existing market equilibrium and causing price adjustment to ensure market integration. Typically, a vector autoregressive (VAR) specification of the threshold model is stated as:

$$\Delta P_t = \begin{Bmatrix} \sum_{i=1}^{l} \alpha^{(1)} \Delta P_{t-i} + \theta^{(1)} \varepsilon_{t-1} \text{ if } |\varepsilon_{t-1}| \le c \\ \sum_{i=1}^{l} \alpha^{(2)} \Delta P_{t-i} + \theta^{(2)} \varepsilon_{t-1} \text{ if } |\varepsilon_{t-1}| > c \end{Bmatrix} \quad (7)$$

where P_t the vector of is prices being analysed, c denotes the value of the threshold giving rise to the alternative regimes and ε_{t-1} is the variable used to capture threshold behaviour.

Parity Bound Models (PBM)

The PBM explicitly consider transaction costs and trade flow data, in addition to price series, in analysing market integration; and unlike the conventional dynamic approaches, which strictly accept price transmission or reject a null hypothesis at a given significance level, PBM have the advantage of allowing for a continuum of inter-market price relationships within the range of perfect market integration and complete market segmentation.

Baulch (1997) introduced the PBM to price transmission and market integration analysis, while Barrette and Li (2002) made significant extension to it. The original PBM model is a maximum likelihood function specified as:

$$L = \prod_{t=1}^{r}\left[\lambda_1 f_t^1 + \lambda_2 f_t^2 + (1-\lambda_1-\lambda_2) f_t^3\right] \quad (8)$$

Where λ_2 and λ_1 are the estimable probabilities of the market being in regimes 1 and 2 respectively, $1-\lambda_1-\lambda_2$ is the probability of the market being in regime 3.

Markov Switching Models (MSM)

The standard Markov-switching model is formulated based on the price transmission that if y_t is a time series variable with a finite set of M regimes such that each y_t is associated with an unobservable regime dummy variable s_t; i.e. $s_t \in (1,\ldots,M)$ and s_t = 0 or 1, then a Markov-switching specification of the autoregressive process for y_t in a two-regime case is:

$$\begin{aligned} y_t &= \phi_1 y_{t-1} + \varepsilon_{1t} && \text{If system is in regime 1} \\ y_t &= \phi_2 y_{t-1} + \varepsilon_{2t} && \text{If system is in regime 2} \end{aligned} \quad (9)$$

where ϕ_1 is the autoregressive parameter of the series when the current regime is 1, and ϕ_2 is the parameter when the current regime is 2.

The principal conclusions to make following the review of the techniques employed in the literature for assessing spatial and vertical price transmission, and hence market integration are that the various models, though building upon the limitations of preceding models, have their own limitations. The critical limitations are partly the source of diverse results from different studies and justify our attempt at synthesising findings from price transmission studies in SSA and producing unified results.

3. Meta-Analysis, empirical model and the meta-dataset

3.1. Meta-analysis: *An over view*

Following the pioneer work of Glass (1976), meta-analysis has become the standard technique for searching for general patterns in a body of existing specific research results. Generally, meta-analysis allows researchers to combine results of several studies into a unified analysis that provides an overall estimate of the effects of interest and to quantify the uncertainty of that estimate (Sterne, 2009). Policy analysts often use this tool to synthesize body of existing literature especially when there is a large literature reporting such evaluations worldwide (Hedges and Olkin, 1985).

Meta-analysis is quite popular in medical and marketing research, but is currently gaining increasing significance in the applied economics literature. Among this class of studies in the applied economics literature include: meta-analysis of income and price elasticities of demand (e.g., Gallet and List 2003; Gallet 2007; Gallet 2010 a and b); meta-analysis of technical efficiency and total factor productivity (e.g., Bravo-Ureta *et al.,* 2007; Ogundari and Brümmer, 2011; Tian and Yu, 2012); economic aid impact meta analysis (e.g., Mekasha and Tarp, 2011); language effect in international trade (Egger and Lassmann, 2012); income impact on calorie intake (e.g., Ogundari and Abdulai, 2012); economic freedom and growth (e.g., Doucouliagos, 2005); willingness to pay for farm animal welfare (e.g., Lagerkvist and Hess, 2011) and causes of asymmetric price transmission meta studies (Perdiguero, 2010; Rusnak et al., 2011; Bakucs et al., 2012).

A general technique for conducting meta-analysis is the use of regression, meta-regression analysis (MRA), to quantitatively evaluate the effect of methodological and other study-specific characteristics on published empirical estimates of some indicators (Alston *et al.,* 2000). In other words, MRA investigates the extent to which statistical heterogeneity between published empirical estimates of interest can be related to study specific characteristics.

Because price transmission studies are very likely to differ in terms of analyzed commodities, time frequency and time period of the data used, model specification and even location of countries under scrutiny among others as argued by Frey and Manera (2005), suggest that published empirical estimates of interest are not always unique due to heterogeneity associated with the factors above. Thus, the present study relies on the MRA to assess the effect of the choice of econometric model, study location, type of data and other study-specific characteristics on published empirical estimates of price transmission in SSA and what this implies for policy.

3.2. The Meta-Dataset

The studies used in this paper were sourced from Google Scholar, ISI Web of Science, ASC index, previous bibliography and other online databases. In this way, the meta-dataset for the analysis is obtained from 43 published, conference and working papers analysing price transmission and market integration in SSA[3]. The reviewed studies cover 20 SSA countries and a number of agricultural commodities in SSA. The 43 studies reviewed yielded in all 413 observations from which a number of study specific characteristics or variables are extracted.[4]

A summary of the study variables vis-à-vis the average number of observations for each variable and the corresponding mean, minimum and maximum values of estimated price transmission coefficients are presented in Table 1, while in Appendix A, we present the mean and standard deviation values of the dependent and moderator variables included in the MRA. The review of the study variables and the descriptive statistics of the corresponding price transmission coefficients raise several issues as may be seen in Table 2.

Thus, Table 2 shows that about 52% of the observations in this meta-dataset is published journal articles, about 30% are working papers, while the rest (about 18%) are conference proceeding. Furthermore, the table shows that about 12% and 88% of the observations found evidence of asymmetry and symmetry price transmission (PT), respectively. We also found that more than 96% of the observations with mean price transmission coefficient of 0.341 focus on crop products as against animal products-based studies accounting for about 4% of the observations with a mean price transmission coefficient of 0.318. The fact that most of the observations focus on crop commodity markets agrees with the existing reality that staple food and cash crops are more important in SSA's agriculture and marketing systems compared to livestock. Perhaps because of this, data on crop products is more available for price transmission analysis than data on livestock production in SSA.

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[3] The detail references of the 43 case studies for the meta-analysis could be obtained from the authors.

[4] This observation was made possible because all the primary studies reported more than one estimate with an average of about 10 estimates per study.

The error correction model is the most popular method for analysing price transmission in SSA. About 46% of the observations are based on primary studies that used the error correction model (ECM). This model has a higher power of estimating the effects of policy shocks on price transmission and able to handle the non-linearity in prices and transaction costs revealed in the insights of Baulch (1997) and McNew (1996). In this way, applying the ECM is relevant for SSA, where most price transmission studies were undertaken to estimate the impact of market reforms on the performance of domestic markets. The parity bound model (PMB) is the second most popular price transmission model in the SSA's price transmission literature, representing about 22% of the observations. In line with the analytical theory in price transmission analysis, about 67% of the observations tested for unit roots while 29% extended the analysis to examining causality tests.

Table 1: Summary statistics of the PT coefficient by study specific characteristics

Variables	Number of Observation	PT coefficient		
		Mean	Min.	Max.
Papers published in Journal	213	0.3097	0.0020	0.9980
Papers in Conference proceeding	078	0.4450	0.0390	0.9300
Working papers	122	0.3266	0.0300	0.9980
Studies with asymmetric PT	051	0.2630	0.0700	0.8070
Studies with symmetric PT	362	0.3511	0.0020	0.9980
Studies with Vertical PT analysis	019	0.3176	0.1170	0.8070
Studies with Spatial PT analysis	399	0.3409	0.0020	0.9980
Studies with monthly data	308	0.3782	0.0110	0.9980
Studies with weekly data	105	0.2289	0.0020	0.9660
Studies that use level data	032	0.5092	0.1100	0.9980
Studies that use differences data	381	0.3261	0.0020	0.9980
Studies with focus on food products	398	0.3409	0.0020	0.9980
Studies with focus with non-crops	017	0.3178	0.0200	0.8700
Studies with ARDL method	073	0.3216	0.0110	0.9660
Studies with ECM method	190	0.3082	0.0300	0.9600
Studies with VAR/VER-VECM method	079	0.1981	0.0020	0.8300
Studies with co-integration method	065	0.2779	0.0200	0.8700

Studies with PBM method	091	0.5456	0.0200	0.9980
Studies with OTHER method*	051	0.3133	0.0200	0.9120
Studies with unit root tested	277	0.2736	0.0020	0.9600
Studies with causality tested	120	0.3589	0.0200	0.9600

**Note: Other methods include studies with TAR model, Correlation coefficient, and switching regression.*

Across the variables considered, the minimum estimated price transmission coefficients ranging from 0.002 to 0.117 illustrate that there exist cases of very low levels of price transmission or near market segmentation. About 76% of the reported price transmission coefficients from the primary studies are less than 0.50. These represent cases whereby due to constraints to arbitrage such as price-distorting policies, delays in flow of market information, underdeveloped market infrastructure or autarky due to unprofitable arbitrage, remote agricultural commodity markets in producing areas are isolated from central markets.

Nevertheless, it can be shown that some markets (about 24% with coefficients over 0.50) are considerably responsive to price shocks given the estimated maximum price transmission coefficients ranging across the study-characteristics from 0.503 to 0.998 (perfect price transmission). These represent markets which are possibly connected by efficient trader, market information and transportation networks. Averagely across the variables, price adjustment in response to price shocks in SSA markets range from 0.002 to 0.998 per month or week towards ensuring market equilibrium.

In Figure 1, we present the distribution of the price transmission coefficients from the primary studies. The distribution shows a large dispersion of price response to market anomalies. This is in line with the different extents of price transmission and market integration observed in the analysis and that is expected in SSA due to differences in the key determinants of price transmission across the different countries of SSA.

Since the distribution of the estimated price transmission coefficient extracted from the primary studies is skewed to the right (between 0 and 1), then the impact of market anomalies and price shocks on price transmission in SSA agricultural markets is clearly more positive, with overall minimum, mean and maximum price transmission coefficient being 0.002, 0.340 and 0.998, respectively.

Like the observation made above, the economic interpretation of the distribution of the price transmission coefficients is that some agricultural markets in SSA may be segmented, implying a negligible level of price transmission occurs between some spatially separated markets or different levels of the supply chain due to autarky (with price transmission coefficients around 0). The majority of the markets averagely react to price shocks (with price transmission coefficients around 0.340), while few markets tend to exhibit near-perfect price transmission, implying that changes in prices at a given market or level of the supply chain are fully and instantaneously transmitted to other markets or levels of the supply chain (with price transmission coefficients around 1). Some markets even overreact to price shocks (with price transmission coefficients around 1.5) as may be case where traders use market power and near-oligopolistic pricing strategies to ensure asymmetries in price transmission between remote, producer and urban, consumer agricultural markets (Amikuzuno, 2010).

The overall average of the elasticity of price transmission (0.340) in SSA agricultural markets is low compared with the transmission coefficient (0.740) for the USA agricultural markets even as far back as from 1961-1983 (USDA, 2009), that of the EU12 (0.660) or the EU27 (0.500) reported by EU (2009), or the average price transmission elasticity of 0.62 and 0.34 for selected commodities in India and China respectively (Imai *et al*, 2008).

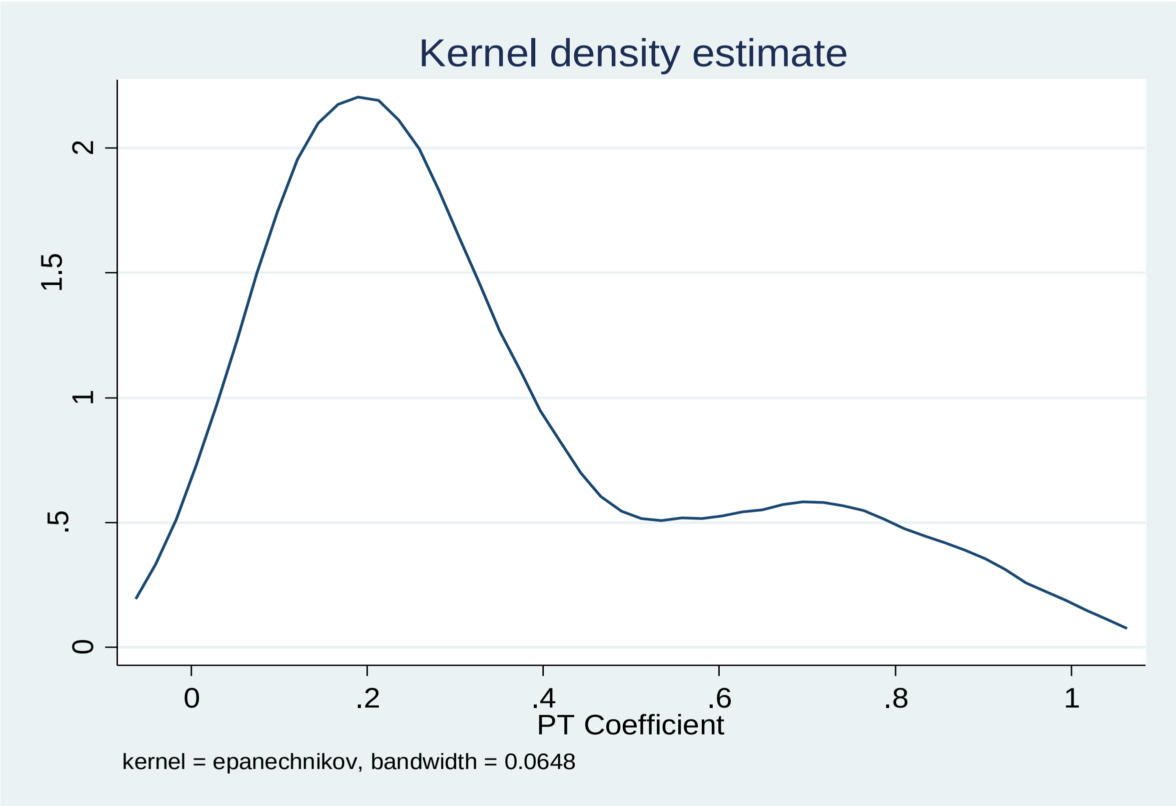

Figure 1: Distribution of the retrieved price transmission coefficients

3.3 The Empirical model

As earlier mentioned, the present study is designed to employ MRA to quantitatively examine the nexus between the study-specific effect on price transmission in SSA and price transmission estimates of interest. The two study–specific effects of interest here include: the coefficients of price transmission and the presence of asymmetric price transmission or otherwise. Guided by this, equation 10 presents the empirical model for the MRA in the study.

$$study\_effect_i' = \psi_0 + \sum_{k=1}^{K} \alpha_k X_k' + \sum_{j=1}^{J} \beta_j D_j' + \varepsilon_i \qquad (10)$$

where, $study\_effect_i'$ is a vector denoting either of the two study effects of interest from the primary studies, namely: 1) the reported price transmission coefficients and 2) the evidence of asymmetric price transmission in the primary studies. The later is a dummy variable that takes a value of 1 if the study identified asymmetric price transmission and 0 otherwise. X_k' and D_j' are vectors of study specific characteristics hypothesized as explanatory variables for the estimated study effect from each primary study. X_k' represents continuous variables such as the number of observations/sample size in a primary study (which range from 34 to 401 in this study), data year (from 1978 - 2010) and year of publication (from 1994 -2011); and D_j' is a set of indicator variables denoting whether or not the primary studies included under this review are working or conference papers; cover food crop products; analyse vertical price transmission; use differenced prices and/or monthly data; and finally whether or not the primary studies employ the ARDL, VAR/VER-VECM, Co-integration, and PBM models, conducted unit root and causality tests, and target one of SSA's sub-regions (i.e. west, east or southern Africa) as the study area. The ψ_0, α_k and β_j are parameters to be estimated while ε_i is the error term of the meta-regression.

The MRA of the price transmission coefficients is performed using the Weighted Least Square (WLS) approach with the square root of the sample size as the weight. The analysis of existence of asymmetric price transmission in the primary studies is undertaken by means of the probit model. The use of WLS for the regression is consistent with the insight that WLS deals with heteroskedasticity in the effect size as earlier revealed by Stanley (2008) and later supported by Nelson and Kennedy (2009).[5]

4. Results and Discussion

Before we discuss the results of the findings, we follow the standard approach in meta-analysis to examine the presence of publication selection bias. In this regard, the study follows Stanley and Rosenberger (2009)'s Root-n meta-regression (MRA) approach using the relationship $PT\_Coefficient_j = \beta_j + \beta_0\left(\frac{1}{\sqrt{n_j}}\right) + \varepsilon_j$ with $\frac{1}{\sqrt{n_j}}$ as the measure

[5] Typically, the WLS us estimated because the sample size (or number of observation) across the primary studies will vary greatly from estimate to estimate.

of precision.[6] The result of this regression shows that publication bias represented by the null hypothesis $H_0 : \beta_0 = 0$ could not be rejected at 10% level of significance while the null hypothesis of genuine empirical effect represented by $H_0 : \beta_j = 0$ was rejected at 1% level of significance. The implication of these findings especially β_0 is that reported price transmission coefficient varies randomly or symmetrically develop around the population (or true) estimates from the sample.

4.1. Study-specific characteristics and price transmission Coefficient: *The nexus*

In this section, we attempt using the full sample of observations, to assess the relative impact of study-specific variables on the price transmission coefficients estimated in the primary studies. Table 2 presents the results of the relationship between reported price transmission coefficients and selected study-specific variables.

Thus, the table shows that the major impacts of the study characteristics on the extent of price transmission as measured by the estimated price transmission coefficients differ across the moderator variables. The coefficients for sample size and year of publication are negative but significant. This means, sample size (number of observations) and year of publication have a decreasing effect on reported price transmission coefficients in the selected studies. In other words, as sample size or year of publication of the study increase, the magnitude of the estimated price transmission coefficients significantly decreases, although by smaller proportions. This observation is in contrasts with the findings of Ogundari and Bruemmer (2011) and Perdiguero (2010) that despite the time lags between years of data collection and publications by empirical studies, more recent studies may estimate higher effect size than previously published studies. This is even more so interesting in SSA markets which are expected to improve in terms of price transmission and market integration along with recent improvement in the quality of infrastructure and market information flow via mobile phones. It might also be that the more improved models and quality of data used by recent studies improves the econometric estimation of price transmission. The reducing-effect of the number of observations (sample size) on the price transmission coefficient imply as more and

[6] The Root-n MRA approach was estimated using weight least square with "n" as the weight. This is however different from the traditional approach based on standard error of reported price transmission coefficient. Lack of adequate information on the standard error of the PT motivated the use of Root-n approach.

more observations are covered by price transmission analysis, then it is less likely to increase the magnitude of the price transmission coefficients.

Furthermore, we found that publication outlet, data frequency and type of agricultural product all have positive and statistically significant effects on the estimated price transmission coefficients. Interestingly, this means conference and working papers seem to estimate higher price transmission coefficients than journal papers do, with estimated coefficients in conference and working papers being respectively on average about 0.07 and 0.16 units higher than similar estimates in journal papers. This is expected due to the rigorous peer review of journal papers. The positive and significant effect of the monthly data variable means studies using data of monthly frequencies improves the magnitude of price transmission coefficients by about 0.06 units over estimates obtained from weekly data.

Based on the type of product analysed, studies based on food crop products appear to have significant and greater positive effects on estimated price transmission coefficients than studies based on livestock products, which constituted only 17 of the 413 observations included in the analysis. Despite the number of observations, given that crop production is more important than livestock in SSA, it is more logical that network of traders and information flow on crop prices should ensure that price transmission spatially or vertically between crop markets should exceed that between markets for livestock. It is also important to note that livestock products are also more perishable and difficult for arbitrageurs to move across spatial markets in SSA where refrigerated transport systems are lacking.

Table 2: Weighted Regression of the MRA for the coefficient of price transmission

Variables	**Parameters**	**Coefficient**	**Std.Err$**	**P-value**
SAMPLE SIZE	α_1	-0.0006***	0.0002	0.014
DATAYEAR	α_2	0.0010	0.0039	0.790
PUBLICYEAR	α_3	-0.0139**	0.0063	0.029
D_WORKINGP	β_1	0.0729**	0.0355	0.041
D_CONFERENCEP	β_2	0.1591***	0.0395	0.000
D_MONTHLY	β_3	0.0623*	0.0371	0.094
D_FOODP	β_4	0.2869***	0.0852	0.001

D_DIFFERENCES	β_5	0.1992	0.0744	0.143
D_ARDL	β_6	-0.0149	0.0418	0.720
D_ECM	β_7	-0.0488	0.0427	0.253
D_VAR-VECM	β_8	0.0001	0.0371	0.997
D_COINTEGRATON	β_9	0.0005	0.0450	0.991
D_PBM	β_{10}	0.2007***	0.0595	0.001
D_UNITROOT	β_{11}	-0.1263***	0.0407	0.002
D_CAUSALITY	β_{12}	0.0724**	0.0339	0.033
D_WESTAFRICA	β_{13}	0.0274	0.0359	0.446
D_EASTAFRICA	β_{14}	-0.0210	0.0351	0.549
Constant	ω_0	25.7745	7.1618	0.000
R-squared			0.3387	
F-statistics (17,403)			22.32	
Prob.>F			0.0000	

Dependent variable is the estimated coefficient of price transmission from the primary studies; $The estimate is a robust standard error;
, **,and * represent levels of significance at 10%, 5%, 1%, respectively.*

All dummies representing econometric models used by the primary researchers in the MRA except the parity bound model (PBM) do not significantly affect the estimated values of price transmission coefficients in SSA. Whereas it is interesting to note that generally there is no model-bias in estimated price transmission coefficients in the primary studies, the insight is that studies that applied the PBM (about 22% of the observations included here) are more likely to have higher (about 0.20 units) estimated coefficients than those that do not use this method.

Lastly, studies that tested for unit roots are more likely to obtain lower estimates of price transmission coefficients (about 0.13 units lower) than studies which did not test for unit roots. As we saw in previous section, most price data are non-linear and studies that tested for unit roots removed data-related non-linearity by differencing or using non-linear models, and in this way, such studies are more likely to avoid the overestimation of price transmission coefficients. In contrast, studies that tested for the existence of causality tended to have significantly higher price transmission coefficients, though the effect of this variable on the value of the transmission coefficient is only 0.07 units.

All other variables included in the MRA regression to assess the impact of the study-specific characteristics on the price transmission coefficients are not significant. Interestingly, even the geographical variables i.e. West Africa, East Africa and Southern Africa have no significant effects on the estimated price transmission coefficients. This means that even though the performance of agricultural markets in the three different sub-regions – west, east and southern Africa might differ, the location of studies is not an essential element for explaining observed differences in the estimated results.

4.2. Determinants of existence of asymmetric price transmission[7]

In this section, we present the results of the determinants of the likelihood of the primary studies to report asymmetric price transmission (APT). The aim is to identify the determinants of asymmetric price transmission from the selected primary studies. Thus, Table 3 presents the results of how study specific characteristics explain the existence of asymmetry in the selected primary studies on price transmission in SSA.

Our findings show that sample size (i.e. number of observations) and year of data (i.e. the sample period) significantly increase the likelihood that the selected studies found asymmetry in their analyses. Evidence in the literature shows sensitivity of the estimated asymmetric price transmission (APT) coefficients to sample size (Bermejo et al, 2011 in Nakajima, 2011). It is expected generally that the larger the sample size for a given analysis, the better it is for especially the non-linear, switching regression models of price transmission to accurately estimate the nature and extent of price transmission between markets or product levels. Similarly, we expect that studies based on data collected more recently (after the market reforms for instance in SSA) should have a higher likelihood of identifying asymmetric price transmission (APT) because of the improved data quality and analytical models applied.

In contrast, publication year has a highly significant but negative effect on the identification of asymmetric price relationships by the primary studies. A negative relationship between year of publication and asymmetry means that more recently published studies have a higher probability of identifying symmetric price relationships

[7] This refers to reciprocal relationship between increases and decreases in prices between spatially separated markets or between intermediate levels in the supply chain for a homogenous product.

between spatial markets or product levels in the value chain. Since data year and publication year are somewhat related, the contrast in the findings is only possible where the lag between data collection and publication of results is huge. In addition, due to recent improvements in market infrastructure and information flow via mobile phones, producers and arbitrageurs in SSA agricultural sector are expected to lose their ability to use market power, and by this guarantee symmetry in the transmission of price shocks between the region's agricultural markets.

Besides, we found that studies published as conference papers, studies based on vertical price transmission, studies that use monthly data and the ARDL model; as well as studies conducted in the West and East Africa sub-regions have higher and significantly positive chances of identifying asymmetric price transmission. The high, positive and significant coefficient of conference papers probably implies that published articles in journals have more lax standards with respect to model specification or applied statistical methods, and this might affect the results in the primary studies.

Regarding the type of data frequency, studies using monthly data are not expected to report more cases of APT than studies based on weekly data. This is because any empirical attempt to quantify dynamic relationships such as APT requires data with a frequency that exceeds the frequency of the adjustment process (for example, the arbitrage processes that integrate markets). That is if, as might be expected in many cases, price transmission takes place within days or weeks, monthly and even lower frequency price data will not be able to capture APT (Loy and von Cramon-Taubadel, 1996 in Meyer and von Cramon-Taubadel, 2004).

Table 3: Probit regression for evidence of asymmetry price transmission

Variables	Parameters	Coefficient	Std.Err	P-value
SAMPLE SIZE	α_1	0.0247***	0.0043	0.000
DATAYEAR	α_2	0.4974***	0.1138	0.000
PUBLICYEAR	α_3	-0.6557***	0.1442	0.000
D_WORKINGP	β_4	-0.6168	0.4477	0.168
D_CONFERENCEP	β_1	1.0531***	0.3711	0.005

D_NON-FOODP	β_2	-0.9198	5.2215	0.860
D_VERTICAL	β_3	8.8608***	1.6353	0.000
D_MONTHLY	β_4	5.4481***	1.1764	0.000
D_ARDL	β_5	0.6831**	0.3481	0.027
D_UNITROOT	β_6	-0.3315	0.4026	0.410
D_CAUSALITY	β_7	-0.2728	0.3326	0.412
D_WESTAFRICA	β_8	3.1446***	0.8109	0.000
D_EASTAFRICA	β_9	2.6628***	0.7332	0.000
Constant	ω_0	308.9175***	93.9387	0.001
Pseudo R-Squared			0.5493	
LR chi2(13)			167.31	
Prob.>chi2			0.000	

Dependent variable equal to 1 if the study has found the existence of asymmetry price transmission and 0 otherwise; ;
, **,and * represent levels of significance at 10%, 5%, 1%, respectively.*

The use of the ARDL model to estimate price transmission is also more likely to identify APT. In fact, the ARDL model and ECM have been the most popular frameworks applied in investigating price asymmetries (Frey and Manera, 2005). The ARDL model has the advantage of handling both stationary price series as well as non-stationary, differenced series, and is widely used in most of the initial price transmission studies in SSA. The revelation again shows that like data frequency, the type of model employed can have significant impact on the identification of APT in price transmission analysis, and modelling price transmission analysis with the ARDL specification affects the pattern of price transmission identified.

Finally, with regards to the location variables, the results show that price transmission studies conducted in west or east Africa have a higher probability of identifying APT than studies located in southern Africa. In the literature, spatial APT in agricultural is caused by poor infrastructure, transport and communication services between remote producer markets and urban central markets, while vertical APT arises from market power by a specific category of traders along the supply chain. On this basis, the results mean that market infrastructure; transport and communication services in West and East Africa may be less developed than that of southern Africa. Alternatively, it may be evidence that arbitrageurs in agricultural markets in West and East Africa tend to use more market power in price determination than do their counterparts in Southern Africa.

5. Conclusions

The analysis of price transmission in sub Saharan Africa (SSA) has received considerable attention over the last 50 years in the Agricultural Economics literature. Most of the analyses have been conducted to assess the effect of market policy reforms implemented by SSA countries between the mid 1980s and early 1990s on the performance of their domestic markets. This is because of the insight that the success of the market reforms depends on the extent of price transmission between spatially separated markets or along product value chains.

Whereas results from the various price transmission analyses on their individual levels often produce useful results for policy making in the target countries of the studies, price transmission results overall show a mixed picture of the extent, nature and determinants of price transmission in SSA. The literature attribute the differences in the results to a set of study-specific elements viz. data-related factors like sample size, data frequency and period of collection; publication-related factors like year and outlet of publication, product covered by the analysis, as well as model- and study location-related variables.

Our meta-analysis highlights the critical role these elements play in determining the size and statistical significance of the price transmission coefficients reported by studies in SSA between 1978 and 2011, and how these attributes affect the identification of asymmetric price transmission (APT) by the studies. We discovered that the sample sizes of reviewed studies have a reducing-effect on estimated price transmission coefficients, meaning as more and more observations are covered by a given study, then the size of the price transmission coefficients estimated is likely to decrease. Furthermore, publication outlet, data frequency and type of agricultural product all have positive and statistically significant effects on the estimated price transmission coefficients. Specifically, conference and working papers seem to estimate higher price transmission coefficients than journal papers, whereas using data of monthly frequencies appear to improve the magnitude of the estimated price transmission coefficients by than what was obtained from weekly data. The results also show that studies based on food crop products tend to have significant and greater positive effects on estimated price transmission coefficients than studies based on livestock products. We attribute this to the greater importance placed on crop production by marketing systems in SSA than on livestock products. Even though model selection does not empirically affect estimated results, the insight is that studies that applied the parity bound model (PBM) are more likely to have higher estimated coefficients than those that do not use this method.

Based on the findings on APT reported by the primary studies under review, our findings showed that the sample size and year of data significantly increase the likelihood that the primary studies found asymmetry in their analyses. In contrast, publication year has a highly significant but negative effect on the identification of asymmetric price relationships by the primary studies, implying that more recently published studies have a higher probability of identifying symmetric price relationships between spatial markets or product levels in the value chain. Besides, studies published as conference papers, or based on vertical price transmission as well as studies that used monthly data and the ARDL model or were conducted in the West and East Africa sub-regions have higher and significant positive chances of identifying asymmetric price transmission. The high, positive and significant effects of these study-specific attributes on the likelihood of the various studies to identify APT implies these attributes are important in determining the nature, extent and drivers of price transmission in SSA. Thus, the study suggests that these study-specific characteristics should be considered in future research and in the use of price transmission results for policy making, and especially in advancing our understanding of price transmission mechanism worldwide.

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Appendix A

Descriptive statistics of variables used in Meta-Regression Analysis (MRA)

Variables	Description	Mean	Std. Dev
Dependent Variables			
D_Asymmetry	Equal to 1 if the article found asymmetry PT	0.1235	0.3294
PT_Coefficient	PT coefficient from the primary study	0.3403	0.2515
Moderators			
SAMPLE SIZE	Sample size from the primary study	133.02	53.29
DATAYEAR	Average year of the data used by the studies	1997.7	6.57
PUBLICYEAR	Year of publication of the primary studies	2005.0	5.29

D_WORKINGP	Equal to 1 if the article is working paper	0.2954	0.4568
D_CONFERENCEP	Equal to 1 if the article is conference paper	0.1889	0.3919
D_MONTHLY	Equal to 1 if the article uses monthly data	0.7458	0.4359
D_FOODP	Equal to 1 if the article is on food products	0.9637	0.1873
D_NON-FOODP	Equal to 1 if the article is on non-food	0.0412	0.1989
D_DIFFERENCES	Equal to 1 if the article uses differences data	0.9225	0.2677
D_VERTCIAL	Equal to 1 if the article focus on vertical PT	0.0460	0.2097
D_ARDL	Equal to 1 if the article uses ARDL method	0.1768	0.3819
D_ECM	Equal to 1 if the article uses ECM method	0.4600	0.4990
D_VAR-VECM	Equal to 1 if the article uses VAR-VECM	0.1913	0.3938
D_COINTEGRATON	Equal to 1 if the article uses co integration	0.1574	0.3646
D_PBM	Equal to 1 if the article uses PBM	0.2203	0.4149
D_UNITROOT	Equal to 1 if the article tested for unit root	0.6723	0.4699
D_CAUSALITY	Equal to 1 if the article tested for causality	0.2906	0.4546
D_WESTAFRICA	Equal to 1 if the article is from West Africa	0.3777	0.4854
D_EASTAFRICA	Equal to 1 if the article is from East Africa	0.2591	0.4387

Note: PT stands for price transmission