

# Using the Nerlovian Adjustment Model to Assess the Response of Farmers to Price and Other Related Factors: Evidence from Sierra Leone Rice Cultivation

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**Abstract**—The goal of this study was to increase the awareness of the description and assessments of rice acreage response and to offer mechanisms for agricultural policy scrutiny. The ordinary least square (OLS) technique was utilized to determine the coefficients of acreage response models for the rice varieties. The magnitudes of the coefficients ( $\lambda$ ) of both the ROK lagged and NERICA lagged acreages were found positive and highly significant, which indicates that farmers' adjustment rate was very low. Regarding lagged actual price for both the ROK and NERICA rice varieties, the short-run price elasticities were lower than long-run, which is suggesting a long term adjustment of the acreage under the crop.

However, the apparent recommendations for policy transformation are to open farm gate prices and to decrease government's involvement in agricultural sector especially in the acquisition of agricultural inputs. Impending research have to be centered on how this might be better realized. Necessary conditions should be made available to the private sector by means of minimizing price volatility. In accordance with structural reforms, it is necessary to convey output prices to farmers with minimum distortion. There is need to eradicate price subsidies and control, which generate distortion in the market in addition to huge financial costs.

**Keywords**—Acreage response, rate of adjustment, rice varieties, Sierra Leone.

## I. INTRODUCTION

AGRICULTURAL sector is the mainstay of most developing nations and is the largest foodstuffs producer and thus far, continues to play a central role in these developing economies. It also contributes to the national gross domestic product (GDP), creates employment for the labor force as well as offering a better livelihood to a substantial number of the population, and as a results assist to alleviate poverty in these developing nations.

There are various arguments to support the concept that farmers in less developed nations such as Sierra Leone do not respond to financial incentives such as price.

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The various existing studies for most of these nations at the crop level have relatively arrived at similar conclusion that the supply response is less elastic [1]. The reasons mentioned for the poor response actually varied from issues related to constraints on finance, infrastructure, irrigation etc. to the absence of consistent agricultural policies.

Calabresi [2], Sen [3], and Binswanger [4] analyzed farmers' response regarding resource allocation in some developing nations (Sierra Leone inclusive) to the ultimate changes in prices. Their results showed that farmers had been persistently adjusting their allocation of resources such as land and capital among crops in response to changes in prices and sufficiently reinforced the hypothesis of farmers' coherent response to financial incentives in their primitive agricultural practices. Correspondingly, studies centered on cross sectional data both from Uganda by Kassie [5] and United State by Salois [6], suggested that most times well-organized allocation of several input factors are not well managed by the majority of the farmers for increasing agricultural production through reallocation of certain resources.

The Agricultural sector in Sierra Leone during the past three decades has not witnessed significant growth both in the factor as well as product markets; instead, it has witnessed many policy changes that resulted in unbeneficial changes in the structure of market incentives confronted by farmers.

Nevertheless, several of these fluctuations have been crop specification, since there have been widespread disparities in major changes in the incentive package [7]. Similarly, the performance of several crops over a particular period replicated wide disparity, possibly in response to changing incentives. Hence, this study assesses the performance of rice crop in Sierra Leone regarding cultivated area as well as the contributions of market incentives with respect to the problem under consideration. However, the insufficient level of the crop's cultivation in Sierra Leone is evidenced by countless problems particularly the endless flared supply as well as the demand for the crop within the country.

Consequently, this has instigated the government to spend huge money on the importation of the grain that should have been locally cultivated at a cheaper cost.

In the early 1960s and early 1980s [8], Sierra Leone was rice grain self-sufficient and even export some key agriculture crops such as cocoa, coffee and rice [9] to earn foreign exchange. Furthermore, rice cultivation was one of Sierra

Leone's major subdivisions of agricultural production that offered the country a place in the mid-1960s for rice exportation in the international market. However, mismanagement by state authorities in the mid-1980s led to the over dependence in rice grain importation.

Additionally, the civil war that engulfed the entire state in the early 1990s to 2001, as well disrupted agricultural activities [10]. Subsequently, there exist a wide food supply-demand gaps [11] and increasing food imports cost [12].

Nonetheless, there exists voluminous empirical literature regarding agricultural supply response. Some of the prominent researchers that have made significant researches on agricultural supply response include Behrman [13], Rao [14], Braulke [15], Bond [16], Strauss [17], Schiff [18], Thiele [19], De Castro [20], Figueiredo [21], Zhang [22], Mooney [23], and Arnade [24].

The aim of this study is to increase the awareness of the description and assessments of rice acreage response in addition to offer a mechanism for the agricultural policy scrutiny. The specific objectives of this research include the quantification of acreage responses of rice within the period 1980-2011, use a reasonably new dynamic methodology to solve the problem under consideration, estimate as well as comparing both short-run and long-run elasticities, and finally to recognize the factors upsetting crop supply response in Sierra Leone.

## II. DATA SOURCE AND MODEL SPECIFICATION

### A. Data Sources

Some data on yield, cultivated area and prices of several crops over the years were retrieved from Food and Agricultural Organizations database (FAOSTAT, 2012). Other data were from government agencies in Sierra Leone for instance, the Ministry of Agriculture, Forestry [25] and Food security (MAFFS); the Sierra Leone Agricultural Research Institute (SLARI); Statistics Sierra Leone (SSL), International Financial documents, Organization for Islamic Nations database and African Development Indicators documents.

In addition, the study sourced information from published articles from reputable journals.

The data set covers the period 1980-2011[26].

### B. Model Specification

In this section, the sources, nature as well as limitations of the data in addition to specification concerns are deliberated. Also, the empirical analysis will be accompanied with a sample of yearly data for the rice crops within the period 1980-2011.

Here, two important rice varieties are discuss and these include the ROK and NERICA varieties, which are disseminated to all Sierra Leonean farmers by the Sierra Leone Agricultural Research Institute (SLARI). These varieties have some advantages such as the high yielding potential, high protein content, short life span and palatability.

However, there are very few additional crops that compete alongside with rice in many specialized rice growing areas

within the country as a result of technical restrictions and agro climatic conditions [27]. Yet, there are several regions where rice faces strong opposition from other crops. Additionally, there is competition between ROK and NERICA rice varieties regarding land use and other resources equally in the specific rice growing areas.

Besides the financial factor as showed by the prices of a particular rice grain, many other factors such as the accessibility of water supply and other agricultural inputs, infrastructural upgrading, support from different institutions, economic benefit of challenging crops, etc., influence on farmers' allocation of available resources to a particular crop. Many estimated models used the area cultivated by the crop as the dependent variable. The cultivated area has been favored over the production since farm production is similarly influenced by climatic conditions that cannot be controlled by the farmers. Similarly, yield is an issue of random variation than area cultivated because of some factors that are uncontrollable by farmers.

Based on the comprehensive literature review, consultations with agricultural specialists and experienced farmers assisted to classify the subsequent issues impacting on farmer's allocation of the cultivated area by a particular crop and these issues include: received prices of a crop by farmers during the previous years (instead of the expected price during the harvest season which is unidentified by the farmers during the planting season), yield of a particular crop acquired in previous year, yield of competing crops as a substitute for the opportunity cost, and farmers' skills and experience regarding rice cultivation.

However, during the planting season, farmers are uncertain of the prices of their produce during the harvest period despite the declaration of support prices that are intended to offer a leveling field to the market price due to scanty institutional procedure for the implementation. A close examination of the previous prices data has showed a substantial variation between the market as well as support prices of many crops. Consequently, the prices received by the farmers in the previous season were utilized as an independent variable [28]. Nevertheless, the actual prices; specifically, market prices that is deflated by the GDP deflator [29] instead of the nominal prices were employed to neutralize the possible effect of inflation in this framework.

It has been well documented that yield is an imperative factor of the profitability of many crops in a particular cropping season. But since the yield of a particular crop at its sowing period is unidentified, farmers focus their expectancies of profitability for a particular crop on the yield achieve in the current year. Lagged area is as well utilized as independent variables with the expectation that it captures the effects of farmers' skill and experience for a particular crop. The ROK acreage can be expressed as follows:

ROK acreage = Y (actual price of ROK at time t-1, ROK yield at time t-1/NERICA yield at time t-1, area cultivated to ROK at time t-1)

NERICA acreage can be expressed as follows:

NERICA acreage = Y (actual price of NERICA at time t-1, NERICA yield at time t-1/ ROK yield at time t-1, area cultivated to NERICA at time t-1)

However, since farmers are unable to get the existing information completely, at this juncture, a lagged price response model is possibly realistic. The Lagged actual prices (nominal prices that are deflated by the GDP deflator in 2002, \$ 16/ kg) are utilized in the model

### III. MATERIALS AND METHODS

For an empirical assessment on how the quantity of crop supplied responds to corresponding changes in its prices as well as other pertinent variables considered previously, it is necessary to employ a statistical model to achieve our goal. We transform all variables of inclusion in logarithmic forms for suitability of mathematical operations as well as for the direct estimation of both the short-run and long-run price elasticities. For this study, the proposed model is elucidated by utilizing Nerlovian model, which defines the changing aspects of agricultural supply by incorporating price expectations [30] and the adjustment costs [31]. Hence, the functional model can be stated as:

$$Q_t = \theta + \lambda P_t^* + \mu W_t + \varepsilon_t \tag{1}$$

where,  $W_t$  represents supplementary exogenous factors and  $\varepsilon_t$  is an error term. As the expected price is unobservable, the expectations are presumed to follow:

$$P_t^* = P_{t-1} + \kappa (P_{t-1} - P_{t-1}^*) \tag{2}$$

$$0 < \kappa \leq 1 \tag{3}$$

where,  $P_t$  indicates real price at time t [32] and  $\kappa$  is the coefficient of expectation [33]. If  $\kappa$  tends to 0, therefore, it does not appear to be a difference between the current year's expected price and previous' year actual price, and if  $\kappa = 1$ , then, the expected price is equal to previous year actual price. However, (2) suggests that cultivators adjust their expectations of future price with regard to previous experience, and that they can learn from their past blunders. Substituting (2) into (1) and simplifying gives:

$$Q_t = \kappa\theta + \kappa\lambda P_{t-1} + \kappa\mu W_{t-1} + (1 - \kappa)\varepsilon_{t-1} + G_t \tag{4}$$

where,

$$G_t = \varepsilon_t - (1 - \kappa)\varepsilon_{t-1} \tag{5}$$

Hence, form (4), it can be seen that the current year expected price [34] is a proportion of both [35] last years' expected and actual price [36]. Consequently, price expectations are weighted moving average of past prices [37] in which the weights decline geometrically[38]-[40].

Equation (5) is the adaptive expectation model [41]. Bearing in mind that the partial adjustment (PA) model [42] with the supposition that the desired area  $Q_t$  is actually a function of price ( $P_t$ ) as well as other exogenous factors ( $W_t$ ):

$$Q_t^* = \theta + \lambda P_t + \mu W_t + \varepsilon_t \tag{6}$$

Since the desired area under cultivation was unobservable [15], the partial adjustment (PA) hypothesis[43] becomes:

$$Q_t - Q_{t-1} = \pi(Q_t^* - Q_{t-1}) \tag{7}$$

$$0 < \pi \leq 1 \tag{8}$$

where,  $\pi$  is the estimated rate of area adjustment coefficient [44] between desired and actual area[45] in the previous time. If  $\pi$  tends to 0, area remains constant from one year to the other, and if  $\lambda = 1$ , then, adjustment is instant. Characteristically, adjustment to the desired level is possible to be imperfect due to physical and institutional limitations, fixed capital, etc. It is significant also that,  $\lambda$  offers the relationship between the short and long-run [46] elasticities. Substituting (7) into (6) gives the partial adjustment model (PAM) model, which is:

$$Q_t = \pi\theta + \pi\lambda P_t + \pi\mu W_{t-1} + (1 - \pi)Q_{t-1} + \pi\varepsilon_t \tag{9}$$

Combining (1) and (6) gives:

$$Q_t^* = \theta + \lambda P_t^* + \mu W_t + \varepsilon_t \tag{10}$$

where the desired area level ( $Q_t^*$ ) as well as expected price ( $P_t^*$ ) are unobservable.

Substituting (2) and (7) in (10) and simplifying, reduces the system to the estimating (11).

$$Q_t = \pi\theta + \pi\lambda P_t + \pi\mu W_{t-1} + (1 - \pi)Q_{t-1} + \pi\varepsilon_t \tag{11}$$

where,

$$\theta_0 = \kappa\pi\theta \tag{12}$$

$$\theta_1 = \kappa\pi\lambda \tag{13}$$

$$\theta_2 = (1 - \kappa) + (1 - \pi) \tag{14}$$

$$\theta_3 = -(1 - \kappa)(1 - \pi) \tag{15}$$

$$\theta_4 = \pi\mu \tag{16}$$

$$\theta_5 = -\pi\mu(1 - \kappa) \tag{17}$$

and

$$G_t = \pi\varepsilon_t - \pi(1 - \kappa)\varepsilon_{t-1} \tag{18}$$

#### IV. RESULTS AND DISCUSSION

In this section, the estimated results of both ROK and NERICA models and the associated statistics are presented and discussed. We first try to examine the plausibility of these results with respect to the economic concept and rationality, a prior expectation [47] of signs of the estimated coefficients [48] and their sizes. Later we attempt to discuss the estimated models in the succeeding sections.

##### A. Estimates of Rice Acreage Response Model

There are two types of rice crop estimated models in this study and these are submitted below and their results are subsequently discuss in the following subtitles

Estimates of ROK Acreage Model and  
Estimates of NERICA Acreage Model

##### B. Estimates of ROK Acreage Model

Table I presents the coefficients ( $\lambda$ ) of the estimated ROK acreage model with the related statistics

The estimated coefficients ( $\lambda$ ) relating to all the variables have the expected signs and therefore are acceptable. Practically, most of the tests regarding model assessment are satisfactory. The  $R^2$  value is 0.611, and it signifies a well-fitted model [49]. F-ratio is reasonably significant, and signifying the joint significance of the parameters [50]. D-W is 1.604 and consistent with Table II the corresponding Durbin(H) statistics is 0.481, indicating that there are no serial correlations [51]. A simple re-set test was applied to test[52] for misspecification in the functional [53] model and it was less than the critical value [54], hence, the null hypothesis regarding the precise functional form of this model cannot be rejected [55]. Consistent with this result, Jarque [56] test for determine the normality in the residual distribution presented a value less than the critical value [54], consequently, the null hypothesis regarding the normal distribution of this residuals cannot be rejected [55].

##### C. The Lagged Actual Price

The individual price elasticity is revealed to be positive and insignificant only for the short run. However, In the long run, the magnitude is comparatively higher. Consistent with these results, the ROK acreage response is 0.188, which suggests that an increase of only 1% in price of ROK rice variety is liable to cause an acreage expansion and will simply bring about 19%. Therefore, the corresponding estimated long-run price elastic [57] is 0.362(Table V).

##### D. The Ratio between ROK and NERICA Rice Varieties Yield

ROK and NERICA rice varieties contest with each other for acreage and other resources and this happens in some regions. Therefore, the ratio (3.096) between ROK and NERICA yields was involved in the function to establish the effect of reasonably higher yield of one variety on the other. Although the coefficient of the variable concern has a positive sign, nevertheless it is marginally significant. As a result, there is certain evidence of higher ROK yield relative to NERICA

variety in challenging for expansion in its acreage, which possibly will happen at the cost of NERICA variety.

##### E. Lagged ROK Acreage

The coefficient ( $\lambda$ ) of ROK lagged acreage is positive and highly significant. Hence, farmers' experience and skills in rice farming and its traditional practices have considerable fashion on its production. Again, the magnitude of the coefficient ( $\lambda$ ) is high, signifying a very slow rate of adjustment of cultivators and specialized environment of its cultivation requirements with respect to agricultural inputs and management requirements demand, such as agricultural inputs in addition to managerial needs. The magnitude of the estimated coefficient of the lagged dependent variable is 0.643. In consequence, the adjustment coefficient ( $\lambda$ ) is fairly large, suggesting faster adjustment of the ROK farmers to several stimuli as well as incentives.

##### F. Estimates of NERICA Acreage Model

Table III presents the coefficients ( $\lambda$ ) of the estimated NERICA acreage model with the associated statistics

The results of diagnostic tests for the adequacy of the model are satisfactory. The  $R^2$  shows 96% of the variation in the dependent variable [58] are explained by the independent variables [59]. F-ratio is high and significant as well, displaying the general goodness of the fit. The Durban Watson test statistic is 1.911, signifying no serial correction [51].

Table IV indicates that the estimated Durbin (H) statistics as well confirms that there is no evidence of serial correlation [60]. The Reset test for misspecification in the functional [53] model also carries a value that is less than the critical value [54], affirming to the accuracy of the estimated functional form [53].

Jarque [56] test for determining the normality in the residual distribution presented a value less than the critical value [54], consequently the null hypothesis regarding the normal distribution of this residuals cannot be rejected [55]. Below is a discussion on the estimated coefficients ( $\lambda$ ) of this model.

##### G. The Ratio Between NERICA and ROK Rice Varieties Yield

The estimated coefficient ( $\lambda$ ) of ratio between NERICA and ROK rice varieties is 0.281 and it is positive though not significant. Hence, increase in NERICA yield with respect to that of ROK did not seem to support farmers' in its acreage expansion, and this could be that the cultivation of NERICA has been restricted to particular areas.

##### H. Lagged NERICA Acreage

The coefficient ( $\lambda$ ) of the lagged NERICA Acreage is found to be positive and significant, and the magnitude of its coefficient is also very high (0.936), signifying farmers' adjustment rate is very low and specialized environment of its cultivation requirements with respect to agricultural inputs and management requirements demand, such as agricultural inputs in addition to managerial needs. The rate at which cultivators adjust the acreage under a particular crop in response to the changes on the factors deliberated earlier could be understood

from the values of the adjustment coefficient ( $\lambda=0.131$ , Table V).

However, a very slow rate of adjustment was witnessed, signifying that acreage was more influenced by institutional as environment well as technological severities and that price incentives functioned slowly.

Regarding lagged actual price, the short-run price elasticity is lower than the long-run [61], suggesting that the long term adjustment of the acreage under the crop.

## V. POLICY IMPLICATIONS

This research employed the Nerlovian model to estimate the acreage response of rice crops to changes in their respective prices as well as other related factors in Sierra Leone. The study utilized the rice crop data from 1980-2011. The coefficients of the acreage response models for the rice crop varieties were estimated using the OLS technique. However, the responses of these crop varieties to changes in their respective prices, as revealed in their corresponding short and long run price elasticities and also accompanied by their adjustment coefficients are documented in Table V.

### A. ROK Rice Variety

Rice cultivation in Sierra Leone needs a better technical skill and experience which is expected to be taught by agricultural experts to farmers within the country. In general, specific types of soil in rice growing regions in addition to climatic conditions as well do not support positive cultivation of several other crops, and hence limiting farmers' selection of crops to be planted. This appears to be realistic for the acreage where ROK cultivation is focused since the estimated coefficient of the price elasticity was 0.187 and was just marginally significant. Conversely, the estimated coefficient of the long run price elasticity was 0.362 as the coefficient of adjustment was 0.466 for ROK rice variety.

### B. NERICA Rice Variety

NERICA rice variety, a long grain aromatic rice variety, is generally cultivated in the Northern Province of Sierra Leone. It is similarly challenging concerning its pre and post-harvest management needs. However, the short run price elasticity of

NERICA acreage within the period covered by this empirical assessment has been estimated to be 0.133 although the long run price elasticity of NERICA acreage was 0.975. The coefficient of the price elasticity was statistically significant. In brief, these results emphasize the role of price factor in influencing acreage dedicated to NERICA cultivation within the period covered. The coefficient of adjustment for NERICA rice has been found to be 0.131, indicative of a very slow rate of adjustment. This, among others factors, is perhaps caused by the specialized environment of the crop in addition to its management practices.

## VI. CONCLUSIONS AND RECOMMENDATIONS

The apparent recommendations for policy transformation are to open farm gate prices and to decrease government's involvement in agricultural sector especially in the acquisition of agricultural inputs.

Impending research have to be focused on how this might be better realized. Necessary conditions should be made available to the private sector by means of minimizing price volatility. Economic efficiency in addition to incentive structures existing in the rice crop sector in Sierra Leone is displaying the capability to utilize the necessary advantage of market situation. Also, it is very possible that a decrease in distortion in the local markets may increase the cultivation of NERICA rice variety in Sierra Leone, which sequentially will improve the livelihood of the farmers. One significant requirement is that farmers should be given the chance to respond to market indicators to translate the challenges of global market into better prospect. Sierra Leone should however, accept and introduce sustainable agricultural policies by effectively utilizing its available resources as well as using a suitable mixture of government policies and market opportunities.

In accordance with structural reforms, it is necessary to convey output prices to farmers with minimum distortion. There is need to eradicate price subsidies and control, which generate distortion in market in addition to huge financial costs.

TABLE I  
THE RESPONSE MODEL OF THE ESTIMATED COEFFICIENTS ( $\lambda$ ) OF ROK RICE VARIETY (1980-2011)

| Variable                       | Coefficient ( $\lambda$ ) | Std. error              | T-statistic | Prob   |
|--------------------------------|---------------------------|-------------------------|-------------|--------|
| Constant                       | 0.810                     | 2.324                   | 0.349       | 0.635  |
| Actual price of ROK at t-1     | 0.188                     | 0.156                   | 1.205       | 0.265  |
| ROK yield t-1/NERICA yield t-1 | 3.096                     | 1.865                   | 1.660       | 0.214  |
| Acreage planted to ROK at t-1  | 0.643                     | 0.165                   | 3.897       | 0.004  |
| R <sup>2</sup>                 | 0.611                     | Mean dependent variable | -           | 8.002  |
| Adjusted R <sup>2</sup>        | 0.598                     | S.D. dependent variable | -           | 0.241  |
| S.E. of regression             | 0.096                     | Akaike info criterion   | -           | -1.713 |
| Sum squared residual           | 0.264                     | Schwarz criterion       | -           | -1.542 |
| Log likelihood                 | 31.002                    | F-statistic             | -           | 6.949  |
| Durban Watson stat             | 1.604                     | Prob (F-statistic)      | -           | 0.000  |

Source: Authors' data analysis, 2013, dependent variable is Ln (ROK Acreage), variables are in logarithm.

TABLE II  
DIAGNOSTIC TESTS

| Statistic    | Value        |
|--------------|--------------|
| DH statistic | 0.481        |
| Jarque       | 4.61(0.102)  |
| Reset test   | 1.13 (0.307) |

Source: Authors' data analysis, 2013

TABLE III  
THE RESPONSE MODEL OF THE ESTIMATED COEFFICIENTS ( $\lambda$ ) OF NERICA RICE VARIETY (1980-2011)

| Variable                         | Coefficient ( $\lambda$ ) | Std. error              | T-statistic | Prob   |
|----------------------------------|---------------------------|-------------------------|-------------|--------|
| Constant                         | -0.027                    | 1.976                   | -0.014      | 0.954  |
| Actual price of NERICA at t-1    | 0.134                     | 0.153                   | 0.876       | 0.299  |
| NERICA yield t-1/ ROK yield t-1  | 0.281                     | 2.664                   | 0.106       | 0.909  |
| Acreage planted to NERICA at t-1 | 0.936                     | 0.178                   | 5.258       | 0.000  |
| R <sup>2</sup>                   | 0.960                     | Mean dependent variable | -           | 7.654  |
| Adjusted R <sup>2</sup>          | 0.932                     | S.D. dependent variable | -           | 0.244  |
| S.E. of regression               | 0.081                     | Akaike info criterion   | -           | -2.121 |
| Sum squared residual             | 0.133                     | Schwarz criterion       | -           | -1.764 |
| Log likelihood                   | 34.126                    | F-statistic             | -           | 95.053 |
| Durban Watson stat               | 1.911                     | Prob (F-statistic)      | -           | 0.000  |

Source: Authors' data analysis, 2013, dependent variable is Ln (NERICA Acreage) variables are in logarithm

TABLE IV  
DIAGNOSTIC TESTS

| Statistic    | Value       |
|--------------|-------------|
| DH Statistic | 0.31        |
| Jarque       | 0.63 (0.83) |
| Reset Test   | 0.05 (0.96) |

Source: Authors' data analysis, 2013

TABLE V  
THE SHORT AND LONG RUN PRICE ELASTICITIES ESTIMATES AND THEIR ADJUSTMENT COEFFICIENTS

| Rice crop variety | Short run elasticity | Long run elasticity | Adjustment coefficient |
|-------------------|----------------------|---------------------|------------------------|
| ROK               | 0.187                | 0.362               | 0.466                  |
| NERICA            | 0.133                | 0.975               | 0.131                  |

Source: Authors' data analysis, 2013

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