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Incorporating Environmental Externalities in Total Factor Productivity Analysis: The Case of Soil Erosion in Nigerian Agriculture

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Abstract

In this study, we argue that conventional methods of measuring agricultural productivity which only uses information about marketed inputs and outputs does not give a true representation of how sustainable the activities of the sector are. Motivated by the Solow-type growth accounting framework, we use the Törnqvist index formula to construct input, output and TFP indices for Nigerian agriculture between 1980 and 2010. We account for environmental externalities by incorporating off-farm damage costs of soil erosion based on different assumptions about possible scenarios of the extent and trajectory of damage costs. The results show that when externalities are not accounted for, productivity in the Nigerian agricultural sector is overestimated. This conclusion is robust to the different assumptions about damage cost scenarios made. The implication is that reducing off-farm erosion damages through improved soil conservation practices will significantly improve productivity and sustainability in the Nigerian agriculture sector.

Keywords; Törnqvist TFP, environmental externalities, soil erosion, USLE

JEL Classification; D24, O13, Q16

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1 Introduction

Sustainable agriculture is one that, over the long term, enhances environmental quality and the resource base on which agriculture depends; provides for basic human food and fiber needs; is economically viable; and enhances the quality of life for farmers and society as a whole (ASA, 1989). How to correctly assess the sustainability of agricultural production is a question that is still stimulating the minds of environmentalist and economists alike. A correct assessment of the sustainability of agricultural production is particularly needful for a country like Nigeria where agriculture contributes over 40% to GDP. However, a fundamental problem is that conventional estimates of agricultural productivity in Nigeria, ignore the role that externalities arising from such factors as soil erosion, pollution from nitrate leaching, including salinisation of ground and surface water may have on the measured indices. The growing recognition of the importance of environmental elements has led to an increasing recognition of the need to incorporate and take account of environmental factors when measuring productivity.

While significant progress has been made in adjusting national income accounts for natural resource depletion, relatively little has been done to incorporate environmental externalities into conventional measures of productivity changes especially in sectors such as agriculture where progress is based on production processes that have significant environmental impacts. Thus far, two major concerns have exercised the minds of researchers and policy makers. One is related to the identification of externalities i.e., which environmental factors should be considered when measuring productivity, and the second has to do with the choice of the appropriate technique for measurement, especially for the sustainable development of the agricultural sector. In examining this issue our goal is to use the ideas formalized by Lynam and Herdt (1989) among others who show that a non-decreasing measure of productivity can be interpreted as an indicator of sustainable economic activity. Byerlee and Murgai (2001) argue that total social factor productivity (TSFP) (i.e., total factor productivity estimated with both market and non-market inputs and externalities, and with all factors valued at social prices) could be that single and all-embracing measure of agricultural sustainability.

Consequently, the objective of this paper is twofold. First is to apply the Solow-type growth accounting technique in computing the conventional TFP indices and then, after adjusting for environmental externalities, we compare the conventional and environmentally adjusted TFP for Nigerian agriculture between 1980 and 2009. Second is to investigate the relative contributions of input and TFP to output growth, which will provide important information to policymakers on sustainable management of inputs and technological utilization in the agricultural sector. Specifically, we consider environmentally adjusted productivity estimates, taking account of off-farm social damage costs of soil erosion. Potential off-farm effects of soil erosion include: impacts on road maintenance and safety, health impacts, recreation, cost to business, damage to infrastructure installations, landscaping etc. (see Pimentel et al., 1995). In Nigeria, soil degradation from agriculture and other sources affects over 50 million people and leads to the greatest loss of GNP (over US$300m per annum) relative to other environmental problems (World Bank, 1990).

This study concentrates on soil erosion externalities from agriculture because of its size and far reaching impacts on other aspects of economic activity. An assessment of soil degradation in Nigeria by the Federal Department of Agriculture Land Resources (FDALR, 2009) shows that apart from natural parameters such as climate regime, soil characteristics, topography and vegetation that affect soil erosion, the single most significant human-induced cause of erosion in Nigeria is farm cultivation.

The balance of the paper is as follows. Section 2 contains a brief literature review of available methods for adjusting measurements of total factor productivity to incorporate externalities. In Section 3 the theoretical framework and methodology adopted are described. Section 4 contains the description of data and soil erosion damage cost scenarios. Section 5 contains the results and Section 6 is a discussion of the policy implications with Section 7 as the conclusion.

2 Conventional vs. environmentally adjusted agricultural TFP

TFP measures originated from the growth accounting procedure popularized by Solow's (1957) seminal work which demonstrated how output growth can be accounted for by growth in labour and capital, with the residual attributed to technical change or productivity differences. These types of growth accounting procedures rely on several critical assumptions relating to the input-output combinations observed, and many times some of these assumptions do not hold in a global context, especially in developing countries where for example, new technologies may take considerable time to be efficiently utilized (Headey et al., 2010; Coelli and Rao, 2005). Agricultural productivity and its determinants are somewhat peculiar and need to be well understood in a different way than general economic productivity. Some of the very first studies that examined agricultural productivity, including Clark (1940), Hayami (1969) and Hayami and Inagi (1969), typically measured only labour or land productivity and focused on a few output, ignoring any potential externalities that may arise from these activities.

Early studies that attempted to link pollution with productivity and efficiency measures mainly focused on the effects of pollution controls on macroeconomic growth e.g. Christainsen and Haveman (1981); Gallop and Roberts (1983) and Fare et al. (1989), while some others focused on the micro aspects, e.g. Pittman (1983) and Pashigian (1984). Sherpard's (1970) seminal paper is acknowledged to be the first to recognize the importance of incorporating environmental externalities in TFP measurements. However, Pittman (1983) is acknowledged to be the first to present a framework which seeks to incorporate environmental pollution into conventional productivity measures. He achieved this by adapting the multilateral productivity index of Caves et al. (1982) and using proxies such as pollution taxes, marketable permits and shadow prices obtained from other studies to environmentally adjust the conventional productivity index.

Within the agricultural sector, changes in technology have been biased towards using more synthetic and industrial inputs. While this has led to increased productivity and hence profits, they have also been responsible for increasing environmental damage. For example, the impact of soil erosion caused by agricultural systems are not typically accounted for in conventional measures of productivity and efficiency change. It is important that measures of agricultural productivity incorporates the impacts on the environment from the production processes used in the sector since costs associated with the environmental damage from these processes are not born by the individual farmeholders, but by the society and the ecosystem (Pretty, 1999). Without taking account of the external costs or benefits of production, productivity estimates can either overestimate or underestimate productivity.

The reason why externalities are not included in conventional TFP estimates is that by definition they are unpriced and most TFP measures use prices as a means by which to weight the contribution of inputs and outputs to overall TFP (e.g., Tornqvist). A major theoretical assumption underlying the adjustment to environmental TFP is the proposition of strong disposability of outputs. This implies that we can costlessly adjust the output mix. However, the fact that desirable and undesirable outputs are jointly produced means that the reduction of undesirable outputs will be costly. Either inputs must be diverted to deal with the externalities and/or production must be reduced. As an alternative, one could implement the assumption of weak disposability of undesirable outputs. In this case, a reduction of undesirable outputs is feasible if and only if desirable outputs are simultaneously reduced, given a fixed level of inputs (Hoang and Coelli, 2011).

Several papers have advanced methods that allow a relaxation of the strong disposability assumption, thereby explicitly incorporating environmental variables (i.e. goods and bads) as components of the technology set. Examples include Fare et al. (1993), Shaik and Perrin (2001) and Rezek and Perrin (2004). Typically, linear mathematical programming methods are used to construct production possibility frontiers to measure productivity efficiency and to calculate shadow prices of undesirable outputs, either parametrically or non-parametrically. The shadow price estimates are then used to adjust the TFP growth.

Another commonly used approach employed in the literature is to construct prices (i.e. shadow prices, damage costs) for the undesirable outputs which can then be combined with quantities and used to adjust the conventional TFP estimates to their environmental counterparts. Pittman (1983) was one of the first to use this approach when he defined environmentally sensitive TFP with shadow prices externally generated. Other studies that have adopted this approach include Oskam (1991, 1992), Ball et al. (2004), Barnes (2002) and Kumar (2006).

Given the options available to compute adjusted TFP measures, it is important to recognize some theoretical and practical issues that may be encountered when using them. Byerlee and Murgai (2001) highlight some of the practical difficulties to include the level of aggregation that should be used, whether it should be at the national or state level. They argue that TFP trends at the state level are a blunt instrument for identifying particular production systems and regions with potential sustainability problems. Another factor is the time period of analysis, a sufficient time period of analysis presents a problem in assessing the usefulness of environmentally adjusted TFP measures in agriculture. As Monteith (1990) has shown, there is the problem of defining the necessary number of years to estimate the trend with some degree of statistical confidence.

According to Monteith (1990), in a variable rain fed environment with a low growth rate in TFP, the number of years required to estimate a statistically valid trend might be as high as 30 years. This problem is compounded by the fact that, in practice, some systems have undergone several stages of technical change in a short period. In Nigeria, for example the National Agricultural Policy (NAP) propelled agriculture from very low external input use to high input use in a period of two decades. Other factors include confounding of labour-saving and land-saving changes and measurement and valuation issues involved in estimation. Some of these issues are likely to remain unresolved because there are yet any universally correct solutions to them (Nanere et al. 2007). However, it is important to highlight these issues so that the meaning of any estimates of environmental adjustments made would be understood in the light of these limitations.

Total factor productivity measurement in Nigerian agriculture has generally followed the conventional approach, with no records of efforts to incorporate environmental externalities in the literature. Most of the papers that attempt to measure productivity in Nigerian agriculture do so at a regional scale and a meta-analysis of these studies can be found in Liverpool-Tasie et al. (2011).

3 Methodology

3.1 Theoretical framework

There are several comparable methods of deriving TFP indices, and one of the least restrictive is to think about it from an accounting relationship in which the value of output is equal to the value of factors used to produce the output plus a residual. We use this approach because it lends itself most easily to aggregate sector level analysis [1]. Consider the accounting relationship

$$\sum_{i=1}^{N} P_i Q_i = \sum_{j=1}^{J} R_j I_j; \qquad \mathbf{PQ} = \mathbf{RI} \tag{1}$$

Where P_i and Q_i are product prices and quantities respectively, R_i and I_i are input prices and quantities respectively and $\mathbf{P}$ and $\mathbf{R}$ are price vectors, whereas $\mathbf{Q}$ and $\mathbf{I}$ are quantity vectors. The accounting relationship above simply implies that inputs I_j, should be paid at the rate R_j such that the total value of production $\sum\limits_{i=1}^{N} P_i Q_i$ is exhausted. Unlike other methods, this framework does not require that all production be technically efficient nor allocatively efficient, that is production does not necessarily have to hold at the frontier. If we express Eq. (1) in rate of change form, we obtain the following results.

$$\sum_{i=1}^{N} P_i \frac{\partial Q_i}{\partial t} dt + \sum_{i=1}^{N} Q_i \frac{\partial P_i}{\partial t} dt = \sum_{j=1}^{J} R_i \frac{\partial I_i}{\partial t} dt + \sum_{j=1}^{J} I_i \frac{\partial R_i}{\partial t} dt \tag{2}$$

Note that the rate of change in a variable is given by $\dot{X} = \frac{1}{X}\frac{\partial X}{\partial t}$ and the cost share of factor j is given by $c_j = I_j R_j / \sum I_j R_j$. Assuming constant TFP, we can rearrange terms in a convenient way by dividing both sides of Eq. (2) by $\sum P_j Q_j dt$ and multiplying the

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[1] See for examples Avila and Evenson (2010), Hoang and Coelli (2011) and Nanere et al. (2007). Many of the other approaches in the literature are more suited for firm or farm level analysis, and we do not consider disaggregated decision making units here.

right hand side of the equality by R_j/R_j and I_j/I_j, to obtain

$$\dot{P} + \dot{Q} = \sum_j c_j \dot{R} + \sum_j c_j \dot{I} = \dot{R} + \dot{I} \tag{3}$$

In a closed economy with competitive equilibrium, TFP can be measured in two alternative ways

$$T\dot{F}P = \dot{R} - \dot{P}, \qquad \text{or} \qquad T\dot{F}P = \dot{Q} - \dot{I} \tag{4}$$

Where $T\dot{F}P$ is the growth in total factor productivity. Avila and Evenson (2010) show that with international trade, the price relationship will not necessarily hold, but the quantity relationship $(\dot{Q} - \dot{I})$ will hold in all economies. Hence, by disaggregating the inputs into three components we can calculate improvements in productivity as

$$Q(t) = A(t) \times f\left(K(t), M(t), L(t)\right) \tag{5}$$

Where $Q(t)$ stands for real output in year t, $K(t), M(t)$ and $L(t)$ represent capital, materials and labour inputs, respectively and $A(t)$ is a productivity index. From this function, the rate of change of the productivity index can be estimated as

$$\frac{\dot{A}(t)}{A} = \frac{\dot{Q}(t)}{Q} - \left[\frac{s_k \dot{K}(t)}{K} + \frac{s_m \dot{M}(t)}{M} + \frac{s_l \dot{L}(t)}{L}\right] \tag{6}$$

Where the dotted quantities represents rates of change with respect to time. In other words, the rate of productivity change is defined as the difference between the growth rate of the output index and the growth rate of the disaggregated input index. In turn, the input index is derived by weighting each factor of production by the proportional change in output that results from a small change in the input alone. Technically, these are the output elasticities and they are denoted by s_k, s_m and s_l. If we assume perfect competition in both the input markets and the output markets and constant returns to scale, these weights are equal to the shares of the individual factors in total costs and consequently sum up to one.

Environmental externalities can be incorporated into the framework by redefining total output $\mathcal{W}$ as the aggregation of marketed output and pollution. Total output then exhibits a rate of growth equal to:

$$\frac{\dot{\mathcal{W}}(t)}{\mathcal{W}} = \frac{s_q \dot{Q}(t)}{Q} + \frac{s_e \dot{E}(t)}{E} \tag{7}$$

According to Eq. (7), the rate of change of total output is equal to a weighted average of the growth of output and growth of pollution. The weights are equal to the shares of output and pollution in the total value of output. Because pollution is damaging, it has a negative shadow price. Qualitatively, its impact on productivity has a similar effect as that of input costs (Nanere et al. 2007). If we define A^* as the productivity index for the joint output function $\mathcal{W}$ when we account for pollution, then the growth rate of A^* is:

$$\frac{\dot{A}^*(t)}{A^*} = \frac{s_q \dot{Q}(t)}{Q} + \frac{s_e \dot{E}(t)}{E} - \left[\frac{s_k \dot{K}(t)}{K} + \frac{s_m \dot{M}(t)}{M} + \frac{s_l \dot{L}(t)}{L}\right] \tag{8}$$

If we assume that $s_q = 1 - s_e$, then by combining Eqs. (6) and (8), we obtain:

$$\frac{\dot{A}^*(t)}{A^*} = \frac{\dot{A}(t)}{A} + s_e\left[\frac{\dot{E}(t)}{E} - \frac{\dot{Q}(t)}{Q}\right] \tag{9}$$

Where s_e is the weight of pollution damages in total output, $\dot{E}$ is the change in pollution damages, E is the level of pollution damages, $\dot{Q}$ is the change in the value of marketed output and Q is the value of marketed output. Eq.(9) shows how the two productivity indicators are related. The first part on the right hand side of Eq.(9) is what is conventionally estimated when undertaking productivity analysis, while the second part provides the environmental adjustment. The following results are derivable from the relationship in Eq.(9)

Proposition 1. *If s_e is negative and pollution grows more slowly than output, i.e., the term in bracket $\left[\frac{\dot{E}(t)}{E} - \frac{\dot{Q}(t)}{Q}\right]$ is negative, then the adjusted productivity index will increase* *more rapidly than the conventionally computed index.*[2]

Proposition 2. *If pollution increases more rapidly than marketed output, the conventional index will overstate the productivity growth rate.*

Proposition 3. *If output increases or stays constant, any decline in pollution will lead to a faster rate of productivity growth than that measured by the conventional index.*

In summary, the revised methodology takes into account a source of productivity growth that is totally not accounted for by using the conventional approach and this is an important source of efficiency gain.

3.2 TFP indices using Törnqvist and Fisher Formulae

The operationalization of the TFP calculations are based on the Hicks-Moorsteen economic theoretic approach. The productivity indices are calculated using the Törnqvist and Fisher indices. Our choice of these index numbers are based on their economic theoretic properties. Specifically, they collectively satisfy the required properties of a good index including: circularity, factor reversal, mean-value, time reversal, positivity, continuity, proportionality and commensurability property[3]. (see Coelli et al., 2005; 96). The Fisher index is a correction of the gap between the Laspeyres and Paasche indices and it is defined as a geometric mean of these two indices thus

$$Q^L_{s,t} = \frac{\sum_{i=1}^{N} p_{i,s} q_{i,t}}{\sum_{i=1}^{N} p_{i,s} q_{i,s}}, \quad Q^P_{s,t} = \frac{\sum_{i=1}^{N} p_{i,t} q_{i,t}}{\sum_{i=1}^{N} p_{i,t} q_{i,s}}, \quad \text{and} \quad Q^F_{s,t} = \sqrt{Q^L_{s,t} \times Q^P_{s,t}} \tag{10}$$

Where $p_{i,j}$ and $q_{i,j}$ represents prices and quantities of the n-th commodity in the N-commodity space $(n = 1, 2, \ldots, N)$ and the j-th period $(j = s, t)$ Without loss of generality, s and t may refer to any two time periods as long as $(t > s)$ and the quantities

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[2] Recall that pollution is regarded as a 'bad', and its impact on overall output is like that of an input since it will have a negative shadow price.

[3] It is important to note that the Fisher index satisfies all the properties listed , with the exception of the circularity test, the Törnqvist fails on the factor reversal and circularity properties.

n may refer to either inputs or outputs and $Q^L_{s,t}$, $Q^P_{s,t}$ and $Q^F_{s,t}$ are the Laspeyres, Paasche and Fisher indices respectively. Total factor productivity is therefore;

$$TFP^F = \frac{\text{Output Index}_{s,t}}{\text{Input Index}_{s,t}} \tag{11}$$

The Törnqvist index in its multiplicative and additive log-change form is as follows;

$$Q^T_{s,t} = \prod_{i=1}^{N} \left[\frac{q_{i,t}}{q_{i,s}}\right]^{\frac{\omega_{i,s}+\omega_{i,t}}{2}} \tag{12}$$

$$\ln Q^T_{s,t} = \sum_{i=1}^{N} \left(\frac{\omega_{i,s}+\omega_{i,t}}{2}\right)(\ln q_{i,t} - \ln q_{i,s}) \tag{13}$$

Where $\omega_{i,s}$ and $\omega_{i,t}$ are the value shares of the n-th commodity in the base and current year respectively and $\ln Q^T_{s,t}$ is the Törnqvist index. The TFP equivalent is thus

$$\ln TFP^T_{s,t} = \ln\left(\frac{\text{Output index}_{s,t}}{\text{Input Index}_{s,t}}\right) = \ln \text{Output Index}_{s,t} - \text{Input Index}_{s,t} \tag{14}$$

We can operationalize Eq. (13) by defining the cost and revenue shares for inputs and outputs specifically as follows, $r_{i,j}$ represents the revenue shares of output i for time $j = s, t$, and $s_{i,j}$ represent the cost shares of input i for time $j = s, t$. Where, q_i are outputs while x_i are inputs, then Eq. (13) becomes

$$= \frac{1}{2}\sum_{i=1}^{N}(r_{i,s}+r_{i,t})(\ln q_{i,t} - \ln q_{i,s}) - \frac{1}{2}\sum_{i=1}^{N}(s_{i,s}+s_{i,t})(\ln x_{i,t} - \ln x_{i,s}) \tag{15}$$

Where Eq. (15) is the logarithmic form of the Törnqvist index applied to output data and the input data respectively, using input quantities as the corresponding cost shares.

4 Data Description and Construction

4.1 Agricultural data

Time series data between 1980 and 2010 are used for the study. For output, we use aggregate national data on crop production and exclude livestock, forestry and fishing. Due to degrees of freedom constraints, all output was aggregated using a multilateral price-weighted Fisher quantity index which is obtained from the FAOSTAT database. For the purpose of this study, we consider four major agricultural inputs: land[4], labour, machinery and fertilizers. We use data on agricultural labour force from UNCTADSTAT. Agricultural machinery[5] data is obatined from FAOSTAT and fertilizer consumption in kilograms per hectare of arable land as obtained from FAOSTAT.

A major concern in computing agricultural TFP is deciding how to obtain appropriate prices for agricultural inputs. Land prices for example depend on location, topography and other geographic and economic characteristics such as soil productivity, potential yield and relative proximity to infrastructure and markets. These characteristics of land prices make any national estimates not to be easily generalizable since they are likely to suffer from wide variations. Our literature search shows that there is only one study which attempt to estimate average land prices across different countries. This study[6], estimates land prices as a multiple of per capita income adjusted for proportions of pasture, cropland, forestland and arid land in total land area (see Brown, 2003). The study shows that the value of land per hectare in Nigeria is between \$101 and \$200 (World Bank, 1999). However, because their calculations are point estimates for each country, we are unable to use this as a proxy.

Alternatively, Breustedt and Habermann (2008) and Parcon et al. (2011) show a sense in which one can value agricultural land, based on the incomes that the farmers are

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[4] Agricultural land refers to the share of land area that is arable under permanent crops. Arable land includes land defined by the FAO as land under temporary crops (double-cropped areas are counted once), Land abandoned as a result of shifting cultivation is excluded. Land under permanent crops is land cultivated with crops that occupy the land for long periods and need not be replanted after each harvest.

[5] Agricultural machinery as defined by FAO refers to the number of wheel and crawler tractors (excluding garden tractors) in use in agriculture at the end of the calendar year specified or during the first quarter of the following year.

[6] World Bank Global Approach to Environmental Analysis (GAEA)(World Bank, 1999)

expected to generate. They also show evidence that crop yield has a significant positive impact on the price of land[7]. On the basis of their result, we proxy the value of agricultural land using cereal yield per hectare obtained from FAOSTAT.[8]

We use the compensation of employees in the economy to proxy labour costs. Compensation of employees is the total remuneration in cash or in kind payable to an employee in return for work done. To obtain the fraction accruing to the agricultural sector, we find the proportion of crop production in GDP and use that to scale the compensation of employee series. The data series are obtained from the National Accounts of Nigeria published by the National Bureau of Statistics (NBS). For agricultural machinery, we use the importation value of the machinery (per $1000) obtained from FAOSTAT. This is simply a way of valuing the agricultural machinery deployed in the economy by using comparable international prices. Data on fertilizer input prices as paid by farmers is directly available from the FAOSTAT database where we retrieve the series.

4.2 Soil erosion estimates using USLE

Until very recently, there has been very little information collected within surveys and experiments to measure the extent of land erosion due to agriculture and other factors in Nigeria. Fortunately, there is now a recently completed project by the Federal Ministry of Agriculture and Natural Resources in Collaboration with SSC Satellibild[9] on the assessment of soil degradation in Nigeria (see FDALR, 2009). The limitation in applying the results from this study is that they provide only point estimates of soil erosion, and we require times series information to be able to incorporate environmental externalities.

To obtain times series estimates of soil erosion in Nigeria, we apply the Universal Soil Loss Equation (USLE). In-spite of some arguments about its reliability and appropriateness, it still remains the most accessible non Satellite based technique for measuring soil erosion (see Grimm, 2003). One major advantage of using the USLE equation is because it is

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[7] The evidence also indicates that farm size, labour and capital endowments have no significant impact on the price of land, hence we do not consider these factors in an attempt to price land.

[8] Parcon et al. (2011) have shown that data on cereal yield provided rankings consistent with those of land prices from the World Bank's study.

[9] SSC Satellibild is a Swedish space corporation with a data Consulting unit.

easily tractable with the available soil and climate related data collected by the Nigeria Meteorological Agency (NiMet) and other agencies in West Africa during the past three decades. Whereas, the data requirements for more sophisticated soil loss prediction models such as the Soil Loss Estimation Model (SLEM) by Elwell and Stocking (1982) are simply not available at the moment. As for the applicability of the USLE model in Nigeria, we stand by the conclusions of Roose (1977) and Bishop and Allen (1989) who have separately found the USLE equation to be a reliable predictor of soil loss for the majority of cultivated lands in West Africa, typical of the gentle slops and iron-rich soils of Nigeria.

Using the Universal Soil Loss Equation (USLE), we can estimate annual soil erosion from agriculture by applying the following equation;

$$\mathcal{E}_t = R_t \times K_t \times SL_t \times C_t \times P_t \tag{16}$$

Where $\mathcal{E}$ is the average annual soil erosion in tons per hectare, (R) is the erosivity of rainfall, (K) is the inherent susceptibility of the soil to erosion by water, (SL) represents a calibration for the slope and steepness of the soil, (C) represents the crop cover and management technique used and (P) is a correction factor for supplemental conservation and cultivation practices on the particular field. Here, we briefly explain how we obtain data for each of the five variables. Note that comprehensive statistics on soil, vegetation, rainfall and land use in Nigeria and West Africa is collected by the Ibadan station of the International Institute of Tropical Agriculture (IITA) based on observation and information from satellite images (specifically LANDSAT).

To obtain values for rainfall erosivity (R), we simply follow the results obtained in Roose (1977) which finds that the ratio between climatic erosivity and annual precipitation is almost always about 0.50 ± 0.05 in West Africa[10]. Hence, by simply multiplying the annual precipitation estimates in Nigeria reported by NiMet with the upper limit of 0.55, we obtain the values of rainfall erosivity which we plug into the USLE equation. For the soil erodibility index, we use the average estimate of soil erodibility for thirteen different

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[10] The study by Roose (1977) is based on a 5 % error and 28 rainfall recording stations in West Africa

soil types in Nigeria obtained by FDALR (2009). The average value of 0.507 was used in the USLE equation for each year. The slope parameter variable (SL) in the USLE model has two components, the angle (S) and the length (L) which are treated together. The slope factor is difficult to estimate without actual detailed field surveying which is not feasible for the present project, hence we follow the procedure that has been used in the literature by setting a uniform value of slope length all over the country (see examples of similar applications by FDALR, 2009:46 for Nigeria and Bishop and Allen, 1989:11 for Mali). This generalization is not likely to significantly affect the results of the model except in very extreme cases. Lal (1994) has shown that the slope-length variable is one of the least important for soil loss estimation. The standard slope length is therefore set at 50m as this is considered to be a normal size for a field on an average small-scale farm although it may exceed that for large-scale mechanized farms (FDALR, 2009). The idea is to relate the estimated slope length factor to a “standard” slope length and the sediment production resulting from this standard slope which is 22m (approximately 72.6 feet). Hence, we use (22/50= 0.44) for the baseline USLE model.

Data for the crop cover and management technique are based on land use and vegetation mapping performed by the FORMECU Land Use and Vegetation Mapping Project (see FDALR, 2009:48). Here, we use the parameter estimate of 0.35 for rainfed arable land as a proxy for the C-factor. For the last factor in the USLE model, i.e. (P), conservation practices, we observe that cultivation and conservation practices are highly heterogeneous in Nigeria, from contour ploughing to mulching, terracing and a host of others. These practices may even vary between adjacent fields and it is impossible to distinguish such detail in an aggregated study such as this. Hence, we set the (P)-parameter to (1.0), which corresponds to conventional ploughing executed perpendicular to the slope of the field manually (see Bishop and Allen 1989:13 and FDALR, 2009:49).

4.3 Damage cost scenarios

To determine the damage costs associated with soil erosion and sedimentation for any country is a tedious exercise. Our literature search reveals that there are only about five

(5) national comprehensive studies that seek to monetize the economic costs of soil erosion, and all of these studies are for the United States. These studies include: Clark et al., (1985); Hansen and Ribaudo (2008), Ribaudo (1986), Ribaudo (1989) and Pimentel et al., (1995).[11] Other studies in the literature derive country specific damage cost estimates for soil erosion by some appropriate adaptation of the estimates that were obtained in these five studies. Some typical examples include. Nanere et al. (2007) for Australia, Cohen et al., (2006) for Kenya, Fox and Dickson (1988) for Canada and Alfsen et al. (1993) for Nicaragua.

In this study, we use a transformation of Ribaudo's (1989) estimates of damage costs arising from soil erosion using US data. We adapt Ribaudo's estimates for the following reasons. Their estimates are easily comparable when soil erosion is measured using the standard USLE framework (Nanere et al, 2007) and the estimates are known to be the most comprehensive, capturing over 12 dimensions of damage. Also, Ribaudo's estimates of the damage cost of soil erosion where derived from three different scenarios depending on the agricultural production techniques used in the regions among other factors. The low scenario estimates correspond to the use of production techniques that are relatively less capital intensive, which is comparable to the prevailing production technique in a developing country like Nigeria. Whereas, the high-scenario and best-scenario estimates are for higher and optimal production techniques respectively.

Ribaudo's study obtained three different point estimates of damage cost of soil erosion per ton, in terms of GDP. The high damage scenario estimate is ($3.57/ton), low-damage scenario is ($1.03/ton) and the best-damage scenario is ($1.78/ton) for 1988. For our study, we adapt these estimates to the Nigerian case by assuming that the relationship between soil erosion damage costs in the US and Nigeria is monotonically related to the relative sizes of these economies in terms of GDP. In other words, the damage cost of soil erosion in Nigeria is proportionally related to the size of the Nigeria economy in relation to the US economy. Therefore, by comparing GDPs for the two economies in

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[11] You may refer to GLC (2008:25). "The Economics of Soil Erosion and Sedimentation in the Great lake Basin" at `http://projects.glc.org/tributary/pubs/documents/Economics_of_Soil_Erosion_Final.pdf` for a thorough review of this literature.

1988, we found that the US economy was approximately 19 times bigger than the Nigerian economy[12]. By simply pre-multiplying Ribaudo's estimates of the cost of agriculture related erosion per ton in terms of lost GDP with 0.05, we obtain an approximation of soil erosion damage cost for Nigeria under three similar scenarios; (1) Low damage cost scenario $0.051/ton, (2) Optimal damage cost scenario $0.089/ton and (3) High-damage cost scenario $0.178/ton. These damage cost estimates are then converted to their local currency equivalents.

Further, because of the non precise nature of the behaviour and evolution of damage costs over time, we construct time series for this variable making two different assumptions. First we assume that damage costs per ton has remained static. This will imply that the real cost of soil erosion damages has decreased steadily over time. Second, we make a more realistic assumption that damage costs per ton has grown in proportion to GDP, this possibility can be defended by arguing that because of the cumulative effect of soil erosion, damage costs are increasing because each additional unit of soil erosion causes a greater feedback impact. Alternatively, it has been argued in the literature that the income elasticity with respect to individual's valuation of environmental 'goods' are generally considered to be greater than zero, hence increasing damage costs (see Nanere et al., 2007 and Schlapfer, 2006, for a discussion of the literature).

5 Results

In this section, we present and discuss a selection of the results we obtained in computing conventional and environmentally adjusted TFP estimates for Nigerian agriculture. We also consider the sensitivity of our results to the different assumptions we make about the static and dynamic trajectory of soil erosion damage costs to the economy. These sensitivity analysis are intended to help generate important policy implications in relation to farm practices, natural resource management and the use of production techniques in the agricultural sector in Nigeria and maybe generalizable to West Africa.

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[12] Specifically, 53,101/2831=18.75, or we may say that the Nigerian economy was 0.0533 of the US economy

5.1 Unadjusted TFP

In Figure 1 and Table 1, we show the trend in conventionally computed input, output and TFP indices for Nigeria agriculture. Notice that the information in Table 1 begins with values from 1988, this is done in other to make the values comparable with the values we obtain after adjusting for environmental externalities. These indices are conventional because there is no adjustment for environmental externalities. The computation was done using `TFPIP` version 1, a `DOS` programme developed by Tim Coelli [13]. The indices are Törnqvist indices which applies a logarithmic transformation as described earlier and they are transitive relative to the first observation. In other words, we set the index to 1 in the first period. Results for the Fisher index are very similar to the Törnqvist indices and so they are not reported here.

A cursory look at the figure shows that but for the sharp fall in the output index during the early 80's the output index has increased steadily but slowly since the mid 1980's. The input index has been relatively more volatile, improving in the 80's, generally declining in the 90's and picking up sharply in the 2000's. Apart from significant improvements in early 1980's TFP growth has generally been low and falling during the period of study. The conclusion that is derivable from the pattern we observe is that the modest output growth in Nigerian agriculture can be attributed to the marginal growth in the input factor that has been experienced over the years through improvements arising from cost savings in input use rather than TFP growth.

To get a better understanding of the patterns we observe between the output, input and TFP indices in Figure 1, we formalize the analysis by decomposing the growth in the output index into that due to growth in the input use versus that due to growth in total factor productivity. However, unlike other studies that use averages to examine relative contribution (see for examples Fuglie, 2010; 2011), we use regression estimates to examine relative contributions including the overall and sub-sample trend growth rates for the three indices. This is to enable us check for statistical significance of the growth rates and the

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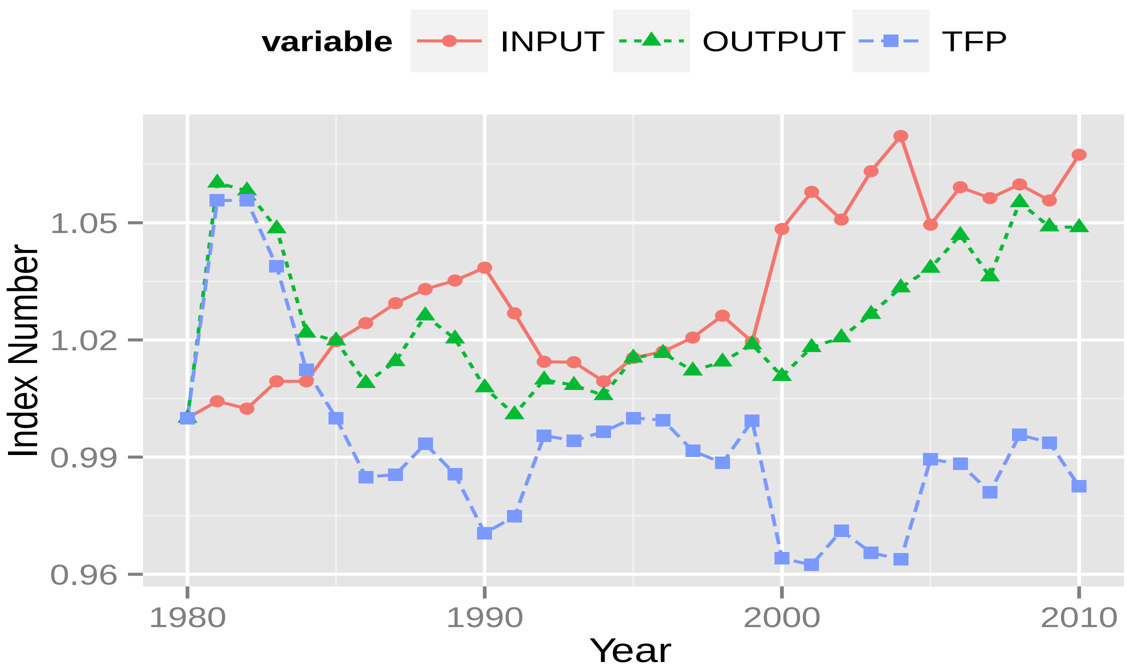
[13] For full details and instruction manual, see Tim Coelli, Centre for Efficiency and Productivity Analysis, School of Economics, University of Queensland Brisbane, QLD 4072, Australia. `http://www.uq.edu.au/economics/cepa/software.php`

Figure 1: Trend in Conventional Törnqvist Indices



relative contribution of TFP and input to the output factor. The results from a regression of the three indices on a linear time trend for the whole period and for three different period subsamples are presented in Table 2. In the overall sample (1980-2010), we observe that the growth rate of TFP decreased by 0.001%, resulting from an estimated growth rate of 0.001% in the output index and 0.002% in the input index. This further validates our assertion that most of the growth in the output index experienced over the entire sample period can mostly be attributed to improvements in input use. By looking at the 10 year interdecadal growth rates, we are able to separate and better understand the current trend in the variables. In the most recent decade of the series (2001-2010), output growth is about 0.004%, resulting from a 0.003% growth in TFP and 0.001% growth in input. This result when decomposed shows that in the last decade, TFP contributed about 75% to overall growth in output which can be considered a closer depiction of the current state of progress in the Nigerian agricultural sector. In sum, the statistical evidence indicates that there has been rising output in Nigerian agriculture particularly in recent years per unit of; machinery, land, labour and fertilizers. In the next subsection we consider weather

Table 1: Unadjusted Törnqvist Indices for Nigeria Agriculture

Year	Input	Output	TFP
1988	1	1	1
1989	1.0044	1.0602	1.0556
1990	1.0025	1.0582	1.0556
1991	1.0094	1.0485	1.0388
1992	1.0092	1.0218	1.0125
1993	1.0197	1.0198	1
1994	1.0245	1.0089	0.9848
1995	1.0295	1.0145	0.9855
1996	1.0331	1.0262	0.9934
1997	1.0352	1.0203	0.9856
1998	1.0385	1.0078	0.9705
1999	1.0267	1.0009	0.9749
2000	1.014	1.0098	0.9958
2001	1.0138	1.0084	0.9947
2002	1.0087	1.0058	0.9972
2003	1.0147	1.0154	1.0007
2004	1.0163	1.0166	1.0002
2005	1.02	1.0121	0.9923
2006	1.0255	1.0144	0.9891
2007	1.0187	1.0188	1
2008	1.0481	1.0107	0.9644
2009	1.0577	1.0181	0.9626
2010	1.0505	1.0206	0.9715
Average	1.022	1.019	0.996

These indices are transitive and relative to the first observation.

this conclusion is still valid when we incorporate environmental externalities in the form of soil erosion.

5.2 Environmentally adjusted TFP

In this section, the results for agricultural TFP when an adjustment is made for environmental externalities in the form of soil erosion is presented and compared with the results in the case where there is no adjustment for environmental externalities. Figure 2 and Figure 3 is a graphical presentation of TFP growth trends in Nigeria agriculture without and with environmental adjustment respectively. In Figure 2 and Table 1, the trend in unadjusted Törnvist indices with 1988 as the base year is presented. By using 1988 as the base year, it is possible to facilitate a direct comparison with the environmentally

Table 2: Trend growth and contribution of input and TFP to output growth

Sample	Trend growth in output	Trend growth in input	Trend growth in TFP	Contribution of TFP to output growth/fall(%)
1980-1990	-0.003 (0.002)	0.004*** (0.000)	-0.007*** (0.002)	-100
1991-2000	0.001** (0.000)	0.002 (0.001)	-0.001 (0.001)	0
2001-2010	0.004*** (0.001)	0.001 (0.001)	0.003*** (0.001)	75
1980-2010	0.001*** (0.000)	0.002*** (0.000)	-0.001*** (0.000)	-

Asterisks indicates the following significance levels; *** for 1%, ** for 5%, and * for 1%. The corresponding standard errors are given in brackets.

adjusted indices since the damage cost estimates we use begins at 1988. When comparing the results from the conventional estimation of the indices with the results after adjusting for non-marketed outputs in form of soil erosion, under the low and static scenarios of soil erosion damage costs, shown in Figure 3 and Table 5, we observe remarkable differences particularly in the first decade.

Figure 2: Trend in Unadjusted Tornqvist Indices

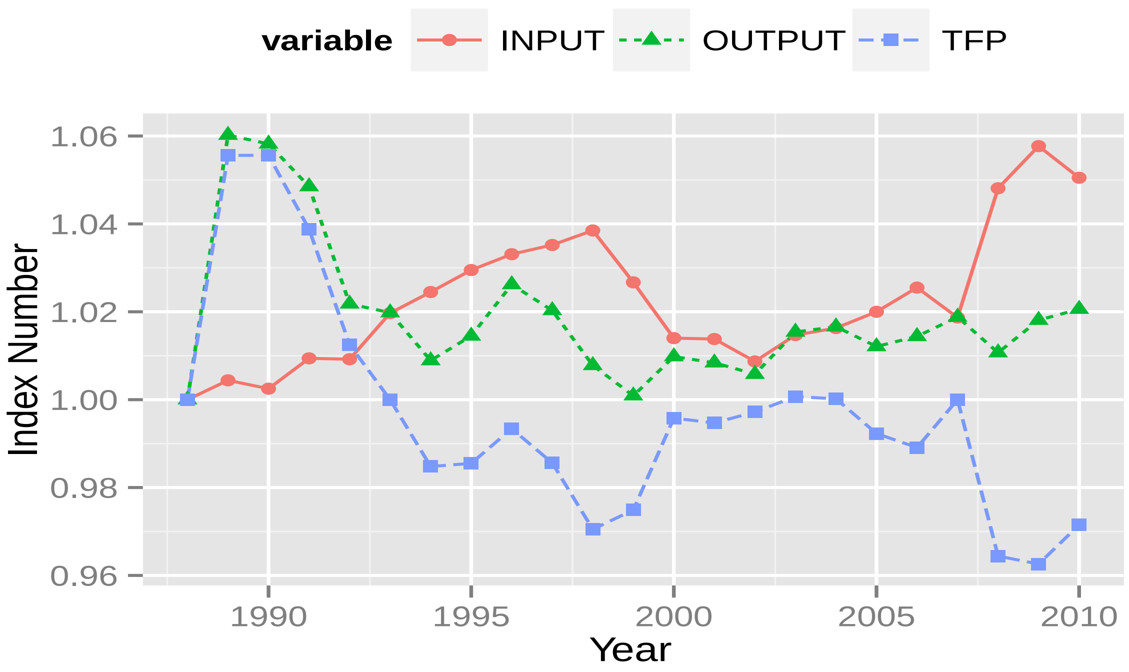


Figure 3: Trend in Environmentally Adjusted Tornqvist Indices (static damage cost)

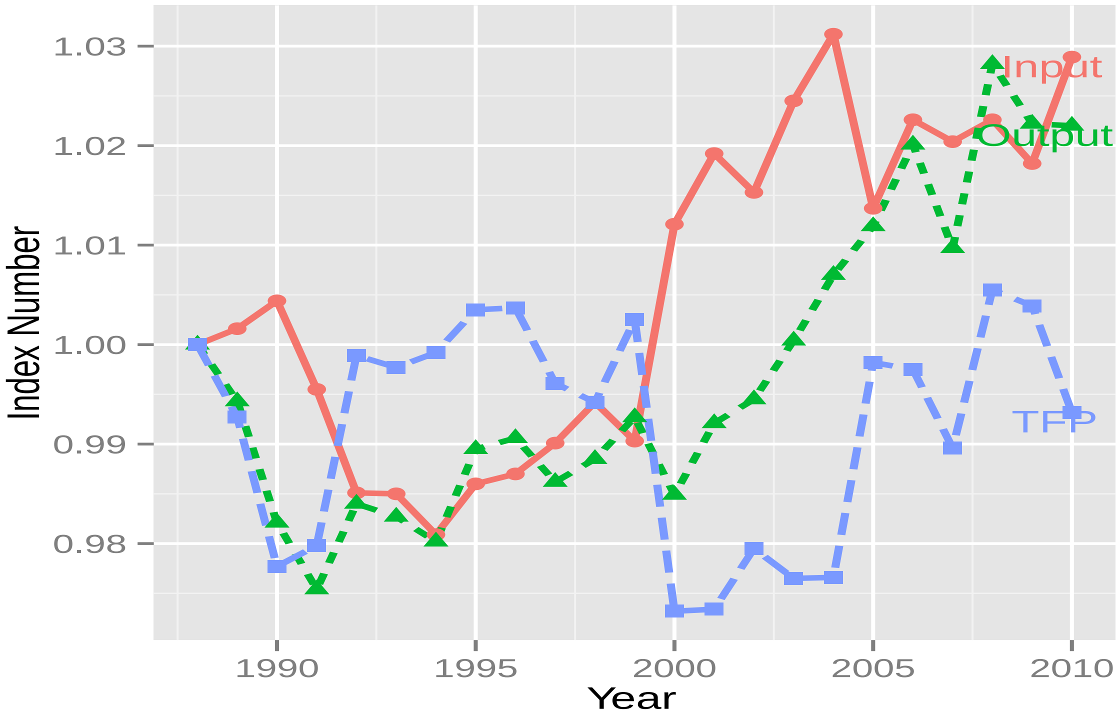
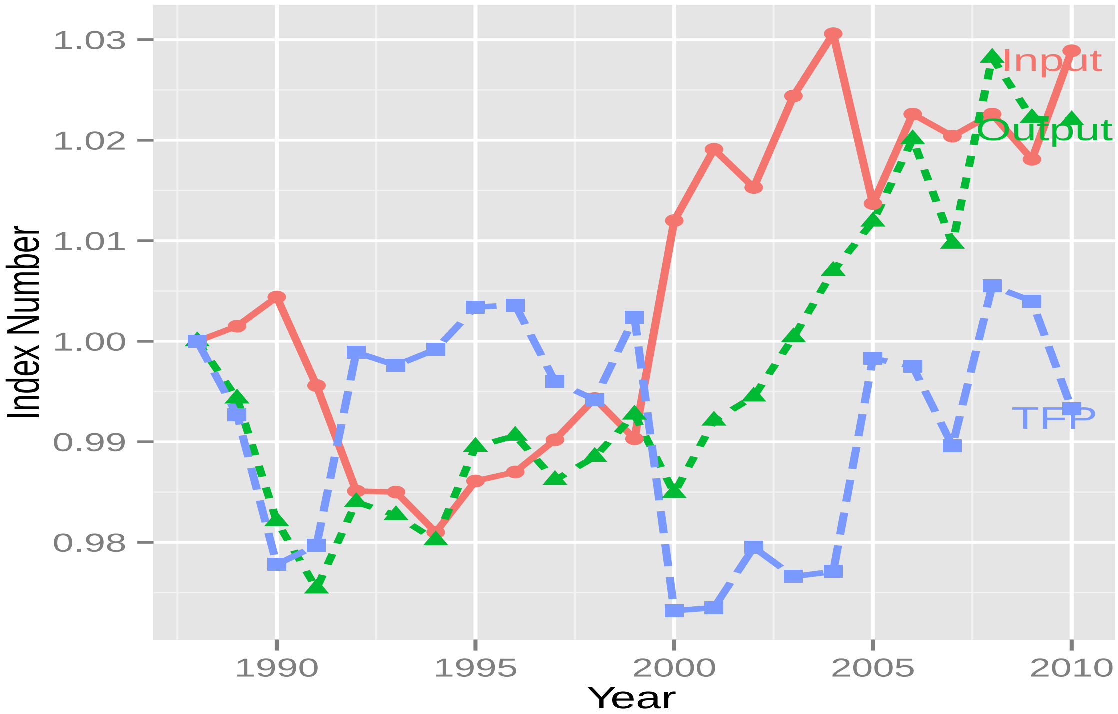


Figure 4: Trend in Environmentally Adjusted Tornqvist Indices (dynamic damage cost)



Specifically, using conventional measures, i.e., accounting for only marketed inputs and outputs TFP is generally rising between 1988 and 1992. Whereas, during the same period,

Table 3: Environmentally adjusted trend growth and contribution of TFP and input to output growth using static erosion damage cost

Sample	Trend growth in output	Trend growth in input	Trend growth in TFP	Contribution of TFP to output growth/fall(%)
1991-2000	0.001**	0.002*	-0.001	-
	(0.000)	(0.000)	(0.001)	
2001-2010	0.004***	0.001	0.003***	75
	(0.001)	(0.001)	(0.001)	
1988-2010	0.002***	0.002***	-0.000	-
	(0.000)	(0.000)	(0.000)	

Asterisks indicates the following significance levels; *** for 1%, ** for 5%, and * for 1%. The corresponding standard errors are given in brackets.

Table 4: Environmentally adjusted trend growth and contribution of TFP and input to output growth using dynamic erosion damage cost

Sample	Trend growth in output	Trend growth in input	Trend growth in TFP	Contribution of TFP to output growth/fall(%)
1991-2000	0.001**	0.002	-0.001	-
	(0.000)	(0.001)	(0.001)	
2001-2010	0.004***	0.001	0.003***	75
	(0.001)	(0.001)	(0.001)	
1988-2010	0.002***	0.002***	-0.000	-
	(0.000)	(0.000)	(0.000)	

Asterisks indicates the following significance levels; *** for 1%, ** for 5%, and * for 1%. The corresponding standard errors are given in brackets.

when we account for non-marketed outputs in the form of soil erosion, TFP is falling. The pattern is however reversed in the mid 1990s and early 2000s, while conventional TFP is falling, environmentally adjusted TFP is rising in that period. On average, during the entire study period (1988-2010), TFP measurement for Nigerian agriculture using conventional inputs and outputs is higher than the estimated levels when we account for environmental externalities assuming low and static damage costs. The relationship is also similar when we assume low and dynamic damage costs scenarios, i.e., damage costs that grow in proportion to the growth rate of the economy (see the averages at the bottom of Table 1, Table 5 and Table 6). These results suggest that by calculating total factor productivity without incorporating environmental externalities, farmers and policy

Table 5: Environmentally adjusted Törnqvist indices with static damage costs

	Low damage cost			Optimal damage cost			High damage cost		
Year	Input	Output	TFP	Input	Output	TFP	Input	Output	TFP
1988	1	1	1	1	1	1	1	1	1
1989	1.0016	0.9943	0.9927	1.0014	0.9943	0.9929	1.0011	0.9943	0.9932
1990	1.0044	0.9821	0.9777	1.0043	0.9821	0.9778	1.0041	0.9821	0.978
1991	0.9955	0.9754	0.9798	0.9959	0.9754	0.9794	0.9965	0.9754	0.9788
1992	0.9851	0.984	0.9989	0.9853	0.984	0.9987	0.9858	0.984	0.9982
1993	0.985	0.9827	0.9977	0.9853	0.9827	0.9973	0.986	0.9827	0.9966
1994	0.9809	0.9802	0.9992	0.9815	0.9802	0.9986	0.9826	0.9802	0.9975
1995	0.986	0.9895	1.0035	0.9867	0.9895	1.0028	0.988	0.9895	1.0015
1996	0.987	0.9906	1.0037	0.9875	0.9906	1.0031	0.9886	0.9906	1.002
1997	0.9901	0.9862	0.9961	0.9908	0.9862	0.9954	0.9922	0.9862	0.994
1998	0.9942	0.9885	0.9942	0.9945	0.9885	0.994	0.9949	0.9885	0.9936
1999	0.9903	0.9927	1.0025	0.9916	0.9927	1.0011	0.9942	0.9927	0.9985
2000	1.0121	0.9849	0.9732	1.0115	0.9849	0.9737	1.0104	0.9849	0.9747
2001	1.0192	0.9921	0.9734	1.0181	0.9921	0.9745	1.0158	0.9921	0.9767
2002	1.0153	0.9945	0.9795	1.0154	0.9945	0.9794	1.0156	0.9945	0.9793
2003	1.0245	1.0004	0.9765	1.0236	1.0004	0.9773	1.022	1.0004	0.9788
2004	1.0312	1.007	0.9766	1.0296	1.007	0.978	1.0267	1.007	0.9808
2005	1.0137	1.0119	0.9982	1.0133	1.0119	0.9986	1.0126	1.0119	0.9993
2006	1.0226	1.0201	0.9975	1.0225	1.0201	0.9976	1.0222	1.0201	0.9979
2007	1.0204	1.0097	0.9896	1.0204	1.0097	0.9895	1.0205	1.0097	0.9895
2008	1.0226	1.0282	1.0055	1.0222	1.0282	1.0059	1.0214	1.0282	1.0067
2009	1.0182	1.0222	1.0039	1.0175	1.0222	1.0046	1.0162	1.0222	1.0059
2010	1.0289	1.022	0.9932	1.0284	1.022	0.9938	1.0274	1.022	0.9948
Average	1.0056	0.9973	0.9918	1.0055	0.9973	0.9919	1.0054	0.9973	0.992

These indices are transitive and hence, they are relative to the first observation. The three different sets of indices corresponds to the case where we assume that the damage costs of soil erosion is static with three different scenarios. Low cost, optimal cost and high cost estimates.

makers have generally viewed the Nigerian agricultural sector to be more productive than it really is. This conclusion is valid when the entire sample period is considered. However, when we examine the results decade by decade, the conclusion does not hold in every decade.

Another striking difference we notice between the conventional and environmentally adjusted TFP is that the differences in the trend of the indices are only significantly pronounced during the initial years of the measurement, as time progresses, the differences become modest and dampened. Although this result seems to be puzzling, the literature

Table 6: Environmentally adjusted Törnqvist indices with dynamic damage costs

	Dynamic low price			Dynamic optimal price			Dynamic high price		
Year	Input	Output	TFP	Input	Output	TFP	Input	Output	TFP
1988	1	1	1	1	1	1	1	1	1
1989	1.0015	0.9943	0.9927	1.0014	0.9943	0.9929	1.001	0.9943	0.9933
1990	1.0044	0.9821	0.9778	1.0043	0.9821	0.9779	1.0041	0.9821	0.9781
1991	0.9956	0.9754	0.9797	0.9959	0.9754	0.9794	0.9966	0.9754	0.9787
1992	0.9851	0.984	0.9989	0.9853	0.984	0.9986	0.9858	0.984	0.9982
1993	0.985	0.9827	0.9976	0.9854	0.9827	0.9973	0.9861	0.9827	0.9966
1994	0.981	0.9802	0.9992	0.9816	0.9802	0.9986	0.9827	0.9802	0.9974
1995	0.9861	0.9895	1.0034	0.9868	0.9895	1.0027	0.9881	0.9895	1.0014
1996	0.987	0.9906	1.0036	0.9876	0.9906	1.003	0.9888	0.9906	1.0019
1997	0.9902	0.9862	0.996	0.9909	0.9862	0.9953	0.9923	0.9862	0.9939
1998	0.9943	0.9885	0.9942	0.9945	0.9885	0.9939	0.9949	0.9885	0.9935
1999	0.9903	0.9927	1.0024	0.9917	0.9927	1.001	0.9944	0.9927	0.9984
2000	1.012	0.9849	0.9732	1.0114	0.9849	0.9738	1.0103	0.9849	0.9748
2001	1.0191	0.9921	0.9735	1.0179	0.9921	0.9746	1.0156	0.9921	0.9769
2002	1.0153	0.9945	0.9795	1.0154	0.9945	0.9794	1.0156	0.9945	0.9793
2003	1.0244	1.0004	0.9766	1.0234	1.0004	0.9775	1.0217	1.0004	0.9791
2004	1.0306	1.007	0.9771	1.0288	1.007	0.9788	1.0256	1.007	0.9819
2005	1.0137	1.0119	0.9983	1.0133	1.0119	0.9987	1.0125	1.0119	0.9994
2006	1.0226	1.0201	0.9975	1.0224	1.0201	0.9977	1.0222	1.0201	0.9979
2007	1.0204	1.0097	0.9896	1.0204	1.0097	0.9895	1.0205	1.0097	0.9895
2008	1.0226	1.0282	1.0055	1.0221	1.0282	1.006	1.0213	1.0282	1.0068
2009	1.0181	1.0222	1.004	1.0174	1.0222	1.0047	1.0161	1.0222	1.006
2010	1.0289	1.022	0.9933	1.0283	1.022	0.9939	1.0272	1.022	0.9949
Average	1.005	0.997	0.991	1.005	0.997	0.991	1.005	0.9973	0.992

These indices are transitive. They correspond to the case where we assume that the damage cost of erosion is dynamic and grows in proportion to the growth in GDP.

provides some explanation why this could be the case. One explanation could be because there is an implied negative relationship between productivity growth and resource degradation as verified in the empirical study by Ali and Byerlee (2002) in Pakistan's Punjab. The more intuitive explanation is that as time goes by, land use policies and technologies adapt to observed externalities and hence over time, the differences between conventional and environmentally adjusted productivity estimates fizzle out. This sort of relationship is commonly referred to as the "proenvironmental bias of technical change".

In Table 3, we present the regression results of the three indices on a time trend, under the assumption of low and static erosion damage costs. The regression results are shown for the entire sample period (1988-2010), and two different decades (1991-2000) and (2001-2010). We observe that the contribution of TFP to output growth during the period 1991 to 2000, is almost non-existent. However, in the latter decade of 2001 to 2010, TFP accounted for a significant 75% of the growth experienced in output during that period. When we examine the results for the entire sample period, we observe that the positive effect of TFP on output growth is completely eclipsed by the contribution of input use. This result is robust weather TFP is measured using only conventional input and outputs or we adjust for externalities.

Further, considering the two dimensions of sensitivity analysis conducted, we observe modest and negligible differences in the pattern of the environmentally adjusted indices. First, on the dimension of static vs dynamic trajectory of damage costs, we noticed that the dynamic damage cost series which was obtained based on the assumption that damage costs from soil erosion grows over time in proportion to the growth rate of the economy, were not too different from the static damage cost series. This is because the growth rate of the Nigerian economy has been rather modest ranging between plus and minus 5%. This could probably explain the close similarities we observe in the results for the static and dynamic versions of the environmental adjustment to TFP measurement presented in Figure 3 vs. Figure 4; Table 3 vs. Table 4 and Table 5 vs. Table 6. On the second dimension of sensitivity analysis which involves different scenarios of pricing soil erosion per ton, ranging from a low cost scenario of \$0.051 to an optimal value of \$0.089 and high value of \$0.178 converted to naira equivalents at 1988 prices. The impact of these different scenarios on estimated Törnvist TFP indices are also negligible and due to rounding errors, (see averages at the bottom of Table 6 and Table 5)

6 Policy discussion

The results show that productivity in the Nigerian agricultural sector is overstated when account is not taken of the externalities that the sector generates in the form of the cost of soil erosion to the rest of the economy. Overall, the policy insight derivable from the results obtained is that reducing off-farm erosion damages through improved soil conservation practices will improve productivity and sustainability in the Nigerian agriculture sector.

Specifically, during the first decade of 1980-1990, the decomposition analysis of the trend in output, input and TFP indices gives a retrospective assessment of the Green Revolution Agricultural Policy that was implemented during that period. Although, the policy was intended to achieve food security and self-sustainability through agricultural intensification, the results shows that a very significant portion of the growth in output is due to cost savings and improvements in utilization of inputs. This observed pattern could be explained by the observation in Coelli and Rao, (2005) that new technologies take considerable time to be efficiently utilized in developing countries. The policy insight therefore is to pursue increased agricultural productivity in a sustainable manner through a mix of extensification and intensification strategies since it takes a while to efficiently deploy conservation and soil management technology.

Finally, the modest contribution of TFP to output growth which is even further dampened when we account for environmental externalities has serious implications for the long term performance of Nigerian agriculture. In the future, Nigeria will find it increasingly difficult to improve agricultural output by expanding agricultural land, labour and inputs without growth in TFP and hence agricultural output will only continue to grow very slowly compared to other emerging economies like Indonesia 3.6% (see Fuglie, 2010) and Brazil 2.6% (see Headey et al., 2010). The likely consequence of the possible slow agricultural growth rates will be to exacerbate the already high levels of resource and labour reallocation from agriculture and rural settlements to other sectors and urban regions of the economy. Although reallocation of labour and resources away from agriculture is an expected phenomenon in the process of development, given the prevailing circumstances, these decisions are likely to be suboptimal with high opportunity costs. Potentially high yielding investment opportunities in the agricultural sector will be foregone, thereby undermining the capacity of the agricultural sector to drive economy-wide development through food security and poverty alleviation.

7 Conclusion

In this study, we argue that conventional methods of measuring agricultural productivity does not give a true representation of how sustainable the activities of the sector are. Hence, we construct output, input and TFP indices for Nigerian agriculture after adjusting for environmental externalities in the form of soil erosion. The results show that when externalities are not accounted for, productivity in the Nigerian agricultural sector is overestimated. When we account for soil erosion assuming that the damage cost of soil erosion is low and static over the years, we find the TFP in the agriculture sector is dampened. The conclusion does not change when we assume that damage costs grow in proportion to the growth rate of GDP. When we conduct the analysis decade by decade, we notice that the conclusion changes in the most recent decade of 2000-2010 where we find that TFP contributes about 75% to the overall growth in agricultural output.

The policy implication emerging from the study is that reducing off-farm erosion damages through improved soil conservation practices will significantly improve productivity and sustainability in the Nigerian agriculture sector. Also, because new technologies take considerable time to be efficiently utilized, current and future agricultural policies should pursue a mix of extensification and intensification strategies unlike previous policy frameworks that have either pursued intensification or extensification of agricultural production.

It is important to highlight some of the limitation of the present study and suggest potential improvements that could help make the results more generalizable to other sectors. Firstly, there are shortcomings in the methods used for estimating erosion from agricultural activities. This is because, it does not account for heterogeneity in the topological characteristics of soil in the different regions, rather we use a homogeneous soil erodibility factor. In the future, if government agencies can collect specific information about soil erosion in each state, then by aggregation, a closer approximation of the extent of soil erosion occasioned by agriculture in Nigeria can be obtained. Second and more controversial is the scaling down of damage cost estimates from U.S agriculture and the application to Nigeria. Although this has been the generally used compromise in similar studies, see for examples Nanere et al. (2007) for Australia, Cohen et al., (2006) for Kenya, Fox and Dickson (1988) for Canada and Franco et al. (1993) for Nicaragua, it is still a bone of contention as the agricultural systems in these countries are generally different. The implication is that the extrapolated results obtained by using damage estimates from the U.S may either overestimate or underestimate the cost of soil erosion in the economy depending on the criteria used for downscaling. Future research could focus on other sectors like the oil and gas sector where it is possible to obtain Nigeria specific estimates of the economy-wide cost of water and air pollution.

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