Market Power in Rice Markets

Error Correction Modelling on Palay and Rice Prices

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Abstract

I model an oligopoly rice production market and derive a reduced form equation relating wholesale rice prices and palay farmgate prices. I estimate the reduced form market power parameters through VECM using national palay and rice prices.

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1 Introduction

In this paper, I build an oligopoly model of the rice market that features both buyer and seller power at the level of trader-millers. This oligopoly model can derive a reduced form relationship between wholesale rice prices and farmgate prices which allows a test to determine the existence of market power in this part of the supply chain. The reduced form may also allow the quantification of the oligopoly conduct parameter, which is a measure of market power in the market.

This market is part of a vertical supply chain for rice, and is simplified here as containing the millers and traders as buyers of palay, who would then would transform palay into rice. There are several possibilities for the structure of the supply chain at this level.[1] Using wholesale rice and farmgate palay is due to the practical limitation of data collection by the Philippine Statistical Authority(PSA). A much more specific test for the existence of market power would entail using buying and selling prices for traders (or trader-millers) for palay. However, the current long series from the PSA does not survey traders. Moreover, there could be several levels in the supply chain between farmgate prices for palay (which we will assume will be the farmer's selling price; although this is not necessarily the case), and the wholesale price of rice, which further complicates the interpretation of the coefficients as the exercise of market power by specific groups of actors.

In the empirical portion of this paper, I run a vector error correction model (VECM) on national average farmgate and wholesale prices to estimate the reduced form parameter linked to market power parameters. The VECM estimates the long-run relationship between non-stationary time series. With this model, I uncover evidence for market power in this part of the supply chain, and I argue that this is mainly buyer power over farmers. The quantificationfrom the VECM estimates for market power is supported by previous cost and return studies for rice. Moreover, I also run the same model at a higher level in the supply chain – wholesale rice and retail regular milled rice – and do not find evidence of buyer or seller market power at that level of the supply chain.

1.1 Market Power Studies for Rice

The expectation is that there will be some market power in farmer to trader/miller level of the supply chain. Research on rice value chains, such as by Mataia et al. (2018) has identified trade flows which indicated that palay markets are local, while the rice market is much broader. Through surveys and key player interviews, they were able to construct estimates of the costs and revenues for the 2014-2015 rice producing season.

Research has been able to quantify this marketing margin along different legs of the supply chain, and compared it to Vietnam and Indonesia as benchmarks. In addition to Matia et al., Bordey et al. (2016) conducted a survey of traders, miller and wholesalers and looked at the gross marketing margin, the difference between wholesale and farmgate prices, and compared them across ASEAN countries. They find that the Philippines' gross marketing margin is significantly larger than the next largest margin of Indonesia's with Php 9.06 vs Php 5.61.

There has also been work on testing theories of spatial market integration. Given the trade policy environment until recently, with the tarrification law, it is not expected that world prices track domestic rice prices. As expected therefore, Briones (2018) rejects cointegration of the Rice Border Price (proxied by Thai White Rice) and national well-milled rice prices. He upholds cointegration between regions, similar to other older studies, such as (Silvapulle and Jayasuriya (1994)). The the error correction model has been used in agricultural economics in studies on market power, such as in Kopp and Sexton (2020) and market integration, such as Ihle, Brummer, and Thompson (2012).

[1] See, for instance Mataia et al. (2018) great work on *Rice Value Chain*.

However, very little work has been done on the investigation of the existence or the size of market power. The few exceptions include an early paper by Reeder (2000) who looks at the hypothesis of symmetric price transmission for positive and negative price changes of farmgate to wholesale, and wholesale to retail. Like most studies of asymmetric price transmission, she posits a hypothesis for a competitive market to be a cost plus a constant margin. Implicitly, it would also imply a symmetric transmission between positive and negative cost changes; that is, if costs were to rise, players would simply increase their prices to maintain margins. The same goes for cost decreases. She argues that asymmetric price responses could be due to market power, although she recognizes that even if asymmetry is found, it need not be due to market power.

Reeder reports her results as follows: a) the hypothesis for symmetric price adjustments cannot be rejected for either Farm to Wholesale, or Wholesale to Retail; b) the speed of adjustments for Wholesale to Retail vis-à-vis Farm to Wholesale is 3 months to 1 month; c) the size of transmission elasticities (whether positive or negative) is much larger for Wholesale to Retail [estimates of .75 to .85 pesos of Retail to a change in wholesale] than Farm to Wholesale [.44 to .02].

Contradicting Reeder's finding on price symmetry is Briones (2018), who finds that positive and negative changes in palay prices affect wholesale prices (well milled rice) differentially using regional data from 1990 to 2016. He finds positive one peso price change results in a change of wholesale prices equal to 1 (full transmittal), while a one peso negative price change will decrease wholesale prices by 0.24.

2 Model

We consider the perfectly competitive palay market on the farmer's side. Our farmers provide a homogenous palay product with a constant returns to scale technology. This gives rise to an industry supply function $Q^P = S(p_f|W)$, where W is a vector of supply side shifters for palay production. We will work with the inverse palay supply function $p_f = S(Q^P|W)$.

Rice is produced by Millers from a linear transformation function $Q^R = aQ^P$, a process which includes drying and milling. Further, producing a unit of rice will entail spending $C(X)$ in a linear cost function, where X is a vector of Miller-Trader cost shifters. Miller traders buy palay from farmers at the price p^F, and then transform paddy rice into rice, which they sell at the wholesale price. Miller traders sell rice according to the inverse demand function $P^W = D(Q^R|\lambda)$.

2.1 Miller-Trader Market Power

In this model, Miller-Traders have market power. We generically include two types of market power: output market power and buyer market power. This market power will affect the profit maximization equilibrium in the supply chain. The Miller-Traders collectively maximize:

$$\Pi^M = P^W(Q^R|\lambda)Q^R - p_f\left(\frac{Q^R}{a}\right)\frac{Q^R}{a} - C(X)Q^R \tag{1}$$

A few notes on Equation (1): The production function converts palay into rice at a given rate a, so can be freely included and quantity can be measured in terms of either palay or rice, and here, we chose Q^R. Second, the rice demand function P^W and the palay supply function p^F are affected by the quantity produced by the industry and the firms take that into account when setting quantities.

Given this market power on the selling side, we have the result that marginal revenue is less than the price, $MR < P^W$. We can write out marginal revenue as $MR^W = P^W + \frac{\partial P^W}{\partial Q}Q\mu^W$. The first term is just the wholesale price of rice. The second term involves the slope of the demand curve, which is negative, and μ^W, which is our conduct parameter at this level of the supply chain. A $\mu^W = 1$ indicates monopoly market power and $\mu^W = 0$ is perfect competition. Hence, the conduct parameter gives us the competition at this level of the supply chain.

With market power on the buying side, the marginal cost of procuring palay is greater than p^F. Specifically, $MC^F = p^F + \frac{\partial p^F}{\partial Q}Q\mu^F$. The first term of MC^F is the farmgate price of palay. The second term is the slope of the supply curve and buyer power conduct parameter μ^F. Similar to the selling conduct parameter, a $\mu^F = 1$ is a monopsonist and a $\mu^F = 0$ is a perfectly competitive buyer.

The miller-traders in the market maximize the profit by taking the derivative of profit with respect to Q. This gives us:

$$P^W + \frac{\partial P^W}{\partial Q}Q\mu^W - \frac{p^F}{a} - \frac{\partial p^F}{\partial Q}\frac{Q}{a}\mu^F - C(X) = 0 \tag{2a}$$

$$\frac{p^F}{a}\left(1+\theta^F\right) = P^W\left(1+\theta^W\right) - C \tag{2b}$$

$$\frac{p^F}{a} = P^W\frac{\left(1+\theta^W\right)}{(1+\theta^F)} - \frac{C}{(1+\theta^F)} \tag{2c}$$

The third equation is a rewriting of the industry optimality condition with the market power terms collected as θ^F on the buyer side and θ^W on the selling side. The cost term $\tilde{C}$ collects the separable cost terms from producing and procuring palay. The market power terms are $\theta^F = \frac{\mu^F}{\varepsilon^S}$ and $\theta^W = \frac{\mu^W}{\varepsilon^D}$, the inverse of the elasticities of demand and supply multiplied by their respective conduct parameters.

Table 1 lists down the competition implications of the market power terms. Note that these terms embody both the elasticites of demand and supply (for palay), as well as the conduct paramters μ^W and μ^F.

Table 1: Market Power Parameters

Market Power Parameter	Magnitude	Interpretation
θ^F	>1	Has Buyer Power
	=0	No Buyer Power
θ^W	<1	Has Seller Power
	=0	No Seller Power

We are unable to identify the components of θ^W and θ^F using only price data. However (2c) gives us our estimating equation, which a reduced form interpretation of the market power parameters. Some manipulation gives us:

$$\tilde{p_t^F} = a + bP_t^W + e_t \tag{3}$$

In the estimating equation, $\tilde{p_t^F}$ is the adjusted palay farmgate, adjusted by milling efficiency a. Furthermore, the coefficient b is $\frac{(1+\theta^W)}{(1+\theta^F)}$. From Table 1, $b < 1$ if either or both θ^W or θ^F are not equal to 0. I will be testing if the long-run relationship between these price series has a b economically and statistically different from 1. The error term e_t will be added as part of the time series regression model.

3 Empirical Section

In this section, I test the hypothesis emanating from the theory, from Estimating Equation (3). Our data is the national price series for farmgate palay and wholesale regular milled rice from the Philippine Statistical Authority, available on their website[2], from January 2010 to June 2019 on a monthly frequency.

We are interested in the equilibrium long run relationship between the farmgate and wholesale price series. As such, the appropriate econometric model to investigate this is the error correction model. The ECM allows us to determine what this long run relationship is by determining if they are cointegrated, and if they are – estimating the cointegrating vector between the two time series.

As a first step we will first check if the series are stationary. If they are stationary, OLS is consistent and we can proceed with a linear model in levels. If they are non-stationary, then there is a possibility that they are cointegrated. We plot the farmage and wholesale prices in Figure 1 and it appears that both farmgate and wholesale RMR have the same behavior over the nine years in the dataset. Before proceeding to the VECM estimation, we scale up the units of farmgate price by $a = .64$ so that the farmgate series has the same units as wholesale rice. The conversion factor of comes from Mataia et al. (2018) who gives us the average milling efficiency for the Philippines. I will also use data primarily from before the

[2] PSA OpenSTAT - Philippine Statistics Authority https://openstat.psa.gov.ph

rice tarifficiation which occurred in March 2019. This event will likely change the equilibrium relationship in the palay market as imports are substitutable to local production.

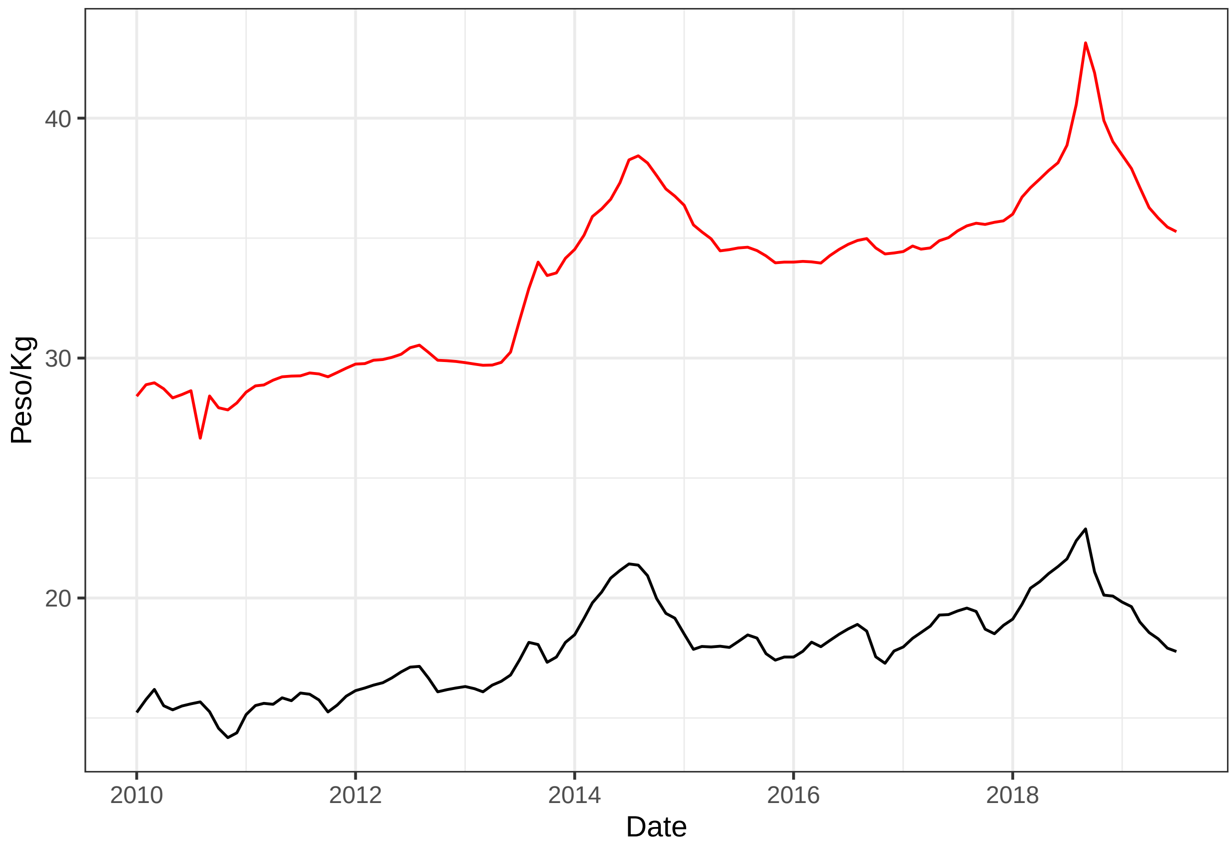

Figure 1: Regular Milled Rice Wholesale Price (RED) and Farmgate Price, National

3.1 Unit Root Tests

To check if they are stationary, we test the series using the Augemented Dickey-Fuller (ADF) test. The needed lags in the ADF regression is selected via the AIC. In the test, we use the specification which includes a constant and trend term. For the farmgate and wholesale price, I am unable to reject the null hypothesis of integration of order 1 in Table 2. A follow-up test on the differenced farmgate and wholesale price was conducted and the null hypotheses of integration of order 2 was rejected. Both series are integrated of order 1, which is needed in the Vector cointegration test.[3] As a note, the VECM estimation does not require that the series are all I(1), only that the integration order is at most one.

[3] Also not reported here are the results of the KPSS test, which similarly rejects the null of stationarity for both series.

Table 2: ADF Test Results

Series	Test Stat	Crit Stat (5%)
RMR Farmgate	-3.019585	-3.43
RMR Wholesale	-2.124516	-3.43

3.2 Johansen Cointegration Test

Given both series are I(1), we now proceed to the Johansen test to determine the cointegration rank. Recall that two series which are non-stationary may be related such that a linear combination of them is stationary: $P^F + \beta P^W \sim I(0)$.Tests using the Johansen procedure (See Johansen and Juselius (1990) and Johansen (1991)), are based on the VECM specification:

$$\Delta y_t = \Pi y_{t-1} + \sum_{i}^{p-1} \Gamma \Delta y_{t-i} + \epsilon_t \tag{4}$$

In our application $y_t = [P_t^F, P_t^W]$, and are I(1), hence Δy_t should be I(0). If the LHS is I(0), then the right hand side must be I(0). Since the right hand side contains Πy_{t-1}, it must be that this must be non-stationary as well. The 2 x 2 coefficient matrix Π can be decomposed into the product of two vectors $\Pi = \alpha\beta'$, where α is interpreted as the % deviation from equilibrium eliminated in one period (one month) and β is the cointegrating vector of length K, where the first element is normalized to one.

The rank of the Π determines the cointegration order. Generally, this will be a K x K matrix with a rank r, where $0 \leq r \leq K$. If the rank of Π is 0, then there is no cointegrating relationship, and the VAR must be estimated in first differences to deal with non-stationarity. If the rank is K, then the vector y_t can be estimated in a VAR with levels. Sequential statistical tests regarding value of the likelihood ratio based on a hypothesized r is conducted according to either the *trace* or *maximum eigenvalue* statistic derived from the maximum likelihood estimation of $\hat{\Pi}$'s eigenvalues (Johansen 1988; Johansen and Juselius 1990).

Before the cointegration tests can be performed, one must first specify the lag order in the VECM specification. In this paper I looked at the lags that minimizes the AIC, BIC, FPE and HQ statistics.[4] Different lag orders were recommended, with the AIC and FPE recommending 12 lags, the BIC recommending 1 and the HQ recommending 2. I used the 12 lags recommendation to conduct the test for cointegration order.

Both test statistics do not reject a single cointegration relationship. With the cointegration order, we can now estimate the VECM itself, with 12 lags and controling for a linear trend outside the cointegrating equation.[5]

The equation for the relationship of Farmgate to Wholesale is given in (5), and is consistent with the hypothesis of market power in this segment of the supply chain. Our coefficient is

[4]See Lutkepohl (2007)

[5]Estimating the VECM was done in the Python package `statsmodels.tsa`.

Table 3: Johansen Test Statistics

r^0	**Trace Test Stat**	**Trace Critical Value**	**Max Eigen Stat**	**Max Eigen Critical Value**
0	24.52	15.49	22.9	14.26
1	1.55	3.841	1.55	3.84

Table 4: VECM Results for Farmgate and Wholesale Rice Prices

	coef	**std err**	**z**	**P> |z|**	**[0.025**	**0.975]**
α_1	-0.2921	0.137	-2.135	0.033	-0.560	-0.024
	coef	**std err**	**z**	**P> |z|**	**[0.025**	**0.975]**
P^F	1.0000	0	0	0.000	1.000	1.000
P^W	-0.7134	0.055	-13.021	0.000	-0.821	-0.606
const	-3.4063	1.509	-2.257	0.024	-6.364	-0.448

$\hat{\beta} = 0.71$. While I have not separately identified the selling or buying side market power terms, we can surmise that most of it is from the buying side. The primary reason is conceptual. The wholesale rice market is national in scope, while palay purchases tend to be regional or provincial.

$$p_t^F = \underset{(1.5)}{3.4} + \underset{0.05}{0.71} P_t^W + e_t \tag{5}$$

Moreover, the estimates here align well with current knowledge on marketing costs of production. The constant is 3.4 pesos, which is deflated by $1 + \theta^F$. The marketing costs of traders and millers sum up to 4.43 nationally.[6] This gives us an estimate of $\hat{\theta}^F$ of 0.303. This estimate of θ^F agrees with the β estimate of 0.71 because $1/1.3 \approx 0.77$. The α term is also interesting as a one unit shock to the equilibrium relationship results in returning to the equilibrium 29% per period by lowering the value of P^F. Its half-life (the time needed to eliminate half the deviation) is 2.39, or about 3 months (one quarter).

What is the interpretation of $\hat{\theta}^F$ in terms of the primitives of elasticity of supply and the conduct parameter? Supposing that this is exclusively monopsony, it can be recalled that $\theta^F = \frac{\partial p^F Q}{\partial Q p^f} \mu^F = \frac{\mu^F}{\varepsilon^s}$. Using the estimate from Balié and Valera (2020) of $\varepsilon^S = 0.55$, we have that the conduct parameter $\mu^F = .19 = .34 * .55$, which is the market power from a five firm oligopsony.

The typical post-estimation diagnostic is to check if the residuals of the VECM have significant autocorrelations up to a lag $h > p$. This test checks if the VECM specification indeed produces *white* noise in its residuals. Large orders of h should be considered for the test for χ^2 distribution to hold (Lutkepohl (2007)). I set the h to twice that of the VECM lag length, and we cannot reject the null that all the lags jointly up to h are zero.

[6] see Mataia et al. (2018), Table 41 and Table 43

3.3 Robustness Test for Market Power

As a robustness check on our economic interpretation of market power in this level of the supply chain, I present results from a VECM using wholesale RMR prices and Retail RMR prices. Our model from (3) can be re-interpreted as the relationship between wholesale and retail RMR prices, with the same market power parameters. In this situation however, our prior is that there is no market power because the geographic market for rice is nationwide. Thus, on the wholesale buying side and the retail selling side, there is an expectation that there is no market power. I apply the same VECM test on these two series. They are both non-stationary and I(1). In equation (6) I estimated the long-run parameter and, as expected, the coefficient on retail prices is 1.02 and statistically indistinguishable from 1.[7]

$$p_t^W = \underset{(1.2)}{-3} + \underset{0.04}{1.02} P_t^R + e_t \tag{6}$$

4 Conclusions

Supply chains and geographical markets in emerging economies tend to be more fragmented due to trade costs. These same trade costs create the opportunity to exercise more power in parts of the supply chain and small markets. This paper contributes to the research on market power in Philippine rice markets by applying error correction to the optimality condition with market power. I have further argued this is likely buyer power, and the discussion in this paper points to an upper bound to buyer power at the national level. While I have not provided an estimate of the elasticity of supply, recent estimates for the elasticity of supply suggests that the conduct parameter is akin to a five firm oligopsony.

To fully leverage these structural estimates of market power, either elasticity of demand and supply – preferably both – must be estimated to identify conduct parameters. Further research can be done to estimate these crucial parameters. These parameters will allow the researcher to measure changes in consumer welfare through counterfactual experiments eliminating the market power parameters. More research can be done on a regional level to see if there are strong geographic heterogeneity in market power estimates. A further avenue for future work is to incorporate structural changes in the model. An example is the 2019 tariffication. While this policy change likely reduced the demand for palay, it might have also increased buyer market power. A model that allows one to disentangle these separate effects will be crucial.

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[7]The AIC and FPE recommends 4 lags.

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