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A Spatial Price Transmission Analysis of Beans and Rice Markets in Rwanda

Charles RURANGA, Martin MUGENZI and Aline MUTABAZI

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Jönköping International Business School (JIBS),
Jönköping University, P.O. Box 1026,
SE-551 11 Jönköping, Sweden,
Web: http://www.ju.se/earp, E-mail: EARP@ju.se

Preface

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Editor: Almas Heshmati
Professor of Economics
Jönköping International Business School (JIBS),
Jönköping University, Room B5017,
P.O. Box 1026, SE-551 11 Jönköping, Sweden,
E-mail: Almas.Heshmati@ju.se

A spatial price transmission analysis of beans and rice markets in Rwanda

Charles RURANGA[1], Martin MUGENZI[2] and Aline MUTABAZI[3]

[1] Corresponding author:
School of Economics,
University of Rwanda, Kigali, Rwanda
E-mail: cruranga@ur.ac.rw

[2] School of Economics,
University of Rwanda, Kigali, Rwanda
E-mail: mmugenzi@ur.ac.rw

[3] School of Economics,
University of Rwanda, Kigali, Rwanda
E-mail: amutabazi@ur.ac.rw

Abstract

An increase in food prices has many effects for consumers especially for vulnerable people because this decreases their purchasing power. We use the spatial price transmission to examine the impact of a change in prices in one market in another market. Specifically, we analyze the spatial price transmission in beans and rice markets. We analyze monthly data from January 2002 to December 2014 of retail prices of beans and rice in Huye, Nyabugogo, Musanze, Gisenyi and Nyagatare markets. The series are stationary in their first differences and the Johansen co-integration tests reveal that the variables are co-integrated implying that there is a long-run relationship. Impulse-response functions show that if a shock on retail price of beans in Musanze is 100 per cent, it will not affect other markets in the first month but in the second month it will affect all markets. If there is a shock of 100 per cent in the retail prices of rice in the Huye market other markets will not be affected in the first month but in the second month the Musanze market will be more affected (25 per cent effect). Variance decompositions reveal that the effect of a shock in the price of beans in the Musanze market will be shared with other markets from the second month. For retail prices of beans, the Granger causality tests show that there is unidirectional Granger causality between prices in different markets; for retail prices of rice there is bidirectional Granger causality.

Keywords: Spatial price, co-integration and impulse-response functions.

JEL Classification Codes: E31; E64; Q11; P42;

1. Introduction

Price transmission analyzes the effects of a change in given prices due to a change in another price. Price transmission can be analyzed spatially from one region or country to another or vertically for one product. Food price crises deteriorate the food security situation and impact the food and nutrition security of the most vulnerable groups who consume purchased food.

A continuous analysis of the food situation is necessary to keep the issue high on policy agenda so that policies can be devised to mitigate the adverse effects of high food prices. Food is a necessity for survival; it is also among the most important ingredients for human development and national stability and it is the first requirement for the social and economic stability of a nation. Any negative shock in food supply or prices affects the lives of millions. Poor, hungry and malnourished people use some of their additional incomes either to produce or purchase more food (FAO et al., 2012).

According to the United Nations Food and Agriculture Organization in the recent past international prices of many food commodities have increased substantially (FAO et al., 2012). Higher prices of agricultural commodities provide positive incentives for increased investments in agriculture. However, better policy responses and improved governance are needed to ensure sustainability and to address the effects of increased price volatility and of higher costs of the food basket for the poor, most of whom are net food buyers (FAO et al., 2012).

There is great concern that if the current food price situation is not circumvented it will be a major source of welfare deterioration for both urban and rural poor (net food buyers). Inflation in food prices is critical for low-income economies like Rwanda. As some anecdotal evidence indicates failures of food security policies in many developing countries including Rwanda show that policy makers lack the evidence needed to make informed policy decisions.

This paper analyzes transmission of food prices in Rwanda. Rwanda is located in East and Central Africa and is bordered by Tanzania to the east, the Democratic Republic of Congo to the west, Uganda to the north and Burundi to the south. According to the 4th Rwandan Population and Housing Census the country's population was 10.5 million and it had 26,338 square km of land. The census also shows that Rwanda had a very high population density with 416 people per square km (NISR and MINECOFIN, 2014). The Rwandan economy is not diversified and its trade balance has been negative for a while now. Since 1994 the Rwandan government has put in more effort by adopting different policies for economic development. Different documents with development targets have been developed for the mid- and long-term. Among these are the Economic Development and Poverty Reduction Strategy (EDPRS) and Vision 2020.

As a result poverty has reduced significantly and the percentage of the population living below the poverty line decreased from 77.8 per cent in 1994 to 44.9 per cent in 2011 (National Institute of Statistics of Rwanda, 2011). As per the World Bank (2012) Rwanda has also improved the conditions of doing business in recent years.

In Rwanda, food prices of many products have increased in recent years. The reasons for this are diverse and inter-related. Rwanda is a developing country with a very high economic growth rate in comparison to its neighbors -- 7.2 per cent between 2003 and 2014 (AfDB et al., 2012; AfDB et al., 2015). The services sector is the main contributor to gross domestic product (GDP) with around a 45 per cent share followed by agriculture with around a 35 per cent share and industry with around a 16 per cent share. Prices and production have changed over time. We discuss price changes in beans and rice. We analyze the prices of beans in five different markets -- Huye, Nyabugogo, Musanze, Gisenyi and Nyagatare (Table 1).

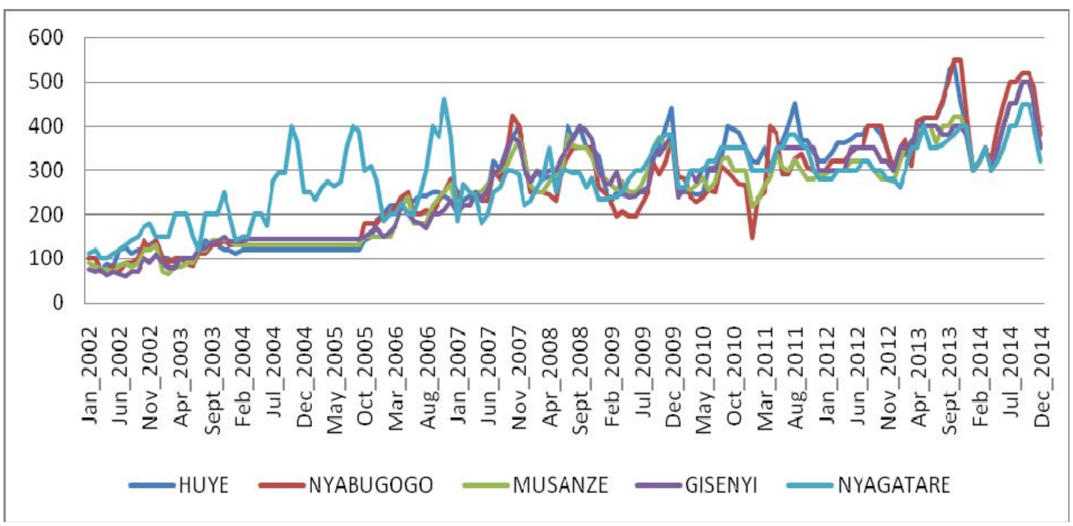
Table 1: Descriptive statistics of retail prices of beans in different markets (2002-14) (in Rwf per kg)

	Huye	Nyabugogo	Musanze	Gisenyi	Nyagatare
Average	264.4	253.9	246.0	255.1	279.0
Minimum	70	70	65	60	100
Maximum	540	550	500	500	463

Source: Authors' computations using data from the Ministry of Agriculture and Animal Resources (MINAGRI) (2016).

Prices of beans increased more than seven times on average in 12 years with increase being the highest (eight times) in the Gisenyi market and lowest at around five times in the Nyagatare market. The average shows that the Musanze market had the lowest price at Rwf 246 per kg (Figure 1).

Figure 1. Retail prices of beans in different markets (2002-14) (in Rwf per kg)



Source: Authors' computations using data from MINAGRI (2016).

Figure **1** shows that the retail prices of beans in all markets had an upward trend between 2002 and 2014. This can be explained by various reasons like an increase in demand in comparison to production (offer) and climate changes where production did not increase as expected.

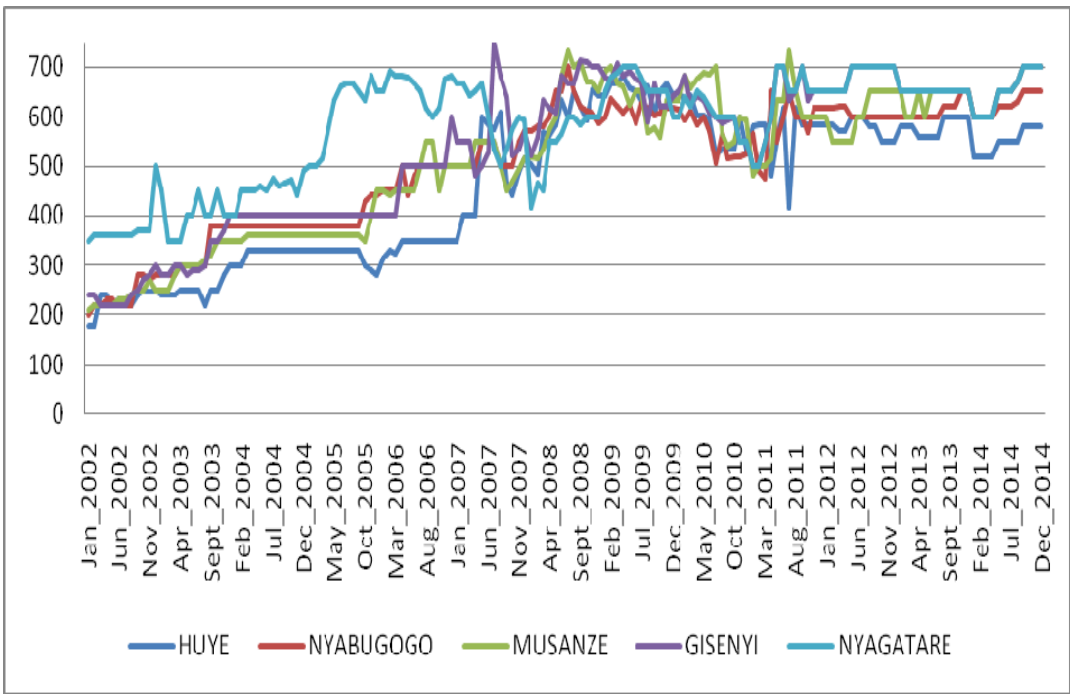
Table 2: Descriptive statistics of retail prices of rice in different markets (2002-14) (in Rwf per kg)

	Huye	Nyabugogo	Musanze	Gisenyi	Nyagatare
Average	465.3	504.2	510.2	533.8	579.3
Minimum	180	200	210	220	350
Maximum	683	700	733	750	700

Source: Authors' computations using data from MINAGRI (2016).

On average rice prices increased around three times between 2002 and 2014 with the highest increase in the Huye market (around four times) and the lowest increase in the Nyagatare market (two times). Figures show that on average the Huye market had the lowest prices at Rwf 465 per kg while the highest rice prices were in the Nyagatare market (Rwf 579 per kg) (Table 2).

Figure 2. Retail prices of rice in different markets (2002-14) (in Rwf per kg)

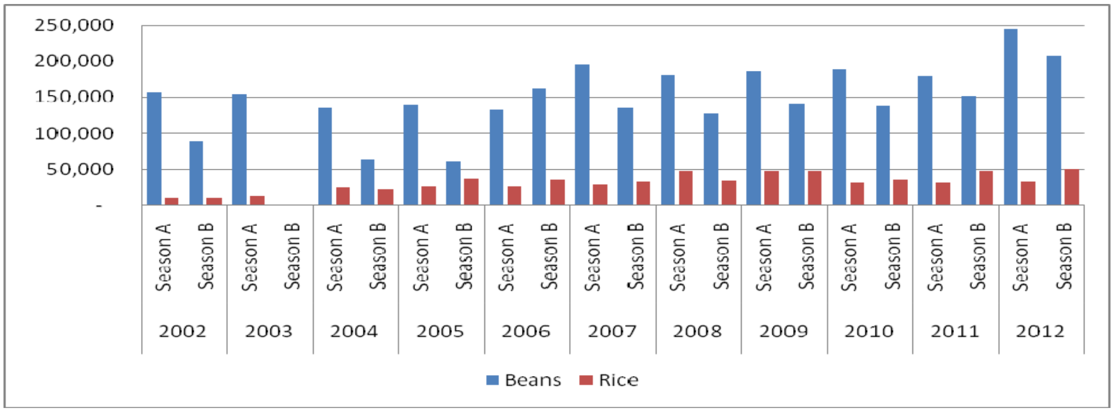


Source: Authors' computations using data from MINAGRI (2016).

On average retail prices of rice increased three times in all the markets between January 2002 and December 2012.

Figure **2** shows that there was an upward trend with fluctuations. After an analysis of retail prices of beans and rice in different markets in Rwanda we analyzed the production of beans and rice in metric tons (MT) in Rwanda (Figure 3).

Figure 3. Production of Beans and Rice (2002-12) (in MT)



Source: Authors' computations using data from MINAGRI (2016).

In general, the production of beans and rice increased but this increase was not significant and the production of beans increased 1.5 times in Season A and 2.3 times in Season B between 2002 and 2012 – a period of ten years -- and rice production increased 3.7 times in Season A and 5 times in Season B in the same period.

Therefore, generating policy relevant evidence and informing policymakers about the situation over time is relevant for interventions to avoid a food crisis. We considered spatial price transmission using the retail prices of food in different markets.

The specific objectives of our study are:

- Examining the existence of short and long run relationships between retail prices of beans and rice in different markets separately;
- Examining the shock effects on the dynamic path of retail prices of beans and rice in different markets separately; and
- Investigating the existence of Granger causality between retail prices of beans and rice in different markets separately;

2. Literature review

Some scholars have analyzed changes in food prices while others have examined the impact of food price transmission. According to FAO et al., (2012) the global food price situation in the world remained relatively stable from the 1970s till the early 2000s. However, since 2005 the prices of agricultural commodities have increased rapidly reaching unprecedented levels. Prices started soaring in 2007 and by mid-2008 they had reached the highest levels in 30 years. Global food prices stabilized over 2009-10 and thereafter starting soaring again for the second time beginning January 2011 and reached a peak in December 2011 exceeding the 2008 levels.

Conforti (2004) shows that price transmission is affected by the following factors: Transport and transaction costs, market power, increasing returns to scale in production, product homogeneity and differentiation, exchange rates and border and domestic policies. There are three types of price transmissions -- spatial price transmission, vertical price transmission and cross-commodity price transmission. In spatial price transmission a commodity is commercialized between two different regions while in vertical price transmission the price of a good increases due to the rising price of one of its inputs and a cross-commodity price transmission happens when the price of a good which may be substituted for another good affect the price of the other good.

Some studies have been done on price transmission using the spatial approach (Conforti, 2004; Getnet et al., 2005; Minot, 2011) and the vertical approach (Conforti, 2004; Goodwin, 2006; Popovics and Tóth, 2005; Vavra and Goodwin, 2005). The food price crisis has many negative impacts for consumers, but it also offers some opportunities for producers.

We analyzed food price transmissions for potatoes and bananas products in Rwanda from the Musanze, Huye, Kibungo, Muhanga and Nyabugogo markets using monthly data for January 2002 and July 2013. Our results show that the prices were co-integrated and there was a long run relationship among the variables that we analyzed (Ruranga and Mutabazi, 2015). An analysis of food price transmission of beans and rice products is not conducted despite it is important to know how changes in prices in one market effect prices in other markets.

3. Data and Methodology

3.1. Data

Data for monthly retail prices was collected for beans and rice. The period of study is from January 2002 to April 2015 with a total of 156 observations. The markets covered are Huye in the Southern Province, Nyabugogo in Kigali City, Musanze in the Northern Province, Gisenyi in the Western Province and Nyagatare in the Eastern Province. Key data sources include the Ministry of Agriculture and Animal Resources and the National Institute of Statistics of Rwanda. This data was used in the spatial price transmission an analysis of beans and rice markets. The variables used are explained in Table 3.

Table 3: Variables and Descriptions

Variable	Description
PBHM	Monthly retail prices of beans in the Huye market
PBNM	Monthly retail prices of beans in the Nyabugogo market
PBMM	Monthly retail prices of beans in the Musanze market
PBGM	Monthly retail prices of beans in the Gisenyi market
PBNyM	Monthly retail prices of beans in the Nyagatare market
PRHM	Monthly retail prices of rice in the Huye market
PRNM	Monthly retail prices of rice in the Nyabugogo market
PRMM	Monthly retail prices of rice in the Musanze market
PRGM	Monthly retail prices of rice in the Gisenyi market
PRNyM	Monthly retail prices of rice in the Nyagatare market

Source: Authors' formulations.

3.2. Unit Root Tests

Stationarity was tested using Augmented Dickey-Fuller (ADF) tests. The general regression equation is presented as:

$$(1) \qquad \Delta Y_t = \alpha + \beta t + \delta Y_{t-1} + \sum_{j=1}^{p} \gamma_j \Delta Y_{t-j} + \varepsilon_t$$

where, α is a constant, β is the coefficient of a time trend series, δ is the coefficient of Y_{t-1} is the lag order of the autoregressive process, $\Delta Y_t = Y_t - Y_{t-1}$ are first differences of Y_t, Y_{t-1} are lagged values of order one of Y_t, ΔY_{t-j} are changes in lagged values and ε_t is white noise. The parameter of interest in the ADF model is δ. The null hypothesis is $\delta = 0$ against $\delta < 0$. If $\delta = 0$, Y_t contains the unit root, this implies that the series is non-stationary.

3.3. VAR Lag Order Determination

The determination of an appropriate lag order in a VAR model was done using the Akaike information criterion (AIC), the Schwarz-Bayesian information criterion (BIC) and the Hannan-Quinn information criterion (HQIC). The general models for this information criteria are formulated as:

$$(2) \qquad AIC(p) = \ln\left|\bar{\Sigma}(p)\right| + \frac{2}{T} pn^2$$

$$(3) \qquad BIC(p) = \ln\left|\bar{\Sigma}(p)\right| + \frac{\ln T}{T} pn^2$$

$$(4) \qquad BIC(p) = \ln\left|\bar{\Sigma}(p)\right| + \frac{2 \ln \ln T}{T} pn^2$$

The AIC criterion asymptotically over-estimates the order with positive probability, while the BIC and HQ criteria estimate the order consistently under fairly general conditions if the true order p is less than or equal to p_{max}.

3.4. Vector Autoregressions (VAR) Standard Form

We used a vector autoregression (VAR) model to analyze linear interdependencies among multiple time series. VAR with p lags in standard form for n variables is given as:

$$(5) \qquad y_t = \psi d_t + A_1 y_{t-1} + A_2 y_{t-2} + \ldots + A_p y_{t-p} + u_t, \quad t = 1, 2, \ldots, T$$

where,

y_t = an (nx1) vector containing each of the n variables included in VAR

d_t = an (qx1) vector of deterministic terms (such as constants, linear trends and dummies)

A_i = (nxn) matrices of coefficients

u_t = an (nx1) vector of error terms. Errors $u_1, u_2, u_3, \ldots, u_T$ are uncorrelated white noise disturbances with mean $E\{u_t\} = 0$ and $E\{u_t u_{t-k}\} = \begin{cases} \sigma^2 \text{for } k = 0 \\ 0 \text{ for } k \neq 0 \end{cases}$, this mean that errors of variances are constant and co-variances are equal to zero. This means u_t is an (nx1) vector with zero mean and a non-diagonal covariance matrix. For further analysis it is suitable to transform Equation 5 and put it in its unrestricted error correction representation.

3.5. Co-integration Tests and the Vector Error Correction (VEC) Model

The theory of integrated variables says that if the series are integrated of order one, I(1), they may have a co-integration relationship. According to Hjalmarsson and Österholm (2007) co-integration methods have been very popular tools in applied economics since their introduction about 20 years ago. Different methods are used to test if the series are co-integrated like the Engle-Granger (EG) approach and the Johansen's procedure. The Engle-Granger approach is the most common single equation approach used for testing co-integration. It has several disadvantages especially for a model with more than two variables where there can be more than one co-integration relationship among the variables (Harris and Sollis, 2003). We used the Johansen approach where the trace test and the maximum eigenvalue test are presented as:

(6) $$\lambda_{\text{trace}}(\text{r}) = -T \sum_{i=r+1}^{n} \ln(1-\hat{\lambda}_i)$$

(7) $$\lambda_{\max}(\text{r, r+1}) = -T \ln(1-\hat{\lambda}_{i+1})$$

where, $\hat{\lambda}_i$ are the estimated values of the characteristics' roots (also called eigenvalues) obtained from the estimated π matrix. T is the number of usable observations.

Let $Y_t = (y_{1t}, \ldots y_{nt})'$ denote a (nx1) vector of I(1) time series. Y_t is co-integrated if there exists an (nx1) vector $\beta = (\beta_1, \ldots \beta_n)'$ such that $\beta' Y_t = \beta_1 y_{1t}, \ldots \beta_n y_{nt}$ □ I(0). In other words, the non-stationary time series in Y_t is co-integrated if there is a linear combination that is stationary or identified of order zero. Enders (2010) demonstrated that the vector error correction model is an appropriate model if the series are co-integrated and is expressed as:

(8) $$\Delta y_t = \psi d_t + \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + u_t$$

where, $\Pi = -(I - \sum_{i=1}^{p} A_i)$ and $\Gamma_i = -\sum_{j=i+1}^{p} A_j$

The reduced rank procedure allows Π to be factorized as $\Pi = \alpha\beta'$ where, α and β are both (nxr) and r is the rank of Π. If the rank of the matrix Π is equal to zero (rank $(\Pi) = 0$), the matrix is null and Equation 8 is the usual VAR model in first differences. If rank of Π $(r) = 1$, there is a single co-integrating vector and the expression Πy_{t-1} is the error-correction term and if $1 < r < n$, there are multiple co-integrating vectors. r corresponds to the number of linearly independent relationships among the variables in y_t. This is advantageous since it delivers a neat economic interpretation of the vector error correction model of Equation 8, whereby the r columns of β represent the co-integrating vectors that quantify the 'long-run' (or equilibrium) relationships between the variables in the system and the r columns of error correction coefficients of α, load deviations from equilibrium (that is, $\beta' y_{t-k}$) into Δy_t for correction, thereby ensuring that the equilibrium is maintained. The Γ_i matrices in Equation 8 estimate the short-run or transient effect of shocks on Δy_t and thereby allow the short and long-run responses to differ. The parameterization in Equation 8 allows the short run adjustment effects embodied in the new equilibrium (which leads to permanent changes in the level) to be distinguished from the effects of lagged differences (which are transitory). If two or more variables are stationary in their first differences, the co-integrated vector error correction (VEC) model is used to describe the dynamic inter-relationship among those variables. Vector error correction models (VECMs) estimate the speed at which a dependent variable may return to equilibrium after a change in an independent variable. VECMs are useful for estimating short-term and long-term effects. The tests of restrictions of the co-integrating vector of intercept or slopes in different models are required.

Impulse-response functions are calculated from reduced forms given in Equation 8 and it is required to have a knowledge of the structural economic representation from which Equations 5 and 8 are obtained. To investigate the dynamic responses of the system from economic variables' shocks additional restrictions on the relationships among economic variables were placed. We used impulse-response functions (IRFs) and variance decompositions to analyze how a shock affected the dynamic paths of all the variables in a VAR model.

3.6. Granger Causality Tests

The Granger causality tests were used to investigate if variable Y can help forecast variable X. If it does not then we say that Y does not Granger cause X (Hamilton, 1994). The Granger causality tests between variables give four possibilities -- unidirectional causality from X to Y, unidirectional causality from Y to X, feedback or bilateral causality and independence or absence of Granger causality (Gujarati and Porter, 2009).

4. Findings and Discussion

We used different techniques to analyze retail prices of beans and rice in five different markets. ADF tests were done to test the stationarity of the data or existence of unit root, the Akaike information criterion (AIC), the Schwarz information criterion (SC) and the Hannan-Quinn information criterion (HQ) for VAR lag order determination while trace and maximum eigenvalue tests were done for co-integration. We also used the vector error correction model and the Granger causality techniques.

4.1 Unit root tests

Unit root tests were conducted to determine the stationarity of retail prices of beans and rice in different markets. The Augmented Dickey-Fuller (ADF) tests were used for retail prices of beans and the results are given in Table 4.

Table 4: ADF tests for monthly retail prices of beans in levels and first differences

Series	Critical value at 5%	ADF test statistic	Prob.
Series at levels			
Prices of beans in the Huye market (PBHM)	-2.880088	-2.087383	0.2501
Prices of beans in the Nyabugogo market (PBNM)	-2.880088	-2.166349	0.2195
Prices of beans in the Musanze market (PBMM)	-2.880088	-1.908973	0.3275
Prices of beans in the Gisenyi market (PBGM)	-2.880088	-1.903624	0.3300
Prices of beans in the Nyagatare market (PBNyM)	-2.880088	-1.697950	0.0550
Series' first differences			
Prices of beans in the Huye market (PBHM)	-1.942910	-11.26585 [a]	0.0000
Prices of beans in the Nyabugogo market (PBNM)	-1.942910	-11.12318 [a]	0.0000
Prices of beans in the Musanze market (PBMM)	-1.942910	-11.07429 [a]	0.0000
Prices of beans in the Gisenyi market (PBGM)	-1.942910	-11.39933 [a]	0.0000
Prices of beans in the Nyagatare market (PBNyM)	-1.942910	-12.55580 [a]	0.0000

Note: [a] significant at less than 1%.
Source: Authors' computations from MINAGRI (2016) data using E-Views 7.2.

The results in Table 4 show that the null hypothesis of existence of unit root is not rejected for retail prices of beans in all markets at levels since the probabilities are greater than the 5 per cent level of significance. ADF test for unit root in the first differenced series shows that all series are stationary at the 5 per cent significance level. If the variables are non-stationary at levels but stationary in the first differences it implies that they are of integrated order one I(1) at levels and integrated order zero I(0) in the first differences. Unit root tests' results using ADF tests for retail prices of rice are given in
Table **5**.

Table 5: ADF tests for monthly retail prices of rice in levels and first differences

Series	Critical value at 5%	ADF test statistic	Prob.
Series at levels			
Prices of rice in the Huye market (PRHM)	-2.880088	-2.143456	0.2282
Prices of rice in the Nyabugogo market (PRNM)	-2.880088	-2.182373	0.2136

Prices of rice in the Musanze market (PRMM)	-2.880088	-1.837675	0.3612
Prices of rice in the Gisenyi market (PRGM)	-2.880088	-1.928545	0.3185
Prices of rice in the Nyagatare market (PRNyM)	-2.880088	-2.382351	0.1484
Series' first differences			
Prices of rice in the Huye market (PRHM)	-1.942938	-7.198986 [a]	0.0000
Prices of rice in the Nyabugogo market (PRNM)	-1.942910	-12.24464 [a]	0.0000
Prices of rice in the Musanze market (PRMM)	-1.942910	-12.61532 [a]	0.0000
Prices of rice in the Gisenyi market (PRGM)	-1.942924	-13.73914 [a]	0.0000
Prices of rice in the Nyagatare market (PRNyM)	-1.942910	-12.27358 [a]	0.0000

Note: [a] significant at less than 1%.
Source: Authors' computations of MINAGRI (2016) data using E-Views 7.2.

The results in
Table **5** show that the null hypothesis of the existence of unit root is not rejected for all variables at levels. ADF test for unit root in the first differences shows that all series are stationary at the 5 per cent significance level. This means that retail prices of rice in different markets are integrated of order one I(1).

4.2 VAR Lag Order Selection

The determination of maximum lag p in a VAR was conducted in the two models of retail prices of beans and rice in different markets. The Akaike information criterion (AIC), the Schwarz information criterion (SC) and the Hannan-Quinn information criterion (HQ) were used for this and the results for retail prices of beans are given in
Table **6**.

Table 6: VAR Lag Order Selection for retail prices of beans

Endogenous variables: PBGM PBHM PBMM PBNM PBNyM
Included observations: 152

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-3927.823	NA	2.05e+16	51.74767	51.84714	51.78808
1	-3508.804	804.9579*	1.15e+14*	46.56320*	47.16002*	46.80565*
2	-3490.702	33.58336	1.26e+14	46.65397	47.74814	47.09846
3	-3475.609	27.00893	1.44e+14	46.78432	48.37584	47.43085
4	-3458.234	29.94851	1.60e+14	46.88466	48.97352	47.73323

Note: * indicates lag order selected by criterion.
Source: Authors' computations of MINAGRI (2016) data using E-Views 7.2.

Table **6** shows that the selected lag in the model of retail prices of beans is one. This means that the appropriate model for analysis of retail prices of beans is VAR (1). The results of lag order selection for retail prices of rice are given in

Table **7**.

Table 7: VAR Lag Order Selection for retail prices of rice

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-4171.690	NA	5.07e+17	54.95645	55.05592	54.99686
1	-3659.203	984.5149	8.30e+14	48.54214	49.13896*	48.78459*
2	-3625.723	62.11408	7.44e+14	48.43057	49.52473	48.87505
3	-3588.682	66.28436	6.36e+14*	48.27213*	49.86364	48.91866
4	-3564.510	41.66393*	6.46e+14	48.28303	50.37189	49.13160

Endogenous variables: PRHM PRGM PRMM PRNM PRNyM
Included observations: 152

Note: * indicates lag order selected by the criterion.
Source: Authors' computations of MINAGRI (2016) data using E-Views 7.2.

In
Table **7** SC and HQ criteria chose lag order one while AIC indicates lag three. If the criteria indicate different lags the use of the lag order given by Schwarz information criterion is recommended. This implies that the selected lag order is one and the appropriate model is VAR (1).

4.3 Co-integration tests

Co-integration tests are done to determine the existence of long-run equilibrium relationships between variables. We used the Johansen co-integration test and the trace test results for beans are given in
Table **8**.

Table 8: Johansen's co-integration trace test results for beans

Null Hypothesis	Alternative Hypothesis	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
$r = 0$	$r > 0$	0.220389	110.3893	69.81889	0.0000
$r \leq 1$	$r > 1$	0.158189	72.04949	47.85613	0.0001
$r \leq 2$	$r > 2$	0.136528	45.53080	29.79707	0.0004
$r \leq 3$	$r > 3$	0.116036	22.92460	15.49471	0.0032
$r \leq 4$	$r > 4$	0.025199	3.930350	3.841466	0.0474

Note: Trace test indicates 5 co-integrating eqn(s) at the 0.05 level.
**MacKinnon-Haug-Michelis (1999) p-values.
Source: Authors' computations of MINAGRI (2016) data using E-Views 7.2.

The trace test indicates that there are five co-integrating equations. The maximum eigenvalue test results for the co-integration test of beans are given in Table 9.

Table 9: Johansen's co-integration maximum eigenvalue test results for beans

Null Hypothesis	Alternative Hypothesis	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
$r = 0$	$r = 1$	0.220389	38.33985	33.87687	0.0137
$r = 1$	$r = 2$	0.158189	26.51869	27.58434	0.0680
$r = 2$	$r = 3$	0.136528	22.60620	21.13162	0.0308
$r = 3$	$r = 4$	0.116036	18.99425	14.26460	0.0083
$r = 4$	$r = 5$	0.025199	3.930350	3.841466	0.0474

Note: Max-eigenvalue test indicates 1 co-integrating eqn(s) at the 0.05 level; **MacKinnon-Haug-Michelis (1999) p-values
Source: Authors' computations of MINAGRI (2016) data using E-Views 7.2.

The maximum eigenvalue test demonstrates that there is one co-integrating equation. Both tests indicate that retail prices of beans in selected markets are co-integrated. The Johansen's co-integration trace test results for rice are given in Table 10.

Table 10: Johansen's co-integration trace test results for rice

Null Hypothesis	Alternative Hypothesis	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
$r = 0$	$r > 0$	0.310939	123.6439	69.81889	0.0000
$r \leq 1$	$r > 1$	0.183894	66.29038	47.85613	0.0004
$r \leq 2$	$r > 2$	0.143145	34.99596	29.79707	0.0115
$r \leq 3$	$r > 3$	0.044397	11.20508	15.49471	0.1992
$r \leq 4$	$r > 4$	0.026977	4.211588	3.841466	0.0401

Note: Trace test indicates three co-integrating eqn(s) at the 0.05 level; **MacKinnon-Haug-Michelis (1999) p-values.
Source: Authors' computations of MINAGRI (2016) data using E-Views 7.2.

The results given in Table 10 using the trace test indicate that there are three co-integrating equations. The Johansen's co-integration maximum eigenvalue test results for rice are given in
Table **11**.

Table 11: Johansen's co-integration maximum eigenvalue test results for rice

Null Hypothesis	Alternative Hypothesis	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
$r = 0$	$r = 1$	0.310939	57.35353	33.87687	0.0000
$r = 1$	$r = 2$	0.183894	31.29442	27.58434	0.0159
$r = 2$	$r = 3$	0.143145	23.79088	21.13162	0.0206
$r = 3$	$r = 4$	0.044397	6.993493	14.26460	0.4899
$r = 4$	$r = 5$	0.026977	4.211588	3.841466	0.0401

Note: Max-eigenvalue test indicates three co-integrating eqn(s) at the 0.05 level;
**MacKinnon-Haug-Michelis (1999) p-values.
Source: Authors' computations of MINAGRI (2016) data using E-Views 7.2.

The results of the maximum eigenvalue test given in Table 11 show that there are three co-integrating equations. The trace test and maximum eigenvalue test give the same conclusions that there are three co-integrating equations.

4.4 Vector Error Correction Model

If the time series are not stationary at levels but stationary in their first differences and co-integrated the appropriate model specification is the vector error correction model. Estimation results of VECM give the parameters in the co-integration equation (β), the adjustment coefficients (α) and short-run coefficients.

4.4.1 Retail Prices of Beans in the Musanze Market (PBMM) Model

Parameters of the co-integrating equation for the VEC model in retail prices of beans in the Musanze market (PBMM) along with their t-statistics are:

$$\Delta PBMM_t = -59.21 + \underset{(5.24462)}{1.39PBHM_{t-1}} - \underset{(-5.92791)}{1.51PBGM_{t-1}} - \underset{(-5.26147)}{1.05PBNM_{t-1}} + \underset{(2.78769)}{0.35PBNyM_{t-1}}$$

(.):t-statistics

All parameters in the co-integration equation of retail prices of beans in Musanze are statistically significant at the 5 per cent level of significance. This implies that there is a long-run relationship between PBMM and PBHM, PBGM, PBNM and PBNyM in Rwanda. The estimates of the short-run parameters of the same model with their standard errors and t-statistics are:

Parameters of PBNM and PBHM in the co-integration equation are statistically significant while those in PBMM, PBGM and PBNyM are not significant.

4.4.2 Retail prices of rice in the Huye Market (PRHM) Model

Parameters of the co-integrating equation for VEC in the PRHM model along with their t-statistics are:

$$\Delta PRHM_t = -396.4 - \underset{(-0.45131)}{0.45PRMM_{t-1}} - \underset{(-8.13444)}{8.19PRGM_{t-1}} + \underset{(6.25385)}{8.43PRNM_{t-1}} + \underset{(0.93370)}{0.48PRNyM_{t-1}}$$

(.):t-statistics

Parameters of PRGM and PBNM are statistically significant at the 5 per cent level of significance and parameters of PRMM and PRNyM are not statistically significant.

This implies that there is a long-run relationship between PRHM and PRGM and PRNM in Rwanda. The estimates of the short-run parameters of the same model with their standard errors and t-statistics are:

$$\Delta PRHM_t = 0.03PRHM_{t-1} + 0.004PRMM_{t-1} + 0.06PRGM_{t-1} - 0.01PRNM_{t-1} - 0.02PRNyM_{t-1}$$

$$(2.41714) \quad (0.484466) \quad (7.27660) \quad (-1.29125) \quad (-0.54802)$$

(.):t-statistics

Short-run parameters in PRHM and PRGM are statistically significant while those in PRMM, PRNM and PRNyM are not significant.

4.5 An analysis of Structural Shocks

An analysis of how a shock effects the dynamic path was done using impulse-response functions (IRFs) and variance decompositions. Impulse-response functions (IRFs) give the dynamic marginal effects of each shock on all the variables over time while variance decompositions demonstrate the importance of each of the shocks as a component of the overall variance of each of the variables over time. The results of impulse-response functions for the beans model are given in
Table **12**.

Table 12: Normalized Impulse-Response Functions (IRFs) for the beans model (in %)

Month	Shock of 100% on PBMM				Shock of 100% on PBHM			
	PBHM	PBNM	PBGM	PBNyM	PBMM	PBNM	PBGM	PBNyM
1	0.00	0.00	0.00	0.00	80.03	0.00	0.00	0.00
2	13.27	20.65	8.39	11.29	94.44	27.69	20.10	2.31
3	14.88	19.97	5.43	6.42	95.02	30.73	17.82	-5.43
4	14.82	21.18	7.16	6.72	94.95	33.73	20.69	-6.88
5	14.36	21.32	6.94	6.26	94.71	34.80	21.05	-8.35
6	14.27	21.50	7.11	6.18	94.53	35.50	21.55	-8.95
7	14.16	21.56	7.13	6.09	94.44	35.85	21.74	-9.34
8	14.11	21.60	7.16	6.06	94.39	36.04	21.86	-9.53
9	14.08	21.62	7.17	6.03	94.36	36.15	21.93	-9.64
10	14.07	21.63	7.18	6.02	94.34	36.21	21.96	-9.70
11	14.06	21.64	7.19	6.01	94.33	36.24	21.98	-9.73
12	14.06	21.64	7.19	6.01	94.33	36.26	21.99	-9.75
Month	Shock of 100% on PBNM				Shock of 100% on PBGM			
	PBMM	PBHM	PBGM	PBNyM	PBMM	PBHM	PBNM	PBNyM
1	117.53	21.35	0.00	0.00	132.70	49.62	13.20	0.00
2	131.96	69.95	-19.24	3.39	149.62	49.89	22.45	9.28
3	138.31	82.86	-18.37	12.82	150.97	61.44	20.62	12.04
4	140.01	88.11	-22.10	16.56	152.14	63.51	19.10	13.33
5	140.71	91.50	-23.24	19.13	152.47	64.67	18.30	14.30
6	141.09	93.14	-24.09	20.38	152.61	65.34	17.82	14.79
7	141.29	94.07	-24.49	21.11	152.68	65.69	17.56	15.06

8	141.40	94.57	-24.73	21.50	152.73	65.88	17.41	15.21
9	141.45	94.84	-24.86	21.72	152.75	65.98	17.33	15.29
10	141.49	94.99	-24.93	21.84	152.76	66.04	17.29	15.34
11	141.50	95.08	-24.97	21.90	152.77	66.07	17.26	15.36
12	141.51	95.12	-24.99	21.94	152.77	66.09	17.25	15.38

Shock of 100% on PBNyM				
Month	PBMM	PBHM	PBNM	PBGM
1	48.01	19.26	-4.49	22.19
2	46.35	18.36	12.85	21.40
3	45.77	16.47	15.42	23.32
4	45.63	13.59	17.78	25.17
5	45.32	12.13	18.85	25.66
6	45.16	11.38	19.47	26.07
7	45.07	10.94	19.79	26.26
8	45.02	10.70	19.97	26.37
9	44.99	10.57	20.07	26.43
10	44.98	10.50	20.12	26.47
11	44.97	10.46	20.15	26.48
12	44.96	10.44	20.17	26.49

Source: Authors' computations of MINAGRI (2016) data using E-Views 7.2.

The results of the reactions of all markets to any shock for 12 months given in Table **12** are interesting and useful for policy formulations. For instance, if a shock is 100 per cent on the retail prices of beans in Musanze it will not affect other markets in the first month; in the second month it will affect all markets with more effect in the Nyabugogo market (20 per cent) followed by the Huye market (13 per cent). This result is aligned with the reality of the Rwandan economy. Table 12 gives information up to 12 months and the effect if a shock is in another market. The results of impulse-response functions (IRFs) for the model of retail prices of rice are given in Table **13**.

Table 13: Normalized Impulse-Response Functions (IRFs) for model of rice (in percentage)

Shock of 100% on PRHM					Shock of 100% on PRMM			
Month	PRMM	PRNM	PRGM	PRNYM	PRHM	PRNM	PRGM	PRNYM
1	0.00	0.00	0.00	0.00	-14.14	0.00	0.00	0.00
2	25.10	16.40	-8.60	9.77	-2.00	29.62	0.93	15.26
3	18.45	22.28	-17.51	13.02	-5.73	22.23	-3.05	19.24
4	24.09	22.15	-18.96	14.97	-4.43	27.22	-1.35	20.04
5	22.10	23.27	-18.67	15.28	-4.78	23.96	-1.09	19.95
6	23.21	22.15	-18.27	15.30	-4.69	25.08	-0.32	19.81
7	22.60	22.50	-17.95	15.19	-4.67	24.27	-0.36	19.71
8	22.84	22.15	-17.92	15.15	-4.70	24.63	-0.27	19.69
9	22.70	22.31	-17.89	15.13	-4.67	24.46	-0.34	19.68
10	22.76	22.23	-17.92	15.13	-4.69	24.56	-0.33	19.69

11	22.73	22.28	-17.92	15.13	-4.68	24.52	-0.34	19.69
12	22.74	22.26	-17.92	15.13	-4.69	24.54	-0.34	19.69
Shock of 100% on PRNM					Shock of 100% on PRGM			
Month	PRHM	PRMM	PRGM	PRNYM	PRHM	PRMM	PRNM	PRNYM
1	-8.68	11.43	0.00	0.00	8.72	16.66	12.24	0.00
2	1.01	37.30	-1.66	9.78	12.93	15.45	32.79	1.65
3	-3.66	31.01	9.15	11.20	9.34	19.89	57.13	6.82
4	-0.69	33.63	9.83	10.04	10.04	24.31	63.60	13.14
5	-2.24	31.74	12.05	9.56	9.36	25.92	65.92	15.77
6	-1.37	32.27	11.55	9.27	9.67	26.30	65.09	16.26
7	-1.83	31.94	11.73	9.27	9.56	26.20	64.70	16.13
8	-1.60	32.09	11.50	9.27	9.64	26.09	64.35	15.96
9	-1.72	32.04	11.54	9.30	9.61	26.04	64.32	15.88
10	-1.66	32.08	11.50	9.30	9.63	26.02	64.30	15.85
11	-1.69	32.06	11.51	9.30	9.62	26.02	64.32	15.85
12	-1.67	32.07	11.51	9.30	9.62	26.02	64.33	15.86

Shock of 100% on PBNyM				
Month	PRHM	PRMM	PRNM	PRGM
1	7.31	17.48	7.47	22.00
2	3.43	10.46	8.57	21.65
3	4.53	9.75	1.97	26.30
4	4.05	8.64	1.11	29.68
5	4.38	8.35	-0.05	30.36
6	4.24	8.17	0.20	30.42
7	4.31	8.19	0.16	30.22
8	4.27	8.19	0.28	30.14
9	4.28	8.21	0.28	30.10
10	4.27	8.21	0.29	30.10
11	4.28	8.21	0.29	30.11
12	4.28	8.21	0.29	30.11

Source: Authors' computations of MINAGRI (2016) data using E-Views 7.2.

Table **13** shows the reactions of prices of rice in different markets due to a shock in one market. For instance, a shock of 100 per cent in rice prices in the Huye market (PRHM) will not affect the other markets in the first month but in the second month PRMM will be more affected at 25 per cent followed by PRNM at 16 per cent. The same analysis can be done with other shocks and reactions in different markets of rice as presented in Table **13**. Variance decompositions results for the beans model are given in Table 14.

Table 14: Variance Decomposition for the beans model

Overall variance / Shock	Month	PBMM	PBHM	PBNM	PBGM	PBNYM

RPMM	1	100	0	0	0	0
	2	96.45719	0.779302	1.88745	0.311838	0.564222
	…	…	…	…	…	..
	12	94.51893	1.468081	3.305856	0.369617	0.337519
RPHM	1	39.04191	60.95809	0	0	0
	2	41.92084	54.86196	2.097634	1.104979	0.014588
	…	…	…	…	…	..
	12	45.56402	46.22177	5.723037	2.148707	0.342466
RPNM	1	56.91524	1.878548	41.20622	0	0
	2	57.37541	9.828465	32.09478	0.680198	0.02115
	…	…	…	…	…	..
	12	56.85035	22.50414	18.15479	1.488582	1.002146
RPGM	1	58.22111	8.141117	0.57614	33.06163	0
	2	63.2827	7.833926	1.073032	27.674	0.136335
	…	…	…	…	…	..
	12	65.93696	11.45005	0.950435	21.12237	0.540188
RPNYM	1	17.47853	2.812733	0.152755	3.734212	75.82177
	2	17.33516	2.756291	0.721073	3.700237	75.48724
	…	…	…	…	…	..
	12	18.44279	1.568668	2.88032	5.675287	71.43293

Source: Authors' computations of MINAGRI (2016) data using E-Views 7.2.

Table 14 shows that after a shock on the retail prices of beans in the Musanze market the effect in the first month will be 100 per cent in the Musanze market; in the second month the effect will be 96 per cent where around 2 per cent will be in the Nyabugogo market and the remaining will be shared by the other markets and after 12 months the effect will be 94 per cent in the Musanze market, 3 per cent in the Nyabugogo market and the remaining will be in the other markets. Table 14 also gives information on shocks and effects on retail prices of beans in the other markets. Variance decomposition results for the rice model are given in Table 15.

Table 15: Variance Decomposition for the rice model

Overall variance / Shock	Month	PRHM	PRMM	PRNM	PRGM	PRNYM
PRHM	1	100	0	0	0	0
	2	92.70076	4.303685	1.837179	0.505534	0.65284
	…	…	…	…	…	..
	12	79.85934	6.876547	6.382399	4.056415	2.825295

PRMM	1	1.958948	98.04105	0	0	0
	2	0.945071	93.90096	4.069775	0.004013	1.080185
	…	…	…	…	…	..
	12	0.288529	92.34307	4.611468	0.009307	2.747625
PRNM	1	0.738183	1.280534	97.98128	0	0
	2	0.486727	9.701458	89.18517	0.017597	0.609052
	…	…	…	…	…	..
	12	0.145054	14.99044	81.97578	1.599636	1.28909
PRGM	1	0.723107	2.643818	1.42663	95.20645	0
	2	1.635096	3.472795	8.237607	86.63615	0.018349
	…	…	…	…	…	..
	12	1.755583	10.44676	63.17739	21.22659	3.393674
PRNYM	1	0.490242	2.804316	0.512003	4.439775	91.75366
	2	0.297513	1.893783	0.590095	4.347376	92.87123
	…	…	…	…	…	..
	12	0.194361	0.877316	0.105192	7.656556	91.16658

Source: Authors' computations of MINAGRI (2016) data using E-Views 7.2.

Table 15 shows how variance decompositions in rice are distributed in different markets from the first month up to 12 months. The importance of the shock is distributed among all the markets. Twelve months after a shock in the Huye market, it will have more importance in Musanze market (7 per cent); a shock in the Musanze market will have more effect in Nyabugogo (5 per cent) while a shock in the Nyabugogo market will have more importance in Musanze (15 per cent).

4.6 Granger causality

Granger causality tests investigate if a scalar "y" can help in forecasting another scalar "x" (Hamilton, 1994). In the Granger causality analysis there are three possibilities -- unidirectional causality, bilateral causality and bidirectional causality -- and absence of causality or independence of series. Results of the Granger causality tests of retail prices of beans in different markets are given in
Table **16**.

Table 16: Granger causality of retail prices of beans in different markets

Pairwise Granger Causality Tests
Sample: 1 156
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
PBHM does not Granger Cause PBMM	155	0.61634	0.4336
PBMM does not Granger Cause PBHM		*8.61609*[a]	0.0038

PBGM does not Granger Cause PBMM	155	2.84248	0.0939
PBMM does not Granger Cause PBGM		3.85035	0.0516
PBNM does not Granger Cause PBMM	155	0.24478	0.6215
PBMM does not Granger Cause PBNM		*7.52996*[a]	0.0068
PBNyM does not Granger Cause PBMM	155	0.07450	0.7853
PBMM does not Granger Cause PBNyM		4.01715 [b]	0.0468
PBGM does not Granger Cause PBHM	155	*11.0172* [a]	0.0011
PBHM does not Granger Cause PBGM		0.08332	0.7732
PBNM does not Granger Cause PBHM	155	2.14953	0.1447
PBHM does not Granger Cause PBNM		*15.9212* [a]	0.0001
PBNyM does not Granger Cause PBHM	155	0.15992	0.6898
PBHM does not Granger Cause PBNyM		3.24088	0.0738
PBNM does not Granger Cause PBGM	155	0.26854	0.6051
PBGM does not Granger Cause PBNM		*6.43324* [b]	0.0122
PBNyM does not Granger Cause PBGM	155	9.9E-05	0.9921
PBGM does not Granger Cause PBNyM		*4.07522* [b]	0.0453
PBNyM does not Granger Cause PBNM	155	2.13707	0.1458
PBNM does not Granger Cause PBNyM		3.11199	0.0797

Note: [a] significant at less than 1% and [b] significant at 5%.
Source: Authors' computations of MINAGRI (2016) data using E-Views 7.2.

The results in
Table **16** show that for retail prices of beans there is unidirectional Granger causality from Musanze to Huye, from Musanze to Nyabugogo, from Musanze to Nyagatare, from Gisenyi to Huye, from Huye to Nyabugogo, from Gisenyi to Nyabugogo and from Gisenyi to Nyagatare. There is no bidirectional Granger causality between all the variables and there is absence of Granger causality between Gisenyi and Musanze, between Huye and Nyagatare and between Nyabugogo and Nyagatare.

Table 17: Granger causality of retail prices of rice in different markets

Pairwise Granger Causality Tests
Sample: 1 156
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
PRHM does not Granger Cause PRMM	155	*6.64340* [a]	0.0109
PRMM does not Granger Cause PRHM		*25.7251* [a]	1.E-06

PRGM does not Granger Cause PRMM	155	*11.9416* [a]	0.0007
PRMM does not Granger Cause PRGM		*14.2607* [a]	0.0002
PRNM does not Granger Cause PRMM	155	*38.5239* [a]	5.E-09
PRMM does not Granger Cause PRNM		*11.5243* [a]	0.0009
PRNyM does not Granger Cause PRMM	155	3.77960	0.0537
PRMM does not Granger Cause PRNyM		1.62707	0.2041
PRGM does not Granger Cause PRHM	155	*11.1272* [a]	0.0011
PRHM does not Granger Cause PRGM		*12.1901* [a]	0.0006
PRNM does not Granger Cause PRHM	155	*28.4451* [a]	3.E-07
PRHM does not Granger Cause PRNM		*5.44135* [a]	0.0210
PRNyM does not Granger Cause PRHM	155	2.64089	0.1062
PRHM does not Granger Cause PRNyM		0.94930	0.3314
PRNM does not Granger Cause PRGM	155	*47.2258* [a]	2.E-10
PRGM does not Granger Cause PRNM		*7.49170* [a]	0.0069
PRNyM does not Granger Cause PRGM	155	1.15335	0.2846
PRGM does not Granger Cause PRNyM		3.40411	0.0670
PRNyM does not Granger Cause PRNM	155	3.05335	0.0826
PRNM does not Granger Cause PRNyM		3.54926	0.0615

Note: [a] significant at less than 1%.
Source: Authors' computations of MINAGRI (2016) data using E-Views 7.2.

The results in
Table **17** show that for retail prices of rice there is bidirectional Granger causality between Huye and Musanze, between Musanze and Gisenyi, between Huye and Gisenyi and between Nyabugogo and Gisenyi. There is no unidirectional Granger causality among the variables and there is absence of Granger causality between Musanze and Nyagatare, between Huye and Nyagatare, between Gisenyi and Nyagatare and between Nyabugogo and Nyagatare.

5. Summary and Conclusions

In recent years food prices have increased and have reduced consumers' purchasing power. We analyzed the spatial price transmission in beans and rice markets in Rwanda using monthly retail prices from January 2002 to December 2014 for 156 observations. Price transmission was analyzed spatially in the selected markets of Huye, Nyabugogo, Musanze, Gisenyi and Nyagatare. Spatial price transmission is important for analyzing the impact of a change in prices in one market in another market. We used different econometric techniques to examine the relationship between monthly retail prices in five different markets.

The retail prices of beans and rice in selected markets had upward trends where on average the prices of beans increased more than two times while the prices of rice increased more than three times. The stationarity test done using the Augmented Dickey-Fuller showed that all the series were not stationary at levels but stationary in their first differences which means that the variables were integrated of order one. Lag selection criteria indicated that the appropriate lag for VAR models was one for beans and rice prices' models separately. The Johansen co-integration test and trace and maximum eigenvalue tests showed that the variables were co-integrated and the findings revealed that there was a long-run relationship between the variables. Vector error correction tests showed that there was a short-run relationship.

We also analyzed structural shocks using impulse-response functions (IRFs) and variance decompositions. IRFs were calculated for the beans and rice markets for 12 months. IRFs showed that a shock of 100 per cent on the retail prices of beans in Musanze led to no affects in the other markets in the first month; in the second month it affected all markets at different levels and the more affected market was Nyabugogo (20 per cent) followed by Huye (13 per cent). IRFs for retail prices of rice showed that a shock of 100 per cent on prices of rice in the Huye market did not affect the other markets in the first month and in the second month Musanze was more affected (25 per cent) followed by Nyabugogo (16 per cent). This result was aligned with the reality of Rwandan economy but further studies are recommended for more details. Variance decompositions showed that after a shock on the retail prices of beans in the Musanze market the effect was 100 per cent in the Musanze market in the first month and in the second month the effects were shared by Musanze (96 per cent), Nyabugogo (2 per cent) and the remaining shared by the other markets. After 12 months the effects were 94 per cent in the Musanze market, 3 per cent in the Nyabugogo market and the remaining in other markets. Retail prices of rice variance decompositions were distributed in different markets and the results showed that after 12 months of a shock in the Huye market, the shock had more importance in the Musanze market (7 per cent); a shock in the Musanze market had more effect in Nyabugogo (5 per cent) while a shock in the Nyabugogo market had more importance in Musanze (15 per cent).

The Granger causality tests demonstrated that for retail prices of beans there was unidirectional Granger causality from Musanze to Huye, from Musanze to Nyabugogo, from Musanze to Nyagatare, from Gisenyi to Huye, from Huye to Nyabugogo, from Gisenyi to Nyabugogo and from Gisenyi to Nyagatare. For rice retail prices there was bidirectional Granger causality between Huye and Musanze, between Musanze and Gisenyi, between Huye and Gisenyi and between Nyabugogo and Gisenyi. These findings are relevant for policymakers and other economic operators.

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