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Price transmission in domestic agricultural markets: the case of retail and wholesale markets of maize in Rwanda

Jules Ngango, Seungjee Hong*

Department of Agricultural Economics, Chungnam National University, Daejeon 34134, Korea

*Corresponding author: hseungj@cnu.ac.kr

Abstract

One of the main challenges receiving much attention in the Rwandan agriculture and food industry in recent decades is the increases in maize prices. Indeed, a rise in maize prices causes higher living expenses for households because maize, which is a major staple food crop, constitutes a significant share of total food consumption among households in Rwanda. The aim of this study was to assess the extent of integration and how prices are transmitted between retail and wholesale markets of domestic maize in Rwanda. This study used monthly data of retail and wholesale prices of maize from January 1995 to December 2019. This empirical investigation was based on a linear cointegration approach and an asymmetric error correction model framework. Using the augmented dickey-fuller residual-based test and the Johansen Maximum Likelihood cointegration test, the results revealed that the retail and wholesale markets of maize are integrated. Hence, prices in these markets do not drift apart in the long run. The results of the Granger causality test revealed that there is a unidirectional causal relationship flowing from wholesale prices to retail prices, i.e., wholesale prices influence retail prices. Accordingly, the results from the asymmetric error correction model confirmed the presence of a positive asymmetric price transmission between wholesale and retail prices of maize in Rwanda. Thus, we suggest that policymakers take a critical look at the causes and factors that may influence asymmetry price transmission.

Keywords: asymmetric price transmission, error correction model, maize markets, market integration, Rwanda

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Introduction

Maize is a major staple food crop in Rwanda that serve as an essential source of nutrition. Over the last two decades, the total maize production has increased substantially from 58,618 Metric tons in 1998 to 1,531,300 Metric tons in 2018 (FAOSTAT, 2019). This growth in maize production is very significant in terms of improving food security in the country (Acquah et al., 2012). However, the performance of the maize production sub-sector in terms of boosting the Rwandan economy has remained unsatisfactory. This is probably due to the barriers concerning policies regulating the market and the low base of market infrastructure, especially in rural areas (Mulinga, 2013; Ngango and Kim, 2019). Particularly, Abdulai (2007) noted that in most Sub-Saharan African countries, agricultural commodities are traded in an environment that is characterized by poor road infrastructures. These poor roads give rise to high transfer costs that possibly will prohibit arbitration between two locations, resulting in fragmented food markets. Moreover, isolated markets may convey inaccurate price information that might distort producer marketing decisions and contribute to inefficient product movements (Abdulai, 2007).

The fundamental economic questions arise here in how the domestic markets of maize are integrated, and how price signals should be transmitted at the national level. A price transmission process is an appropriate approach in investigating the efficiency of the market. Thus, economists who study market efficiency try to determine how the price transmission processes integrate the market vertically and horizontally (Frederick et al., 2018). An understanding of price movements within a country and the degree to which prices are transmitted nationally is of economic significance to a country. Besides, it provides forecast information on how producers and consumers in the domestic markets will react in response to price changes. In addition, Acquah et al. (2012) noted that the integrated markets are important avenues for raising farmers' income levels and promoting the country's economic development. In the state of well-integrated markets, farmers allocate their resources according to their comparative advantage and then invest in modern farm inputs to obtain enhanced crop production; food becomes available and affordable, thereby improving the food security status of households.

Prices of agricultural commodities in Rwanda exhibited high fluctuations in the past two decades, with prices falling during harvest season and rising after that (Nsabimana and Habimana, 2017). Typically, Morales (2018) noted that the significant factors influencing price fluctuations of food crops are the imperfections in price transmission. Price transmission analysis can be used to investigate the relationship between world prices and local prices for a given product, domestic prices for the same commodity in different cities, and prices of two related commodities in the same market channel (Balcombe and Morrison, 2002). Therefore, studies on price transmission provide information on how shocks in one market are transmitted to another, reflecting the competitiveness of markets, effectiveness of arbitrage, and pricing efficiency (Abdulai, 2007).

In the case of Rwanda, a significant issue that has emerged in the past two decades is the increases in maize prices. This increase in maize prices gives rise to higher living expenses for households because maize alone constitutes a significant share of total food consumption among households in Rwanda (Musabanganji et al., 2015). According to Nsabimana and Habimana (2017), the primary causes of maize prices' increases in Rwanda are the high transportation costs, marketing costs, and market power in the maize supply chain. In addition, it is widely viewed that some actors' market power in the maize supply chain leads to imperfections in price transmission (Frederick et al., 2018). Therefore, it is necessary to examine the competitiveness of the maize supply chain and provide a clear understanding of the degree of price transmission between retail and wholesale markets of domestic maize in Rwanda. Indeed, this is a crucial factor in designing appropriate policy insights directed at diminishing the level of living expenses for households.

However, a limited number of studies have attempted to analyze price transmission in the Rwandan agricultural markets. Nsabimana and Habimana (2017) conducted a research study on the asymmetric effects of rainfall on food crop prices. Additionally, Musabanganji et al. (2015) analyzed the price transmission of the major foodstuffs across the three selected local markets of Southern Rwanda. Yet, to the best of our knowledge, the literature does not comprise any study that has attempted to examine the price transmission between wholesale and retail markets of agricultural commodities in Rwanda. Consequently, to address this gap in the literature, this paper's main objective is to analyze the degree of integration and how prices are transmitted between wholesale and retail markets of maize in Rwanda.

Materials and Methods

Data and summary statistics

Monthly nominal wholesale and retail prices of maize from January 1995 to December 2019 (300 observations) were obtained from the National Institute of Statistics of Rwanda (NISR). The prices are measured in Rwandan Francs (RWF) per kilogram (RWF·kg^{-1}). With regards to the summary statistics, Table 1 presents the mean, standard deviation, maximum, minimum, median, skewness, and kurtosis for the nominal wholesale and retail prices of maize during the study period. The results show that the average wholesale and retail prices of maize over the study period were 309.75 RWF·kg^{-1} and 345.50 RWF·kg^{-1}, respectively.

As shown in Fig. 1, the wholesale and retail prices of maize in Rwanda have exhibited notable fluctuations over the study period.

Table 1. Summary statistics of retail and wholesale prices.

Statistics	Retail price	Wholesale price
Mean	345.50	309.75
Standard Deviation	100.75	98.60
Maximum	420.16	378.30
Minimum	297.80	270.00
Median	356.32	309.75
Skewness	- 0.98	- 0.79
Kurtosis	3.77	2.81
Observations	300	300

Nominal prices are expressed in RWF·kg^{-1}.

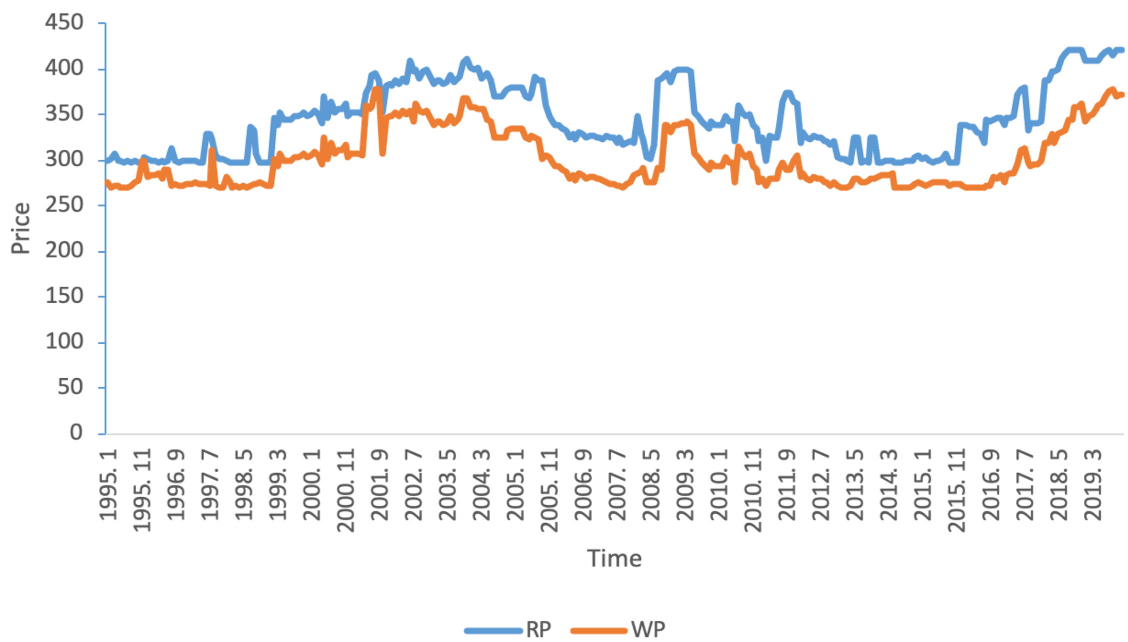

Fig. 1. Graph of the trend in monthly average retail price (RP) and wholesale price (WP) of maize in Rwanda, from January 1995 to December 2019.

Analytical framework

In the empirical literature, several studies have used an asymmetric error correction model (AECM) to test the asymmetric price transmission since the direct estimation of Houck's (1977) model in the presence of cointegrated variables may lead to spurious results (Barahona et al., 2014). The econometric model adopted in this study is based on cointegration because it can be used to analyze the long-run relationship between prices and their short-run adjustment towards equilibrium. Meanwhile, the time-series properties of the data used in this study were conducted before examining price transmission. In particular, the stationarity test, cointegration test, and the asymmetric error correction specification are applied in this study.

Stationarity test

Testing for stationarity is a prerequisite since econometric relation between the time-series has the presence of trend components. Typically, the first step involves determining whether the price series have a unit root or not. This is done by using the augmented Dicky-Fuller (ADF) test (Dickey and Fuller, 1979). The presence of a unit root in the data series implies that the series are non-stationary. If one identifies the series as non-stationary, the first difference of the series is tested for stationarity to determine the order of integration. The number of times (d) a series is differenced to make it stationary is typically the order of integration, I (d). In other words, the I (0) variable is stationary at a level while the I (1) variable needs to be differenced once to make it stationary. The ADF test, as mentioned, considers the null hypothesis that a given series is non-stationary. With the use of retail price (RP), the ADF test is modeled in the following form:

$$\Delta RP_t = \beta_0 + \gamma RP_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta RP_{t-1} + \varepsilon_t \quad (1)$$

Here, ΔRP_t denotes the change in RP_t at time *t*, and ε_t is a pure white noise error term that is independently and identically distributed as a normal distribution with zero mean and constant variance and is assumed to be homoscedastic. Besides, *m* is the number of lags included in the model to ensure that the residuals have zero mean and constant variance. The testing for non-stationarity is performed by testing the null hypothesis that, H_0: $\gamma = 1$ against the alternate hypothesis of stationary, that is, H_1: $\gamma < 1$. Rejecting the null hypothesis implies that the time series data are stationary.

If the non-stationarity tests reveal that the series are integrated of order one, i.e., I (1), the next step is to test for cointegration of price series.

Cointegration tests

As discussed above, cointegration necessitates that the economic variables be non-stationary in order to progress with the following tests. There are two prominent methods for testing cointegration that are commonly used in the empirical literature. Those include the augmented dickey-fuller residual-based test by Engle and Granger (1987) and the Johansen Maximum Likelihood cointegration test by Johansen and Juselius (1990).

Concerning the augmented dickey-fuller residual-based test, Engle and Granger (1987) suggested that if two variables are non-stationary, a linear combination of these variables can be stationary. They developed a two-step approach to test for cointegration between two non-stationary series. The Engle and Granger cointegration approach's basic idea is to test whether the residuals from the ordinary least square estimation are stationary. If the wholesale price (WP_t) and retail price (RP_t) are cointegrated of order one, I (1), the Engle and Granger cointegration is expressed as follows:

$$RP_t = \beta_0 + \beta_1 WP_t + \mu_t \quad (2)$$

$$\Delta\mu_t = \gamma\mu_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta\mu_{t-1} + \varepsilon_t \quad (3)$$

In the above, equation (3) represents the ADF unit root for determining the order of integration of the μ_t term. The term ε_t is a pure white noise error term, and m is the number of lags that are included in the model. The Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) were used to select the appropriate lag length.

The null and alternative hypotheses in the cointegration test are specified as:

❖ H_0: the series are not cointegrated, residuals are nonstationary

❖ H_1: the series are cointegrated, residuals are stationary

Regarding the Johansen Maximum Likelihood cointegration test by Johansen and Juselius (1990). This test is considered more powerful than the Engle and Granger cointegration test. The key drawback of the residual-based test is that it assumed a single cointegrating vector. However, when the regression has more than one cointegrating vector, this method becomes inappropriate (Johansen and Juselius, 1990). The Johansen method permits all possible cointegrating relationships and allows the number of cointegrating vectors to be determined empirically. Johansen and Juselius (1990) suggested two likelihood ratio (LR) tests to estimate the number of cointegrating vectors, namely the maximum eigenvalue test, which tests the null of r cointegrating vectors against the alternative of r + 1 cointegrating vectors. And the Trace test which examines the null of r cointegrating vectors against the alternative of r > 1 cointegrating vectors. Both maximum eigenvalue test and Trace test statistics are expressed as follow:

$$\lambda_{trace} = -2LnQ = -T\sum_{j=r+1}^{P} Ln(1-\lambda_j) \quad (4)$$

$$\lambda_{max} = -2Ln(Q: r+1) = -TLn(1-\lambda_{r+1}) \quad (5)$$

The trace test carries out a joint test for the eigenvalues, whereas the maximum eigenvalue test carries out individual tests for the eigenvalue. The trace and maximum eigenvalue test, most of the time, provide similar results. However, in the situation where they differ, the trace test results are chosen over the maximum eigenvalue test (Alexander, 2001). Both tests have the null hypothesis that there are at most *r* cointegration vectors, and the procedure for determining the number of cointegrating vectors follows a sequential procedure. In the first step, the null hypothesis H_0 ($r_0 = 0$) is tested against alternative hypothesis H_1 ($r_0 > 0$). And when this null hypothesis is not rejected, we conclude that there are no cointegrating vectors among variables. Whereas when H_0 ($r_0 = 0$) is rejected, we conclude that there is at least one cointegrating vector.

Therefore, if a long-run equilibrium relationship exists between time series data, then a vector error correction model (VECM) is used to assess the features of the cointegrated series in the short run. A vector autoregressive (VAR) or an autoregressive distributed lag (ADRL) models can be employed to evaluate the price dynamics in the short-run if the time series data are not cointegrated. Moreover, the Johansen test also allows for testing restrictions on the cointegration relations β and the adjustment speeds α in the VECM (Azzam, 1999).

Asymmetric error correction model (AECM)

The asymmetric error-correction model is an appropriate model for variables found to have one or more cointegrating vectors because it adjusts to both short-run and long-run relationships (Engle and Granger, 1987). To estimate asymmetric price transmission between retail and wholesale prices, the AECM is applied in this study since the direct estimation of Houck's (1977) model in the presence of cointegrated variables may lead to spurious results (Barahona et al., 2014). The AECM is expressed as follows:

$$\Delta RP_t = \beta_0 + \sum_{i=0}^{M} \beta_{1i}^{+} \Delta WP_{t-i}^{+} + \sum_{i=0}^{N} \beta_{1i}^{-} \Delta WP_{t-i}^{-} + \sum_{i=1}^{Z} \beta_i \Delta RP_{t-i} + \varphi^{+} ECT_{t-1}^{+} + \varphi^{-} ECT_{t-1}^{-} + \varepsilon_t \quad (6)$$

Where ΔRP_t and ΔWP_t represent retail and wholesale price changes. ECT_{t-1}^{+} and ECT_{t-1}^{-} denote the lagged positive and negative residuals of the regression between RP_t and WP_t. At this point, for the specification of the Equation (6), we assume that retail prices (RP) are a function of wholesale prices (WP).

The Granger causality test is also performed to ascertain the direction of the causal relationship between WP and RP. In this regards, three possible causal relationships between the two price series (i.e., WP and RP) are the following: 1) a unidirectional causal relationship flowing from WP to RP; 2) a unidirectional causal relationship flowing from RP to WP; and 3) bidirectional causal relationship between WP and RP.

After specifying the model with the ordinary least squares, the null hypothesis, which is applied to test the asymmetric price transmission, is expressed as follows:

$$HO_1: \sum_{i=0}^{M} \beta_{1i}^{+} = \sum_{i=0}^{N} \beta_{1i}^{-}, \text{ and } HO_2: \varphi^{+} = \varphi^{-} \quad (7)$$

The null hypothesis was tested using a joint F-test. In general, the rejection of HO_1 and HO_2 entails that the p-values should be less than 0.05 (i.e., below 5% level of significance).

Results and Discussion

Unit root test results

The results of the unit root tests using the augmented dickey-fuller (ADF) test are reported in Table 2. The p-values or test statistic can be used as a guideline for decision making, accepting, or rejecting the null hypothesis. At level series, by comparing the test statistics with the appropriate Dickey-Fuller critical values, our results fail to reject the null hypothesis of non-stationarity at 1, 5, and 10% level of significance for both retail and wholesale market price series. This implies that both market variables are non-stationary at levels and have a unit root. Therefore, the first difference was taken to attempt to transform them into stationary variables.

After taking the first difference and testing for stationarity with the ADF test, the results in Table 1 show that the null hypothesis of non-stationarity was rejected at the 1% level of significance for both retail and wholesale market price series. Hence, we conclude that wholesale and retail price series are stationary in the first difference, or integrated of order one, i.e., I (1). In the next step, we proceed with the cointegration analysis to establish a long-run relationship among variables, which is one the objective of this study.

Table 2. The results of unit root tests (augmented Dicky-Fuller, ADF).

Variables	Level series		First difference	
	t-statistics	p-value	t-statistics	p-value
Retail price	- 2.721	0.2276	- 13.001	0.0000
Wholesale price	- 2.662	0.2521	- 13.123	0.0000
1% Critical value	- 3.985		- 3.985	
5% Critical value	- 3.425		- 3.425	
10% Critical value	- 3.130		- 3.130	

Cointegration test results

In this sub-section, we undertake the cointegration test to determine the extent of integration between wholesale and retail maize markets in Rwanda. The results obtained from the Engle-Granger cointegration test are reported in Table 3. Typically, the Engle-Granger cointegration analysis is based on the unit root test of the residuals (û) obtained from the OLS regression of the Equation (2). If the ADF test results confirm that the residuals (û) are stationary at level, formerly, the price series are said to be cointegrated. The results listed in Table 3 show that the null hypothesis of no cointegration ($\gamma = 0$) is rejected at the 5% level of significance, confirming retail and wholesale prices of maize are cointegrated.

Table 3. The results of unit root tests (augmented Dicky-Fuller, ADF).

Market	β_0	β_1	R^2	γ
Retail price - Wholesale price	19.46**	0.77**	0.795	- 0.098**
	(14.62)	(21.34)		(- 3.713)

β_0 and β_1 are parameters in equation (2); γ is the parameter in equation (3).

R^2 is a statistical measure that represents the proportion of the variance for a dependent variable that is explained by an independent variables in a regression model, equation (2).

** denotes statistical significance at the 5% level. The t-statistics are given in parenthesis. The critical value for the augmented dickey-fuller at the 5% level is - 2.874.

The results of Granger causality test are given in Table 4. The results indicate that wholesale prices influence retail prices. In other words, these results imply that there is a unidirectional causal relationship flowing from wholesale prices to retail prices. This confirms our assumption made in equation (6), that the retail prices can be specified as a function of wholesale prices.

Table 4. Granger causality test results between retail prices (RP) and wholesale prices (WP).

Causality	Chi-square test statistics	Degree of freedom	p-values
H_0: WP do not influence RP	22.427***	1	0.000
H_0: RP do not influence WP	1.106	1	0.235

*** denotes statistical significance at the 1% level.

Concerning the results of the Johansen cointegration test, Table 5 reports the results. The existence of the r number of cointegrating vectors means that the two variables have a long-run relationship. In particular, the Johansen cointegration test suggests that if the trace statistic test is higher than the critical value, the null hypothesis is rejected. Thus, based on the results in Table 5, the price series exhibited a cointegration relationship at the 1% level of significance. Therefore, we conclude that that retail and wholesale prices of maize are cointegrated, which implies that they have a long-run relationship. This finding allows us to use the asymmetric error correction model to test the asymmetric price transmission between retail and wholesale prices of maize in Rwanda.

Table 5. Results of Johansen cointegration test statistics.

Market	Null hypothesis	Trace statistic	1% critical value (trace statistic)	Conclusion
Retail price - Wholesale price	$r = 0$	39.709	20.04	Cointegrated
	$r \leq 1$	5.568	6.65	

Asymmetric error correction model (AECM) results

To shed light on the primary purpose of this study, in this sub-section, we use the AECM to examine the movement of maize price series in a long-run equilibrium relationship. The results of the AECM are shown in Table 6. Regarding the asymmetry test, the decision to reject the null hypothesis of the asymmetric test requires that the p-values of the joint F test be less than 0.05. The results in Table 6 show that the null hypothesis of the asymmetric test, HO_1, is rejected at the 1% level. Briefly, the AECM suggests an asymmetric price transmission in the domestic maize market of Rwanda.

Table 6 also shows that the rise in wholesale prices for the current period and the previous period (lagged price series) is about 0.317, while its decrease is about 0.171. Specifically, this finding implies that an increase of a unit (i.e., Rwandan franc) in wholesale price generates a change of 0.317 in the retail price. On the other hand, a decrease in a unit in wholesale price causes a change of 0.171 in the retail price. In sum, this finding implies that the increase in maize prices at the wholesalers was more fully transmitted to retailers than the decreases in wholesale prices. This result corroborates with the studies of Frederick et al. (2018) and Barahona et al. (2014), who have also found evidence of asymmetric price transmission in South Korea and Thailand. Nevertheless, the lagged price series are not statistically significant in explaining the influence of a change in wholesale prices to retail prices.

The results for the error correction term (ECT) that captures the speed of price transmission are also given in Table 6. The results show that the speed of adjustment parameters (i.e., ECT^+ and ECT^-) is negative and statistically significant, indicating a degree of market integration and a long-run equilibrium relationship between retail and wholesale prices.

Table 6. Estimated coefficients of the asymmetric error correction model.

Variables	Estimates	p-values
Constant	- 0.261***	0.000
ΔWP_t^+	0.479***	0.000
ΔWP_{t-1}^+	- 0.162	0.207
$\sum \beta_{1i}^+$	0.317***	0.009
ΔWP_t^-	0.294***	0.004
ΔWP_{t-1}^-	- 0.123	0.185
$\sum \beta_{1i}^-$	0.171***	0.004
ECT_{t-1}^+	- 0.232*	0.071
ECT_{t-1}^-	- 0.264**	0.023
Null asymmetric HO_1	0.004	
Null asymmetric HO_2	0.115	
Diagnostics		
R^2	0.71	
AIC	4.15	

The values reported for the null hypothesis of the asymmetric test, HO_1 and HO_2 are the p-values of the joint F test.
AIC, Akaike information criterion.
***, **, and * denote statistical significance at the 1, 5, and 10% levels, respectively.

Conclusion

This paper applies the cointegration and asymmetric error correction methods to assess the degree of integration and how maize prices in Rwanda are transmitted between wholesale and retail markets. The data used in this study involve monthly retail and wholesale prices of maize from January 1995 to December 2019.

The empirical results show that the retail and wholesale maize markets in Rwanda have a common price movement, i.e., they are integrated into the long run. Therefore, the prices do not drift apart in the long-run. The results of Granger causality test reveal that there is a unidirectional causal relationship flowing from wholesale prices to retail prices, i.e., wholesale prices influence retail prices. Furthermore, we found evidence that the price adjustment towards the short-run equilibrium after a shock is asymmetric, and it is characterized by positive asymmetric price transmission. Specifically, our results suggest that the increase in maize prices at the wholesalers was more fully transmitted to retailers than the decreases in wholesale prices.

Based on the results of the study that confirmed asymmetric price transmission, which is typically considered as an evidence of market imperfection, the following policy implications are proposed. Policymakers should be careful in planning mechanisms of efficient transfer from wholesale to retail level in order to increase the competitiveness in the maize market supply chain and improve the market efficiency.

Nevertheless, our study did not manage to approve the sources of this asymmetric price transmission. Hence, further research in this field should focus on determining the causes of the asymmetry.

Authors Information

Jules Ngango, https://orcid.org/0000-0002-9584-5318
Seungjee Hong, https://orcid.org/0000-0002-8277-5090

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