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PUBLIC SECTOR AGRICULTURAL RESEARCH EXPENDITURES AND OUTPUT IN LESOTHO: ANALYSIS OF CAUSALITY AND COINTEGRATION

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This article investigated the causal relationship between public agricultural research expenditures and agricultural output in Lesotho. Cointegration and Granger-causality tests were performed to determine the causal relationship between agricultural research and agricultural output. Lag length tests were performed to facilitate the Cointegration analysis. Results of the empirical analysis indicated that agriculture in Lesotho is driven by agricultural research. The results also showed that it takes seven to eight years for public agricultural research expenditures to have a significant impact on agricultural output in Lesotho.

1. INTRODUCTION

About 76% of Lesotho's total land area of 30 355 km² is classified as suitable for agriculture. Only 14% of this agricultural land is arable and the remaining 86 % is pastureland (BOS 1994). In spite of the country's poor resources base, agriculture is the primary occupation of 85 percent of the Basotho (Lesotho people) accounting for about 10 percent of the country's GNP and contributing approximately 23 percent of its export earnings. Despite its importance, the sector's productivity continued to decline and its capacity to absorb the rapid population growth (2.6% per annum) is thus becoming increasingly limited. In consequence, the sector also failed to retain the rural labour force because of the low agricultural incomes compared to alternative employment opportunities. It has therefore become clear that it is crucial for agriculture in Lesotho to be more productive in order to assume its leading role in economic growth.

Several attempts have and are still being made by the government to make agriculture more productive. Notably, is the establishment of the new agricultural research system in 1989 with the main objective of developing technologies of improved production practices, raising farm incomes and

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conserving the natural resource base. The Agricultural Research Division of Lesotho (ARD) established since 1952 conducts the bulk of research, selects, screens, and adapts new and improved technologies for use by farmers with adaptive agronomic being its main focus².

As agricultural research is a major investment of Lesotho's public funds, it is important to evaluate its impact on agricultural output. Such kind of analysis is very valuable in informing policy, especially when the government has often been criticized of underspending on agricultural research (ISNAR 1989). Agricultural research in Lesotho has been basically project-driven both in terms of funding and program orientation. During the 1980s and the early 1990s operational support programs, capital funds for field research, and training costs of research staff were provided almost entirely by donors. The Government's contribution has been minimal comprising mainly personnel emolument costs. The present study is accordingly motivated by the critical importance of recognizing agricultural research as the driving force of growth in agriculture and hence the need for the government of Lesotho to minimise the heavy reliance on donor funding, which is highly unreliable and unsustainable. This investigation is indeed more important to Lesotho, now than ever because of the dwindling supply of donor funds. Because substantial research in Lesotho is undertaken by the public sector³, this study investigates how effective spending on agricultural research has been in promoting productivity growth in Lesotho. The task set for this paper is therefore to examine the causal relationship between agricultural productivity and public agricultural research expenditures and the time that it takes research to have impact on output.

2. APPROACHES TO CAUSALITY ANALYSIS IN AGRICULTURAL RESEARCH

Although there are numerous studies of the rate of return to agricultural research and development (R&D) expenditures, there have been few attempts to establish causality between R&D expenditure and productivity. Nevertheless, from the literature three broad schools of thought concerning the relationship between research and output can be identified: a supply-driven or

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² Other institutions engaged in agricultural research include the Department of Livestock of the Ministry of Agriculture, the Forestry Research Section of the ministry and the Faculty of Agriculture.

³ Public sector in this study is taken to include government, semi-public, and academic research institutes.

science based view, a demand-driven or endogenous technical change perspective and the view comprising a feedback relationship. The notion of supply-driven causality (technology-push hypothesis) has been formalised into traditional production function models, where an industry's final output is a function of conventional inputs (factors of production) such as labour and capital, along with novel inputs such as research expenditures. In this literature there is an implicit assumption that research expenditures are causally prior to output in the sense of Granger (1981) (Ruttan, 1982; Rose-Ackerman & Evenson, 1985; Thirtle & Bottomley, 1989; Pray & Ahmed, 1991 and Evenson & McKinsey, 1991).

The demand driven causality is based on the "demand-pull" hypothesis. Innovation is considered as an endogenous variable influenced by market. Innovations are in some sense "triggered" in response to demands for the satisfaction of certain "needs" (Mowery & Rosenberg 1979). The view is referred to as the induced innovation hypothesis and its advocates include Mowery and Rosenberg (1979), Rosenberg (1982), Bosworth and Westaway (1984), and Oehmke (1986). On the other hand, the feedback causality approach involves possible feedback between output and research. It combines both the "demand-pull" and "technology-push" hypotheses and reveals the simultaneity between the two. In this view it is argued that 'while the scale of R&D activity affects the rate of growth of productivity,..., the rate of growth, in turn, affects the relative cost of R&D and, hence its demand' (Baumol & Wolf, 1983). Success in R&D and the consequent increase in agricultural productivity may thus raise the relative price of R&D, reducing the quantity demanded. Baumol *et al* (1983) developed models of the feedback process and demonstrated how this feedback process can lead to an oscillatory behavior and to a slow down of the economy's long-run productivity but did not empirically test the formal model. Mairesse and Siu (1984); Pardey and Graig (1989) and Schimmelpfennig and Thirtle (1994) empirically tested for the feedback relationship between public research expenditures and productivity.

3. THE DATA AND EMPIRICAL ANALYSIS

When measuring the effect of public sector agricultural research on agricultural output, the most obvious omissions of relevant variables are conventional inputs such as land, labour, fertilizer, seed and livestock. To deal with the contribution of the conventional inputs to agriculture, two measures of agricultural output have been used in this study to remove, explicitly or implicitly, qualitative changes in inputs. The first measure is the output index, which measures constant values of total agricultural output of Lesotho

deflated by GDP deflators using 1985 as the base year. Thirty-two observations were used (1961-1992).

The second method, which measures the presumed technological impact of agricultural research on agricultural output, is a partial measure of productivity in the form of yield. This measure is indeed crude since it attributes growth in agriculture to only one major input, land. The series consists of annual observations from 1965 to 1992. Nevertheless, it is justifiable to use partial productivity measure based on the input, which is the obvious constraint (Salmon, 1991 and Evenson & McKensey, 1991). Since land is the obvious constraint on agricultural output growth in Lesotho, it is appropriate to focus on its partial productivity, that is, output per hectare (yield). The study therefore employs yield as the standard productivity index.

Research expenditure comprises total research funds contributed by the Lesotho government and major donor agencies towards public agricultural research in the country. The data are in constant values, deflated by GDP deflators using 1985 as a base year. The series extends from 1961 to 1992 since data beyond 1992 is not available.

3.1 Cointegration tests

The concept of cointegration means that there is an equilibrium relationship among a set of non-stationary variables. This implies that the stochastic trends of these variables are linked and that the variables cannot move independently of each other (Enders, 1995). The two most popular residual based cointegration tests: the Augmented Dickey-Fuller (ADF) and the Phillip-Perron (PP) tests were employed in this analysis. These tests have been recommended in the literature because they account for serial correlation and heteroskedasticity in the error terms of the test regression, an element which is missing in other tests such as the Durbin Watson test (DW) and the Dickey-Fuller test (DF). The residual based testing procedure was suggested by Engel and Granger (1987). Three steps are involved in the testing procedure. The first step is to pretest the variables for their order of integration. Second, if integrated of the same order, the long-run equilibrium relationship is estimated and residuals saved. Finally, the saved residuals are tested for stationarity using the ADF test statistic based on the hypothesis that $\alpha^* = 0$ in equation 1. If stationary the null hypothesis of no cointegration is rejected, and this means that the series are cointegrated of order (1.1).

$$\Delta \varepsilon_t = \hat{\alpha}^* \hat{\varepsilon}_{t-1} + \text{Augmented terms} + \mu_t \quad (1)$$

Where the augmentation terms are necessary to ensure that the above regression has residuals that appear to be white noise (Mackinnon, 1991). The results of these tests are reported in Table 1.

Table 1: Cointegration test results

Regression	Cointegrating		
	ADF	PP	C-Value
1. LEXP/LOUT	2.328	2.285	3.5
2. LOU/LEXP	3.766*	4.418**	3.5
3. LEXP/LY	1.808	1.832	3.5
4. LY/LEXP	2.744	2.833	3.04

* and **=significant at 10 and 5 percent level respectively. LEXP=log of public agricultural research expenditures, LOU=log of agricultural output, and LY=log of yield. C-val.=critical value. Critical values for the ADF and PP tests are asymptotical critical values at 10 per cent level printed by SHAZAM.

Based on all the tests, when expenditure is used as a regressand, the null of non-cointegration cannot be rejected. However, when output and yield are used as a regressands different conclusions are reached. When output is used as a regressand, all tests agree and the null of non-cointegration is rejected. When yield is used as a regressand, both the ADF and PP tests agree and the null of non-cointegration cannot be rejected.

The conflicting conclusions between the three tests are probably due to their weakness in detecting cointegration among the series. As Banerjee *et al* (1993) observed, the power of these tests to discriminate between unit roots and borderline-stationary processes is weak and the small sample properties are poor. Also, because the series employed in the study are short, this might cause the power of the tests to reject the null to be low and consequently, the tests tend to accept the null even when it is false. Due to the said weaknesses causality is tested using an error correction model framework in the following section before conclusions are drawn from these mixed results.

3.2 Error correction and Granger causality tests

One of the major benefits of cointegration is that it allows a single formulation that combines in one model the short-run dynamics and the long-run relationship between the variables. This formulation is known as the Error Correction Model (ECM) framework. Engel and Granger (1987) showed that the cointegrating regression and the ECM had a one-to-one correspondence,

since if two variables are cointegrated, their short-run dynamics can be written with an ECM representation. Given a two variable case, the ECM can be demonstrated as follows. Let $\{y_t\}$ and $\{x_t\}$ be time series variables which are $CI(1,1)$. The variables have the error-correction form:

$$\Delta x_t = \delta_1 + \alpha_1 (x_{t-p} - \beta y_{t-p}) + \sum_{i=1}^{p-1} \gamma_{11}(i) \Delta x_{t-i} + \sum_{i=1}^{p-1} \gamma_{12}(i) \Delta y_{t-i} + \mu_{xt} \quad (2)$$

$$\Delta y_t = \delta_2 + \alpha_2 (x_{t-p} - \beta y_{t-p}) + \sum_{i=1}^{p-1} \gamma_{21}(i) \Delta x_{t-i} + \sum_{i=1}^{p-1} \gamma_{22}(i) \Delta y_{t-i} + \mu_{yt} \quad (3).$$

Where $(x_{t-p} - \beta y_{t-p}) =$ the error-correction term
 $\beta =$ the cointegrating parameter
 μ_{xt} and $\mu_{yt} =$ white-noise disturbances (which may be correlated with each other)

α_1 and α_2 are known as speed of adjustment coefficients (Enders, 1995).

Engel and Granger (1987) proposed a technique for estimating equations 2 and 3 called 'The Engel-granger two step estimator'. To circumvent the cross-equation restrictions involved in the direct estimation of these two equations, the Engel-Granger two step technique uses the value of the residual

$$\hat{V}_{t-p}$$

to estimate the deviation from long-run equilibrium in period $(t-p)$. Thus, step one of the estimation technique comprises the estimation of the cointegrating regression of equation 4

$$x_t = A + \beta y_t + \mu_t \quad (4)$$

and saving the residuals which are then used as an instrument for the expression

$$\{x_{t-p} - \beta y_{t-p}\}$$

in 2 and 3. This comprises the second step of Engel-granger estimation technique. However, before 2 and 3 can be estimated, it is important to know the appropriate lag length of the model, since choosing p (order of the model)

unnecessarily large will reduce the forecast precision of the corresponding ECM (ρ) model and thus affect causality tests. The Akaike Information Criterion (AIC) and the Swartz Criterion (SC) statistics have been predominantly used in the literature to test for the order of Vector Autoregressive and EC models (VAR/ECM). The two approaches have also been used in this analysis. These tests have been found to be consistent estimators of the appropriate order of the VAR/ECM.

The tests revealed that appropriate lag lengths for ECM models of output and expenditure, and yield and expenditure are 8 and 7 years, respectively. This result is consistent with the theoretical literature which states that the peak effect of research and development on agricultural output does not occur until six or seven years (Schimmelpfennig & Thirtle, 1994). After determining the appropriate order of the VAR/ECM model, the correct model is specified and estimated. From the estimated model, causality tests have been undertaken in the following section.

3.3 Causality tests results

Although cointegration says nothing about the direction of the causal relationship between the variables, if two variables are found to be cointegrated, it follows that there must be Granger causality in at least one direction. Causality tests are based on the test proposed by Granger (1981). The test hinges on the idea that random variable x is causally prior to random variable y if the past history of x improves significantly our ability to predict series y compared with our ability to predict y using all relevant information apart from x . Under these circumstances x is said to Granger-cause y .

Using Monte Carlo methods, Geweke, Meese, and Dent (1983) found that the Wald (λ_w) test outperforms other tests in detecting the presence and absence of causality. Hence, the Wald test has been used in this analysis to test for causality.

The residuals obtained from the cointegrating regressions 2 and 3 were used in estimating the short-run dynamics in the ECM models (i) for expenditure and output and (ii) for expenditure and yield and causality tests were performed on the estimated parameters. The tests are reported in Table 2 below. Column 1 gives the direction of causality (i.e., expenditure $\rightarrow$ output indicates that we are testing if expenditure leads output).

Table 2: Granger test results

Direction of causality	λ_w	p-value	t_{cal}	p-value
1. Null: Research does not cause output/productivity				
expenditure → output	1.95	0.04**	12.23	0.09*
expenditure → yield	1.91	0.05**	17.68	0.007***
1. Null: Output/productivity does not cause research				
output → expenditure	2.59	0.92	0.07	0.47
yield → expenditure	1.09	0.98	-0.27	0.39

λ_w is the Wald Chi-square statistic, t_{cal} is the t statistic *, **, *** mean significant at 10, 5 and 1 percent levels respectively.

The results of Table 2 indicate that the hypothesis that research does not cause output was rejected in all cases. The null of no causality was strongly rejected when partial productivity (yield) was used as a measure of agricultural output. This conforms to the argument that 'the productivity variable is, a priori, the most appealing measure of agricultural output if one is looking for support of science-based view of technological change' (Pardey & Craig 1989). The results provide empirical evidence that agricultural research influenced agricultural output or productivity of production factors in Lesotho. On the other hand, causality from output to research was strongly rejected regardless of the measure of agricultural output used.

3. CONCLUSIONS

While the preceding analysis could not give conclusive results on cointegration and stability in the relationship between public agricultural research expenditures and agricultural output, the analysis revealed a unidirectional causality between research and output with research being causally prior to agricultural output. The rejection of causality from output to research is not surprising given that in Lesotho research is mainly funded by donor agencies whose main objective is to help develop the poor performance of agriculture (e.g. mainly supply driven). Their decisions to allocate funds to the agricultural research are not influenced by the good performance of the sector as it would be the case with demand driven research. Also, given that agriculture in Lesotho is mainly subsistence, one would not expect agricultural research to be demand driven. This results imply that in the case of Lesotho, the traditional single equation approach to investigating the returns to R&D may be adequate, at least for these data. Furthermore, the analysis shows that the minimum time it takes for agricultural research to have significant impact on agricultural output is 8 years.

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