Unravelling the links between agriculture and economic growth:
a panel time series approach for post-WW II Africa

Evert J. Los and Cornelis Gardebroek

Agricultural Economics and Rural Policy group

Wageningen University, The Netherlands

Hollandseweg 1, 6706 KN Wageningen, The Netherlands

tel. +31 317 482951 ; fax +31 317 484736 ;

koos.gardebroek@wur.nl

Abstract

This study explores the interaction between agricultural development and economic growth for 52 African countries in the period 1961-2010. The study applies panel co-integration and Granger causality approaches in order to unravel the links between economic and agricultural development. The estimation results imply that the agricultural sector performs different roles in different stages of economic development. In low income countries, increasing the level of food production plays a pivotal role in generating further economic development, whereas in the more developed upper middle income countries the outflow of labor to other economic sectors is crucial for understanding economic growth. The profoundly stated argument that reallocation of labor from agriculture towards other economic sectors is among the main drivers of economic growth for developing countries, is therefore only found to be valid under specific circumstances. Moreover, panel causality results show the existence of a bidirectional causal relation between agricultural and economic development.

Keywords

Agricultural Development – Economic Growth – Africa – Non-Stationary Panels - Panel Co-Integration – Panel Causality

1. Introduction

The presumed relation between agriculture and economic growth is an extensively debated topic. Often, a low productivity level and a slow growth of the agricultural sector are perceived as the main causes for low incomes and slow economic growth in developing countries (Alston and Pardey, 2014). Unsurprisingly, there is widespread evidence for a positive relation between increases in agricultural productivity and economic growth (Gollin, 2010; Self and Grabowski, 2007). Moreover, the agricultural sector is in various influential development reports often advocated as a vital tool and crucial sector for generating economic growth and fighting poverty (World Bank, 1981 and 2008).

The causal direction of the relation between agriculture and economic development however is subject to debate (Gollin, 2010; Tiffin and Irz, 2006). Some literature emphasizes the importance of increases in agricultural productivity as prerequisite for economic growth. According to this literature – mainly in developing countries, where the agricultural sector accounts for a large share of the workforce and accounts for roughly 25% of the value added in the economy – growth in agricultural productivity causes significant aggregate effects and will therefore also influence the general economic growth within a country (Gollin, 2010; Diao et al., 2010). However, it is also possible that (non-agricultural) economic growth positively affects agricultural productivity since this is to a large extent dependent on technology and inputs from other economic sectors (Hwa, 1988). Therefore, agriculture might also benefit from wider processes of economic growth.

The recent economic growth in most developing African countries could potentially shed light on the causality of the aforementioned relation between economic growth and agricultural development. In these African countries, real GDP rose between

2000 and 2008 on average with 4.9% (Roxburgh et al., 2010), whereas the period between 1975 and 1996 virtually showed no growth at all for the majority of the African countries (Wiggins, 2014). According to the World Bank more investments, a growing world economy and higher prices for natural resources are the main drivers of this growth process. At the same time, the recent history of African agriculture is often looked at with ambiguity, with periods of 'lost decades' in terms of agricultural development interspersed with periods of agricultural revival (Wiggins, 2014).

The African situation therefore provides a case that enables us to study more deeply the relation between economic growth and agricultural development. Did, alongside with the general economic growth, the productivity in the agricultural sector also benefit from this economic 'boom'? Was, in other words, the general economic growth in these countries also able to push the productivity in the agricultural sector to a higher level? Or did growth in agricultural productivity produce surpluses of food and labor that enabled general economic growth? Beyond, it enables us to study the role of trade in agricultural products as well as the influence of reallocating labor towards other economic sectors.

The purpose of this research is to empirically assess the relation between agricultural development and economic growth for African economies between 1960 and 2010. The main question that this research aims to address is how economic growth and agricultural development are mutually interacting in the African context. Most of the aforementioned literature in the field of agricultural and economic development is mainly concerned with the influence of agricultural development on economic growth (e.g. Humphries and Knowles, 1998; Hwa, 1988; Gollin et al., 2002). Yet, a rigorous cross-country analysis of the relation between agricultural and economic growth is lacking in the literature on this subject. Furthermore, only very little research is actually concerned with the reversed causal relation of general economic growth towards changes in agricultural productivity (Tiffin and Irz, 2006). Gollin (2010) furthermore states that there are only very few examples of 'convincingly identified causal links' between agricultural development and economic growth. Beyond, other empirical research in the field has failed to make use of panel time-series analysis, which enables the use of time series techniques and combines this with additional data and power gained from panel analysis. Applying these techniques contributes to the existing empirical literature on the relation between agricultural and economic development.

The rest of the paper is organized as follows. Section 2 provides a review of both theoretical and empirical studies on agriculture and economic growth in Africa. Section 3 presents the data sources, whereas section 4 discusses the empirical model specification and the econometric methodology. Results are discussed in section 5 and conclusions are given in section 6.

2. Theoretical Framework

2.1 Introduction

The role of agriculture in the process of economic growth has been considered quite differently over time. In most early work on economic development, agriculture is often ignored and industrial development is often emphasized as the main driver of economic growth (Self and Grabowski, 2007; Tiffin and Irz, 2006). According to Timmer, nation-builders in developing countries often perceived agriculture as '*the home of traditional people […] – the antithesis of what nation builders in developing countries […] envisaged for their societies*' (Timmer, 1992, p. 27).

In the 1970's however, the paradigm shifted towards a more agriculture-oriented perspective on economic development. The Green Revolution in Asia emphasized the potential of agriculture in contributing to economic growth (Diao et al., 2010). Moreover, poor economic growth rates in many African countries challenged the view that industrial development was the main source of economic development (Tiffin and Irz, 2006). Development strategies started to suggest a greater emphasis on agriculture. Whereas in the past, the domestic policies of developing countries showed a strong bias against the agricultural sector through price, tax and exchange-rate policies that harmed agricultural productivity (Wiggins, 2014), the reports and development strategies in the early 1980's suggested more favorable agricultural policies and a greater emphasis on the agricultural sector in the process of economic development (World Bank, 1982). However, the steadily declining global agricultural commodity prices from the 1980's till the early 2000's eroded the interest in agricultural development again. A development strategy focusing on agriculture did not seem sensible with declining prices and cheap cereals could be imported for supplementary feeding of the population. The recent price spikes in agricultural commodity prices and the recent economic growth in many African countries led a renewed interest in the role of agriculture in development though, with the 2008 World Development Report (World Bank, 2008) focusing on agriculture as a landmark.

2.2 Conventional Wisdom: Agricultural Productivity as Prerequisite for Growth

Federico (2005) identifies three essential tasks that agriculture performs in the process of economic growth: the product role, the factor role, and the market role. The product role refers to the goods provided by the agricultural sector and is twofold: it feeds the population and exports of agricultural products provide foreign currency. The factor role refers to the supply of manpower and capital to other sectors, such as the industry and the service sector. Lastly, the market role refers to agriculture as an outlet for products from the manufacturing sector.

The product role is central in Schultz's (1953) *food problem* theory. According to Schultz, low income countries are unable to develop since most people have to spend a high percentage of their income and labor to procure food. Simply stated, only after the productivity in the agricultural sector has increased and agricultural output has grown, a country can further develop itself and start a process of modern economic growth (Dethier and Effenberger, 2012). This profoundly states an idea of causality: increases in agricultural productivity must precede economic growth.

Next to facilitating the dietary needs of citizens, the increase in agricultural productivity plays a pivotal role in releasing labor to other sectors in the economy - the factor role of agriculture (Johnston and Mellor, 1961; Tiffin and Irz, 2006). The foundation under such reasoning lies in Lewis' (1954) dual-sector model that assumes a labor productivity differential between the agricultural (subsistence) sector and the non-agricultural sector. According to this model, economic growth in developing countries is unable to take off as long as labor is allocated in sectors with a low marginal product of labor, such as agriculture (Humphries and Knowles, 1998).

Higher agricultural productivity also increases the income of the rural population, raising demand for (domestic) industrial output (Dethier and Effenberger, 2012). Via this market function, increases in agricultural productivity contribute to economic development. The idea of 'agricultural demand-led industrialization' builds upon this idea. Using general equilibrium models, Adelman (1984) concludes that a development strategy based upon such an agricultural demand-led industrialization (ADLI) is more favorable for the development of economies than a development strategy that focuses on export-led industrialization, partly due to the larger reduction in employment as a result of the ADLI-strategy. This strategy seems to work best for developing countries that have a relatively closed economy with respect to trade in agricultural products.

The hypothesized driving role of agriculture has also been criticized. According to the so-called 'agro-pessimistic' view the agricultural sector is a relatively low productivity sector, and therefore it is questionable whether expanding and stimulating growth in agriculture will have positive effects on the overall economy (Gollin, 2010). Matsuyama (1992) questions the validity of Schulz's food-problem thesis since in a globalized world food can be imported reducing the need for generating a food surplus domestically. Schultz however considered food imports too costly for low income countries (Gollin et al., 2007). According to Byerlee et al. (2005) many developing countries have abundant resources (e.g. metals and oil) that they can supply to international commodity markets. For such countries, it may very well be possible to depend on food imports, implying that the agricultural sector would not have to modernize and develop before a wider process of economic growth can take-off.

An important issue on the presumed role of agriculture in development is the distinction between open and closed economies (Matsuyama, 1992; Dercon, 2009). For closed, landlocked countries modernization and development of the agricultural sector might be more crucial for development due to the lower potential of trade.

A number of empirical studies confirmed the leading role of agriculture in economic development. Using data from various countries in the period 1960-1995 and controlling for institutional quality and country heterogeneity, Self and Grabowski (2007) find that agricultural modernization (e.g. fertilizer and tractor use intensity) has an impact on the long-run economic growth. Gollin et al. (2002) analyzed data for 62 developing countries between 1960 and 1990 and conclude that increases in agricultural productivity were an important explanation for the growth in GDP per capita. Countries that were able to increase their agricultural productivity, could release labor from the traditional agricultural sector to other sectors such as the industrial or service sector. However, both Gollin et al. (2002) and Self and Grabowski (2007) do not conclude anything with respect to the causal direction of this relation. Tiffin and Irz (2006) do test for Granger causality between GDP and agricultural value added in panel data for 85 developed and developing countries. Five countries in their dataset exhibit bi-directional causality, implying that causality runs from both GDP to agricultural value added as well as the other way around. For four countries, the causality seems to run from GDP per capita to agricultural value added. However the overwhelming majority of the countries in the dataset exhibit causality from agricultural value added to GDP. This leads Tiffin and Irz to conclude that in most cases growth in agricultural productivity must precede wider economic growth. Their research however fails to include other potentially influencing determinants of growth, meaning their analysis could be biased due to omitted variables, leading to a possible spurious correlation between agricultural and economic development.

2.3 Reverse Causality: Impact of Economic Growth on Agriculture

Next, we turn to literature to literature that stresses the impact of general economic growth on agricultural development. A major reason why agriculture could profit from general economic growth is that modern technology and inputs become available from the industrial sector that may raise agricultural productivity (Hwa, 1988). Fan (1991) even states that wider technological change is crucial for further development of the agricultural sector, due to the small potential of output increases when using conventional inputs. In a case-study on Malaysia, Gemmel et al. (2000) found that expanding manufacturing output in the short-run reduced agricultural output due to competition over resources, but in the long-run had a positive impact on agricultural productivity due to spill-over effects and sectoral complementarity between agriculture and manufacturing.

Whereas in the previous section it was mentioned that growth in agricultural productivity pushes labor out of agriculture (factor role), some authors consider these labor movements as a result of wider economic growth, pulling agricultural labor towards other sectors and increasing the value added of remaining agricultural labor (Tiffin and Irz, 2006). Gardner (2000) finds that the main causes for growth in farm income in U.S. agriculture between 1910 and 2000 were due to general economic growth and resulting higher wages in the non-agricultural sector that pulled labor out of agriculture, increasing labor productivity per agricultural worker and living standards of the farm population. Of course this does not imply that aggregate agricultural output increase as a result of these labor market adjustments, as it only implies that the labor that remains allocated in the agricultural sector becomes more productive.

In another study on 52 developing countries in the period between 1980 and 2001 Gardner (2003) does find a significant positive relation between the growth in the value added per agricultural worker and national GDP per capita. However, his results do not confirm that agricultural output is the leading variable in the relation and he therefore questions the conventional wisdom that increases in agricultural output must precede further economic growth. Given that value added in the agricultural sector grew faster after 1980 than before, suggests that increases in national GDP per capita preceded the increases in agricultural value added.

There are also studies that stress the impact of general economic growth on farm incomes. Estudillo and Otsuka (1999) found that incomes of rice-farming households in the Philippines have risen mainly due to growth and economic development in the non-agricultural sector. Whereas income from rice production decreased considerably over the years, the importance of off-farm jobs for rural household incomes increased. Higher incomes have a positive influence on the access to new technology and modern inputs and the availability of capital, which in turn positively affects the level of agricultural output. Reardon et al. (1994) conclude that non-farm profits of African farmers are in substantial cases reinvested in the farm. Beyond, this non-farm income is often also used as collateral, meaning it helps to facilitate the access to credit. This also shows that general economic growth and increasing options for off-farm income also positively affect agricultural productivity growth.

Tsakok and Gardner (2007) conducted an analysis on four different countries during four different time-spans (England (1650-1850), the United States (1800-2000) and South-Korea and China after the Second World War) in order to study whether agricultural development has always been a necessary precondition for further economic transformation of a country. They conclude that countries are able to transform and develop their economies without the requirement of a modernized and developed agricultural sector.

These studies show the reverse effect that general economic development can have on agricultural productivity. In other words, the relation between agricultural development and general economic growth is not only characterized by a causal relation from increases in agricultural productivity to economic growth, but that this relation is rather determined by interdependency and complementarity between other sectors in the economy and agriculture (Hwa, 1988).

2.4 Conceptual Framework

Based on the literature discussed in the previous subsections, figure 2.1 provides a conceptual framework that is the basis for the empirical analysis in this study.

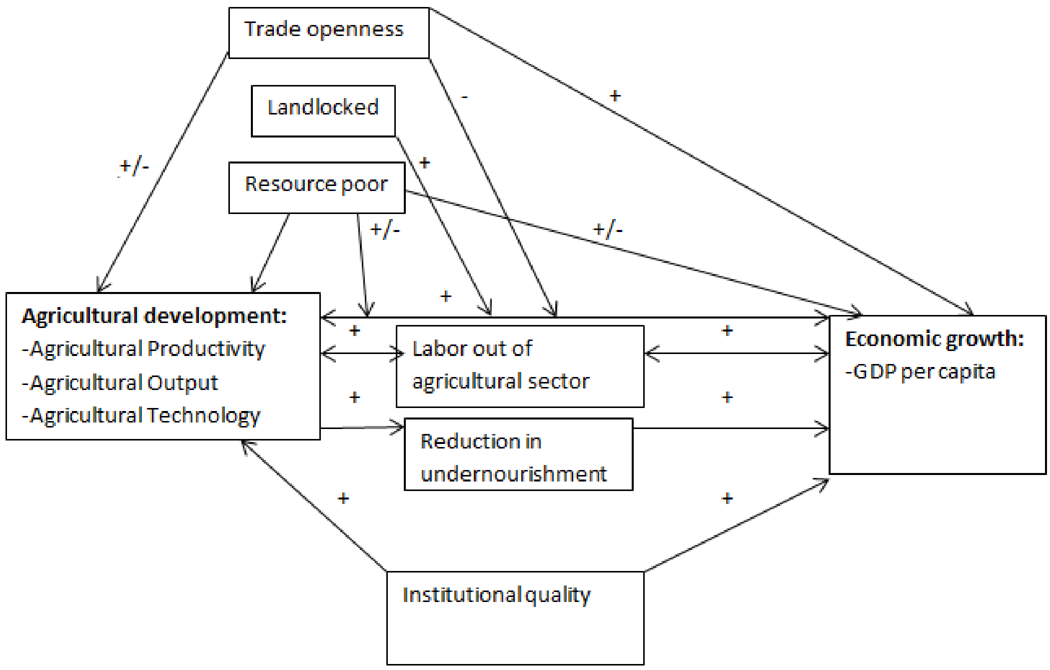

Figure 1: Conceptual Framework. Two-sided arrows indicate uncertainty in the direction of causality.

The main relation is between agricultural development and economic growth. Agricultural development here can be identified through various indicators: growth in total factor productivity, growth in total output and the application of modern technology. As can be seen from figure 2.1, the relation between agricultural development and economic growth can run in both ways, reflecting the aforementioned uncertainty on the causal relation between these factors (e.g. Gollin, 2010; Gardner, 2003). The framework includes the discussed mechanisms playing a role in the relation between agricultural development and economic growth. Next to a direct link, there is also a relation through the reduction in undernourishment as a result of a more developed agricultural sector (Schultz' (1953) *food problem* thesis). It is expected that this link will only go in one direction, meaning an increase in agricultural output must precede the alleviation of undernourishment and the further process of economic growth. Furthermore, the reallocation of labor between sectors is explicitly accounted for. This relation is indicated as two-sided, meaning that agricultural productivity could precede the reallocation of labor towards other sectors that in turn drive the economic growth, but that it could also be the other way around: due to growth in non-agricultural wage rates, labor gets pulled out of the agricultural sector, regardless any preceding productivity increases in the agricultural sector (Gardner, 2000).

Additionally, there are several factors that intervene in the direct relation between agricultural development and economic growth such as the geographical circumstances of a country and the wider access to international commodity markets. As indicated by Matsuyama (1992), the potential of trade in agricultural products may reduce the importance of a developed agricultural sector as prerequisite for further economic growth. Landlocked countries in turn face higher transportation costs, especially in combination with an underdeveloped infrastructure, indicating a higher dependence on the domestic agricultural sector (Dercon, 2009).

Trade openness and the amount of domestic resources can also have a direct influence on either the economic growth or agricultural development of a country. Empirical research often mentions the positive association between economic growth and different measures of openness, also for developing countries (e.g. Harrison, 1994). The influence of the amount of resources in a country on its economic development is however subject to discussion. Sachs and Warner (1995) pointed out that, contrary to dominant beliefs, economies with abundance in natural resources tend to grow less rapid than their natural-resource-scarce counterparts. These resource-poor countries however face a lower agronomic potential (Dercon, 2009), which negatively influences agricultural output. Finally, the institutional quality of a country could act as a spurious variable that influences both the agricultural development and the economic growth (Gollin, 2010). This would weaken the importance of the direct relation between them, since the institutional environment acts as an external factor that addresses both agricultural development and economic growth.

3. Data

For the empirical analysis extensive data from 52 African countries is collected. A list of these countries can be found in Appendix 1. Data is gathered for the time-span between 1961 and 2010. During this period, most African countries regained their independence. For all 52 countries, several variables are observed regarding economic and agricultural development, institutional quality, indicators of nutritional quality and the amount of resources available in a country. For a refined empirical analysis the countries are grouped based on their economic status, landlocked versus non-landlocked countries, and resource rich versus resource poor countries. Moreover, four income classes are distinguished based on World Development Indicators as used by the World Bank. The World Bank defines low-income economies as countries with a GNI per capita below $975 in 2008. Lower middle-income economies are countries with a GNI per capita between $976 and $3855. Upper middle income economies have a GNI per capita between $3856 and $11906. Countries defined as high income economies have a GNI per capita above $11906 (World Bank, 2010). With the exception of Equatorial Guinea, none of the African countries can be considered as a high-income country based on this definition. Resource rich countries are defined as countries where the annual total per capita earnings derived out of natural capital are above $5000. Groupings on the basis of these definitions are given in Appendices 2-4.

The various variables are defined as follows. Economic growth is measured by the variable *gdp* that measures the per capita Gross Domestic Product. The Maddison Historical Database uses a recalculation to Geary-Khamis Dollars (also referred to as *international dollar*), which is often used to compare the GDP-values in different countries in a specific year. The base year is 1990, meaning that the values of the GDP of the different countries have the same purchasing power parity as the 1990 US$ in the United States.

Openness of the different African economies is measured through two indicators. The variable *foodbvrage* measures the share of food and beverage imports as a percentage of the total economy (measured at PPP). This variable provides the development of the imports in food and beverages both over time and across countries (Feenstra et al., 2013). The *openness* variable measures the ratio of the sum of both imports and exports to GDP at current prices. For some countries during some years, this value can be higher than 100, meaning that the sum of exports and imports is bigger than the overall production level. This can be the case if the majority of economic activities of a country involves the assembly and export of products made from imported materials (Heston et al., 2012).

Agricultural output is measured by two different variables. *Grossagroutput* measures the sum of the value of the production of 189 different crop and livestock products. The production is valued at a constant, global-average price level with the average of 2004-2006 as a base year (Fuglie, 2012). Another variable that measures agricultural output is the food production index (*foodprod*), which covers all food crops produced in a country that are considered edible and contain nutrients. This means products like coffee and tea are excluded from this list, as they contain no nutritional value. The original data obtained from the World Bank Database (2014c) is transformed in such a way that the year 1961 is the base year in order to enable comparison with other indices.

To measure productivity growth, Total Factor Productivity (*tfp*), is used. This measures the ratio of total agricultural outputs to total inputs. Output is defined as gross agricultural output, meaning it represents the sum of the value of the production of 189 different crop and livestock products. Input is the weighted average growth in both labor, land, livestock capital, machinery power and synthetic NPK fertilizers. An index with 1961 as the base year with a value of 100 is constructed. A problem with calculating these numbers however is that many agricultural inputs (e.g. land and labor) are differing a lot in quality and are not widely traded, which makes price determination difficult. The USDA Database on International Agricultural Productivity, from which the data has been obtained (Fuglie, 2012), compiles estimates from other research on input cost shares for different regions and applies these to the input equation.

As an indicator for agricultural technology, the use of agricultural machinery (*Agrmach*) is used (Fuglie, 2012). Machinery data measures the total stock of farm machinery measured in 40-CV tractor equivalents. In order to enable a comparison between countries of unequal size, these numbers are divided by the total amount of agricultural land in a country. The variable *agrland* measures the total available agricultural land in a country in hectares of "rainfed cropland equivalents". Rainfed cropland therefore has a weight of 1, while irrigated cropland has a higher weight (between 1 and 3, depending on the fertility of the region) and permanent pasture has a lower weight (varying between 0.02 and 0.09, again depending on the region).

The variable *agrlabor* includes all 'economically active' adults in the agricultural sector in the different countries. To calculate the percentage of the population that is employed in the agricultural sector, *agrlabor* is divided by the total population instead of the total working population due to many missing values in this variable. Therefore, this ratio does not represent the official percentage of the labor population working in the agricultural sector.

With respect to institutional quality, a wide variety of different datasets and indicators are available, yet most of them lack any data before 1990. The *political terror scale* however reports data for all African countries starting from 1975. This scale measures the level of political violence and terror experienced in a country in a particular year on a scale of 1 to 5, where high values indicate a strong prevalence of political violence (Political Terror Scale, 2014).

The variable *malnutrition* measures the percentage of children below the age of 5 whose weight for age is more than two standard deviations lower than the international reference on growth standards set by the WHO (World Bank Database, 2014f). The majority of the values for this variable however are missing, as only a few observations per country are available. *Mortalityrate* holds track of the probability (per 1000) that a newborn-baby will die before reaching the age of five. Data is retrieved from the World Bank Database (2014g). Due to the considerable amount of missing values on the *malnutrition* variable, *mortalityrate* can be used to predict missing values of the aforementioned *malnutrition* variable.[1]

The amount of resources available within a country is measured in different ways. The variable *natcap* represents the total per capita earnings of natural capital of a country. It is the sum of all crop, pasture land, timber and non-timber forest, protected

[1] The correlation coefficient between *malnutrition* and *mortalityrate* equals 0.66 and the t-value of *mortalityrate* in a regression on *malnutrition* equals 13.12.

areas, oil, natural gas, coal and minerals. This variable is derived from the Wealth of Nations database from the World Bank (2014f). The original data gives observations for three different years: 1995, 2000 and 2005. The average value of these data has been used as a constant, time-invariant variable for the different countries. It therefore does not give a detailed overview of changes over time, but it does show the differences between countries.

4. Methodology

4.1 Introduction

The combination of data for both a considerable number of countries (52) as well as a sufficient time span (1961-2010), enables the use of the relatively novel panel time-series analysis. Panel time-series, or non-stationary panels, aim to use the techniques of time-series econometrics in order to deal with issues as non-stationary and combine these with the increased amount of data and power from the different cross-sections (Baltagi and Kao, 2000). Empirical research in the field of agricultural and economic development that uses these techniques, however, is still very scarce. In order to study the causal relation between economic and agricultural development, Tiffin and Irz (2006) e.g. estimate a separate time-series equation for each individual country, thereby losing the additional possibilities of panel techniques (e.g. accounting for a cross-sectional dimension). This study therefore aims to combine time-series techniques with the additional data and power gained from the different panels. In the empirical analysis there are a number of steps. First, based on a conceptual model presented in section 2 a set of equations that can be estimated are specified in section 4.2. Second, panel unit root tests are performed on all model variables to determine the order of integration (section 4.3). Third, taking into account the order of integration of all variables, panel cointegration tests are performed. This procedure and the results are presented in section 4.4. Next, the model specification may have to be adjusted to take cointegrating relations into account. The model is then estimated using PDOLS and FMOLS techniques in order to determine the long-run relation between the independent and the different dependent variables. Section 4.5 gives a short overview of the estimation techniques and the estimation results are discussed in section 5. Finally, several panel causality tests are performed. The testing procedure is presented in section 4.6 and section 5 discusses the test outcomes.

4.2 Model specification

Based on the conceptual framework, three equations are formulated in order to identify the links between agricultural and economic development[2]:

$$\begin{aligned}\Delta LogGDP_{it} &= \alpha_{1i} + \beta_{11}\Delta LogGDP_{it-1} + \beta_{12}\Delta AgrProd_{it-1} + \beta_{13}\Delta AgrOutput_{it-1} \\ &+ \beta_{14}\Delta AgrMach_{it\text{-}1} + \beta_{15}\Delta AgrLabor_{it-1} + \beta_{16}\Delta InstQual_{it} + \beta_{17}\Delta Openness_{it} + \varepsilon_{1it}\end{aligned} \quad (1)$$

$$\begin{aligned}\Delta Agrprod_{it} &= \alpha_{2i} + \beta_{21}\Delta LogGDP_{it-1} + \beta_{22}\Delta AgrLabor_{it-1} + \beta_{23}\Delta InstQual_{it} \\ &+ \beta_{24}\Delta NatResource_{it} + \beta_{25}\Delta FoodImports_{it} + \varepsilon_{2it}\end{aligned} \quad (2)$$

$$\begin{aligned}\Delta AgrOutput_{it} &= \alpha_{3i} + \beta_{31}\Delta LogGDP_{it-1} + \beta_{32}\Delta AgrLabor_{it-1} + \beta_{33}\Delta InstQual_{it} \\ &+ \beta_{34}\Delta NatResource_{it} + \beta_{35}\Delta FoodImports_{it} + \varepsilon_{3it}\end{aligned} \quad (3)$$

Equation 1 expresses the change in GDP a function of the changes in agricultural productivity, output and technology in the previous period. Furthermore, agricultural labor one period lagged is included to test whether the push of labor out of the agricultural sector contributes to economic growth. Several additional variables are also

[2] An equation with agricultural technology as dependent variable is not formulated, mainly since research points out that technological development in the agricultural sector is often the result of induced innovation, implying that it is mainly the outcome of specific (resource) endowments that a country is facing. This implies that countries with e.g. a relative scarcity in land will follow a different modernization process than countries that are relatively abundant in this production factor (Hayami and Ruttan, 1971). It therefore becomes rather difficult to estimate the changes in agricultural technology as a result of wider processes of e.g. economic growth, hence the choice not to estimate an equation with agricultural technology as dependent variable.

taken into consideration: institutional quality, the amount of natural resources and the general economic openness of a country. For GDP, the original value is transferred in its natural logarithm, in order to reduce the disturbing influence of outliers.

Equations 2 and 3 in turn estimate the influence of changes in log GDP on two indicators for agricultural development. Lagged log values of GDP are now included in order to capture changes in agricultural productivity and agricultural output. Furthermore, indicators for agricultural labor, institutional quality, the amount of natural resources and food imports are included.

4.3 Panel Unit Root Testing

With (panel) time-series data it is important to test for stationarity in order to rule out spurious regression results due to common (stochastic) trends. For panel time-series some specific tests for stationarity (unit-root tests) have been developed. These panel unit root tests have higher power than standard Augmented Dickey Fuller (ADF) tests, due to the increase in sample size as a result of pooling the observations of various cross-sections. All model variables are tested for stationarity using both the Levin-Lin-Chu (LLC) test and the Im-Pesaran-Shin (IPS) test (Levin & Lin, 1992; Im et al., 2003). Both the IPS and the LLC-unit root tests have been applied in other contemporary research using non-stationary panels (e.g. Neal, 2013; Nasreen and Anwar, 2014; Bittencourt, 2010). The null hypothesis of these tests is that all panels in the dataset contain a unit-root, implying that if it is rejected at least some of the panels are stationary, but not by definition all panels (Baltagi, 2013).

As described by Nasreen and Anwar (2014) and Baltagi (2013), the LLC test estimates a separate ADF regression for each country included in the panel:

$$\Delta Y_{it} = \rho_i Y_{it-1} + \sum_{L=1}^{pi} \theta_{iL} \Delta Y_{it-L} + \alpha_{mi} d_{mt} + \varepsilon_{it}$$

The lag order (ρ) can vary over different countries. In the second step of the LLC-procedure, two auxiliary regressions are estimated: Δy_{it} on Δy_{it-L} and d_{mt} to obtain the residuals ($\hat{e}_{it}$) and a regression of y_{it-1} on Δy_{it-L} and d_{mt} to obtain the residuals ($\hat{v}_{it-1}$). Subsequently, these residuals are standardized (in order to control for the different variances) by the standard error of each ADF regression from the 1st step ($\sigma_{\varepsilon i}$):

$$\tilde{e}_{it} = \hat{e}_{it} / \sigma_{\varepsilon i}$$

$$\tilde{v}_{it-1} = \hat{v}_{it-1} / \sigma_{\varepsilon i}$$

The last step in the LLC procedure is to run the pooled regression $\tilde{e}_{it} = \rho \tilde{v}_{it-1} + \varepsilon_{it}$. The H_0 of this LLC test assumes that $\rho = 0$, which implies that each individual time series has a unit root. The alternative hypothesis assumes that $\rho \neq 0$, implying stationarity of each time-series (Baltagi, 2013). According to Levin and Lin (1992), this test performs well when N is between 10 and 250 and the size of T is between 5 and 250. Regarding our data, with 50 observations over time (T) for 52 different countries (N), the t-statistic should perform well.

The LLC-test however relies on the assumption of cross-sectional independence. This would imply that e.g. the GDP or the agricultural productivity of African countries grows completely independent of each other. The tenability of this assumption is questionable, as growth in a certain country might very well positively affect other, neighboring countries. Therefore, also the IPS-test is taken into consideration, as this test does allow for heterogeneous coefficients. Beyond, this test allows for unbalanced data, whereas the Levin-Lin-Chu test requires strongly balanced data. The IPS-test computes an average of Augmented Dickey-Fuller statistics across the different panel units (Neal, 2013) and allows each series to have individual short-run dynamics

(Nasreen and Anwar, 2014). The H_0 in the IPS test is $p = 1$ in the test equation: $y_{it} = \alpha_i + \rho_i y_{it-1} + e_{it}$

The alternative hypothesis of the IPS-test, in contrast, states that in some panel units p_i is not equal to 1 and that at least a proportion of the different time-series are stationary. Important to note is that when the H_0 of the IPS test is rejected, it implies that at least some of the panels are stationary, but not by definition all panels.

Table 1 provides an overview of the test-statistics for the model variables[3]. For every test, every variable is tested twice: once in its original form (level) and once after the first differences were obtained (differences).

Table 1 Panel Unit Root Tests

			Levin, Lin & Chiu test		Im, Peasaran & Shin test	
Variables	***N***	***T***	***Level***	***Differences***	***Level***	***Differences***
GDP	52	48	3.55	-16.45**	1.15	-25.94**
LOGGDP	52	48	0.23	-16.25**	-1.53	-26.05**
TFP	52	50	1.44	-18.11**	-1.82*	-31.16**
Agr Output	52	50	-12.75**	-22.01**	17.15	3.37
Food Production	52	50	+	+	0.21	-32.70**
Machinery	52	50	-3.51**	-18.97**	1.37	-29.70**
Agr Labor	52	49	-7.27**	-6.09**	2.13	-12.54**
Mortality	52	47	+	+	6.54	5.31
Mortality (T-1)	52	46	+	+	-23.09**	-7.01**
PTS	52	34	+	+	-13.88**	-27.17**
Natcapital			-	-	-	-
Openness	52	48	+	+	-8.39**	-31.84**
Food Imports	48	49	+	+	-8.18**	-31.55**

**=p<0.05; **=p<0.001*

+ = Unbalanced data. - = Time-invariant variable. Note that T always decreases with 1 when testing for differenced variables.

The results of the LLC-test show that all variables are stationary after obtaining first-differences. *Agricultural Labor, Machinery* and *Agricultural Output* however are already stationary in their original form. For variables with unbalanced data, the LLC-test cannot be conducted. Furthermore, the aforementioned assumption of cross-sectional independence is questionable, arguably leading to unreliable test-statistics.

[3] A different panel unit root test is the Hadri-LM test, which can be considered as an extension of the KPSS test in a panel setting. However, according to Hlouskova and Wagner (2006, as cited in Verbeek, 2012) this panel stationary test performs poorly. Therefore, only the LLC and IPS test are taken into consideration here in order to test for unit roots in the main variables of the model.

Based upon the results from the IPS-test, we see that the variables *loggdp, TFP, foodprod, machinery, total inputs* and the *percentage agricultural labor* are integrated of order one (I(1)) and that *pts, openness* and *food imports* are already stationary in their original from (I(0)). The variable for the *<5-mortality-rate* becomes stationary after adding one lag, but in its non-differenced form (I(0)). The variable *agroutput* is not stationary after differencing and therefore, the Food Production Index variable will be used as the indicator for agricultural output, as this variable is stationary after obtaining first differences.

As will be explained in the section on panel co-integration, it is only useful to include I(1)-variables in order to test for co-integration. Thus, the initial equations formulated in equation 1-3 are re-formulated in such a manner that only the I(1)-variables remain. Therefore, the following adjusted equations are formulated based upon the results from the panel unit root tests in order to test for cointegration:

$$\Delta LogGDP_{it} = \alpha_{1i} + \beta_{11}\Delta AgrProd_{it-1} + \beta_{12}\Delta AgrOutput_{it-1} + \beta_{13}\Delta AgrMach_{it\text{-}1} + \beta_{14}\Delta AgrLabor_{it-1} + \varepsilon_{it} \quad \text{(1 Adjusted)}$$

$$\Delta Agrprod_{it} = \alpha_{2i} + \beta_{21}\Delta LogGDP_{it-1} + \beta_{22}\Delta AgrLabor_{it-1} + \varepsilon_{it} \quad \text{(2 Adjusted)}$$

$$\Delta AgrOutput_{it} = \alpha_{3i} + \beta_{31}\Delta \mathrm{LogGDP}_{it-1} + \beta_{32}\Delta \mathrm{AgrLabor}_{it-1} + \varepsilon_{it} \quad \text{(3 Adjusted)}$$

4.4 Panel Co-Integration Tests

In order to test for co-integration among the different variables in the adjusted equations, the panel co-integration test developed by Pedroni (1999) is used. Co-integration tests for individual time-series are said to have low power in the case of small *T* (Baltagi, 2013). Therefore, the use of panel co-integration techniques will increase the power of the test, due to the pooling of the different cross-sections.

Pedroni's test gives different test statistics, which can be divided in two separate categories: group and panel statistics. Group mean statistics give an average result of the test statistics of the individual countries, whereas panel statistics use the within-dimension to pool the statistics (Neal, 2013). The approach of Pedroni's test in both cases is the estimation of a hypothesized co-integration relation for each individual country. Afterwards, the resulting residuals are pooled in order to test for the presence of cointegration. The Pedroni test uses the following cointegration equation:

$$X_{it} = \alpha_i + \rho_{it} + \beta_{1i} Z_{1i,t} + \ldots + \beta_{mi} Z_{mi,t} + \mu_{it}$$

where both the dependent (X_{it}) and the independent variables (Z_{it}) are assumed to be I(1). The individual specific intercept term (α_i) and slope coefficients (β_{mi}) can vary by countries. The null hypothesis (which assumes no co-integration) states that $\rho_i = 1$ for every country *(i)* (Nasreen and Anwar, 2014). Rejecting H_0 therefore implies presence of a long-run relation between the I(1)-variables included in the model.

The Pedroni tests can be performed using one or more of seven different test statistics: four of them are panel statistics: *panel v, panel rho, panel t* and *panel ADF.* The other three tests are group statistics: *group rho, group t* and *group ADF.* Pedroni (1999) gives an overview of these different panel co-integration statistics. According to Neal (2013), the *group* and *panel ADF* statistics are the best indicators when T<100 (which is the case with our time-span ranging from 1961 to 2010 with annual observations), whereas the *panel v* and *group rho* perform relatively poorly in such situations. The main test statistics of the Pedroni co-integration tests in order to judge the existence of co-integration between the variables in the model therefore will be the *ADF panel* and *ADF group* statistics.

Again, since cointegration assumes initially non-stationary variables with the same order of integration only I(1)-variables are included in the Pedroni test. In the adjusted equation 1, *LogGDP* is used as the dependent variable and *TFP, FoodProd, Machinery* and *AgrLabor* are the other variables taken into account. Table 2 provides an overview of the different Pedroni test statistics for adjusted equations 1-3:

Table 2: Pedroni panel cointegration test results.

	Equation (4.1)		**Equation (4.2)**		**Equation (4.3)**	
	LogGDP, TFP, FoodProd, Machinery, AgrLabor		*TFP, LogGDP, AgrLabor*		*FoodProd, LogGDP, AgrLabor*	
	Panel	Group	Panel	Group	Panel	Group
V	0.63		2.38***		0.14	
Rho	0.75	2.44	-1.69*	-0.41	-2.27***	-3.37***
T	-3.17***	-2.59***	-3.31***	-2.54***	-4.37***	-6.24***
ADF	-2.77***	-3.31***	-2.88***	-3.25***	-2.42***	-1.80**
N	*2483*		*2496*		*2483*	

****=P<0.01, **=P<0.05, *=P<0.10. Note that a trend-term was added in all equations*

The different tests clearly give different test statistics. As mentioned above, the *panel ADF* and *group* ADF are the most consistent tests, considering the number of cross-sections and observations of our data. When looking at the results of these tests, there seems to be evidence for the existence of a co-integrating relation between the I(1)-variables for all three equations. Most of the panel and group ADF statistics are significant at the 0.01-level. This shows the existence of a long-run relationship between economic growth and the different indicators for agricultural development, but also between agricultural productivity, GDP and agricultural labor and between food production , GDP and agricultural labor. It furthermore implies that the residuals of the adapted equations are stationary.

4.5 Panel Co-Integration Regression

Once a co-integrating relation between the I(1)-variables is established, the final equations can be estimated in order to identify the relation between the dependent and independent variables. First, it is important to take into account that the conventional

OLS estimator gives inconsistent results when cointegration between the I(1)-variables is present (Nasreen and Anwar, 2014). Recent empirical literature on non-stationary panels therefore uses different regression techniques in order to estimate the regression coefficients. Estimators that have been used in other research (e.g. Eberhardt and Teal, 2011; Neal, 2013; Nasreen and Anwar, 2014) and are said to give consistent results are the Panel Dynamic OLS (PDOLS) developed by Kao and Chiang (2000) and the Fully Modified OLS (FMOLS) developed by Pedroni (2000).

The PDOLS-estimator can be seen as an extension of the conventional Dynamic OLS for single time series. In this estimation method, both lags and leads of the differenced explanatory variables are added in the regression. The inclusion of these leads and lags ensures that the PDOLS-estimator accounts for possible simultaneity and potential serial correlation. Through the inclusion of leads and lags of the differenced regressors, the PDOLS estimator corrects for possible endogeneity (Fayad et al., 2011). The data in this PDOLS-estimator are pooled along the within-dimension of the different panels and seems to perform well in models that contain both stationary and non-stationary variables (Neal, 2013).

The FMOLS-estimator developed by Pedroni allows for cross-sectional heterogeneity, heterogeneous dynamics and generates estimates that are also consistent in small samples (Nasreen and Anwar, 2014). Both the PDOLS and FMOLS-estimators are capable of estimating a co-integration vector among the different panel variables (Neal, 2013). As no single estimator is widely accepted as the most advanced or preferred method for estimating a co-integration regression, both methods will be applied. The results of these panel co-integration regressions can be found in section 5.

4.6 Panel Causality

As discussed extensively in section 2, one of the main questions this research is concerned with is the direction of causality between economic growth and agricultural development for post-war Africa. Once a co-integrating relation between the I(1)-variables is identified, Granger causality tests can be performed based upon the panel vector error correction model (Nasreen and Anwar, 2014). If a co-integrating relation between the I(1)-variables is existent, this implies there is a long-run relation between the dependent variable and the different independent variables, viz. between economic growth and indicators for agricultural development. Therefore, the changes in the dependent variable can be seen as a function of both changes in the regular independent variables as well as the level of disequilibrium in the co-integrating relation (Nasreen and Anwar, 2014).

In order to evaluate the direction of causality between economic growth and agricultural development, several vector error correction models (VECM) are estimated:

$$\begin{aligned} \Delta LogGDP_{it} &= \alpha_{1i} + \sum_{m=1}^{p} \beta_{1im} \Delta LogGDP_{it-m} + \sum_{m=1}^{p} \vartheta_{1im} \Delta Agrprod_{it-m} \\ &+ \sum_{m=1}^{p} \kappa_{1im} \Delta AgrOutput_{it-m} + \sum_{m=1}^{p} \theta_{1im} \Delta AgrMach_{it-m} + \sum_{m=1}^{p} \xi_{1im} \Delta AgrLabor_{it-m} \\ &+ \psi_1 ECT1_{it-1} + \varepsilon_{1it} \end{aligned} \quad (4)$$

$$\begin{aligned} \Delta Agrprod_{it} &= \alpha_{2i} + \sum_{m=1}^{p} \beta_{2im} \Delta Agrprod_{it-m} + \sum_{m=1}^{p} \vartheta_{2im} \Delta LogGDP_{it-m} \\ &+ \sum_{m=1}^{p} \kappa_{2im} \Delta AgrLabor_{it-m} + \psi_2 ECT2_{it-1} + \varepsilon_{2it} \end{aligned} \quad (5)$$

$$\begin{aligned} \Delta Agroutput_{it} &= \alpha_{3i} + \sum_{m=1}^{p} \beta_{3im} \Delta Agroutput_{it-m} + \sum_{m=1}^{p} \vartheta_{3im} \Delta LogGDP_{it-m} \\ &+ \sum_{m=1}^{p} \kappa_{3im} \Delta AgrLabor_{it-m} + \psi_3 ECT3_{it-1} + \varepsilon_{3it} \end{aligned} \quad (6)$$

The Error-Correction term (ECT) in the above equations captures the long-run relation between the variables. For equation 4, it is a one-period lagged error term that is derived from the residuals of the co-integrating relation between *LogGDP* and *TFP*, *Food Production, Machinery* and *Agricultural Labor.* This term indicates the long run relation between the variables. Its coefficient gives an indication on the speed of adjustment towards the equilibrium. For equation 5, the ECT is obtained from the residuals derived from the co-integrating relation between *AgrProd* and *LogGDP* and *AgrLabor.* Likewise, the same goes for equation 6. The ECT here is based upon the residuals from the co-integrating relation between *AgrOutput* and *LogGDP* and *AgrLabor*.

The short-run causality between the variables is identified through the various coefficients of the independent variables. When, e.g., considering the short-run causality from *AgrProd* to *LogGDP* in equation 4, the H_0 of $\vartheta_{1im} = 0$ is tested. In the case this hypothesis gets rejected, it implies that – in the short run – *LogGDP* is caused by *AgrProd.*

These equations are estimated with the Arellano-Bover/Blundell-Bond estimator. This estimator, used in linear dynamic panel-data models, uses lags of the differenced dependent variable and uses differenced versions of the independent variables, which are both in line with the formulations of equations 4-6. In order to keep the number of instruments at a reasonable level, the maximum number of lags to be used as instrument for the dependent and predetermined variables is set at 5. The results of these tests can be found in section 5.2.

5. Results

5.1 Panel Co-Integration Regression Results

Table 3 presents the results of the different PDOLS estimations for the adjusted long-run co-integrating equation 1.[4] The first column presents the results for the full sample of 52 African countries over the period 1961-2010. The only variable that is significantly related to the Gross Domestic Product is the Food Production Index. A higher food

[4] The residuals of this estimation are used to construct the ECT term for equation 4.4.

production is in the long-run strongly related to higher levels of economic growth. The other indicators of agricultural development however do not seem to play any significant role in determining the long-run GDP for the full sample.

Table 3: DOLS Panel Results for cointegration relations using full sample and income based subsamples

Dependent variable: LogGDP	**Full Sample**	**Low Income Countries**	**Lower Middle Income Countries**	**Upper Middle Income Countries**
TFP	-0.021	-0.261**	0.180	0.041
	(0.094)	(0.131)	(0.159)	(0.209)
FoodProd	0.196***	0.244***	0.150*	0.157
	(0.048)	(0.058)	(0.086)	(0.125)
Machinery	0.338	0.362	0.371***	0.058
	(0.225)	(0.524)	(0.136)	(0.051)
AgrLabor	-0.126	-0.163	0.412**	-0.896***
	(0.095)	(0.129)	(0.160)	(0.279)
Obs	2375	1134	736	460
N	52	25	16	10

****=P<0.01, **=P<0.05, *=P<0.10. Standard errors between parentheses.*

When grouping countries by income class however some different results appear. For low income countries, again the Food Production Index is playing a significant and positive role in determining the GDP in the long run. The Total Factor Productivity in the agricultural sector furthermore shows a significant and unexpected negative effect on GDP. For the lower middle income countries, there seems to be a small shift occurring: food production is still significantly and positively related to the GDP-level, however the influence of agricultural machinery also becomes strongly significant. This implies that developments in agricultural technology are strongly related to economic growth in lower middle income countries. Furthermore, although not in line with the expectations, the percentage of labor employed in the agricultural sector is positively related to the dependent GDP variable, implying that labor in the agricultural sector still is productive and beneficial for the GDP.

In upper middle income countries we however see a strongly different long-run relationship: here none of the indicators for agricultural development are significantly related to the GDP-level, yet the amount of labor in the agricultural sector here is strongly and negatively linked to GDP. This implies that the less labor employed in the agricultural sector, the higher the GDP-level is. The push of labor out of the agriculture towards other economic sectors here seems to trigger economic growth.

Summarizing these results, the agricultural sector seems to play different roles in different stages of economic development. In low income countries, food production is most strongly linked to economic growth. This result therefore seems to be in line with the *food problem*-literature discussed in section two, which stated that a shortage of food and the fact that citizens need to devote such large fractions of their resources in order to satisfy the subsistent dietary needs are among the main restrictions for low income countries in order to generate further economic growth. Increasing food production in these countries will have a strong and positive effect on their GDP.

In lower middle income countries, increases in food production are still positively linked to GDP growth, but furthermore agricultural technology seems to play a pivotal role for further economic development. In the more developed, upper middle income countries agriculture is playing a smaller and insignificant role, which could be attributed to the fact that the agricultural sector in these countries is often of smaller (relative) economic size. Therefore, changes in agricultural productivity will have smaller effects on the total GDP compared to lower income countries in which the relative economic size of the agricultural sector is larger.

For upper middle income countries however, labor becomes more important. The strong negative link between the amount of labor employed in agriculture and the level of GDP shows that in these relatively wealthy countries an outflow of labor out of agriculture is positively related to GDP. For the low income countries, this effect of agricultural labor is absent. A possible explanation for this missing effect in low-income countries is that the economy in these countries is not yet developed enough in order to be able to absorb the labor that flows out of the agricultural sector into other economic productive sectors. This implies that a sectoral reallocation of agricultural labor towards other sectors in the economy is only beneficial for further economic growth if countries are already in a more developed economic situation.

Next to the PDOLS estimation, table 4 presents the results of the FMOLS regression. Albeit slightly different, these results are to a large extent comparable to the results obtained in table 3. For the full sample, however, now also *Machinery* and *AgrLabor* share a significant long-run relation with GDP. For low income countries, in contrast with the results of the PDOLS-estimation, now also *AgrLabor* has a statistically significant, negative effect. For the lower middle and upper middle income countries, only minor differences in strength are visible between the PDOLS and FMOLS estimation.

Table 4:Fully Modified OLS results for full sample and income based subsamples

Dependent variable: LogGDP	**Full Sample**	**Low Income Countries**	**Lower Middle Income countries**	**Upper Middle Income Countries**
TFP	-0.004	-0.131**	0.081	0.044
	(0.046)	(0.064)	(0.083)	(0.105)
FoodProd	0.143***	0.211***	0.091**	0.032
	(0.020)	(0.025)	(0.003)	(0.045)
Machinery	0.288**	0.317	0.309***	0.025
	(0.133)	(0.271)	(0.084)	(0.031)
AgrLabor	-0.106**	-0.195***	0.380***	-0.679***
	(0.052)	(0.070)	(0.104)	(0.119)
Obs	2375	1134	736	460
N	52	25	16	10

****=P<0.01, **=P<0.05, *=P<0.10. Standard errors between parentheses.*

Table 5 shows results for countries divided in landlocked and non-landlocked countries in order to see whether the possibility of sea-borne trade plays a significant role in the relation between agricultural development and economic growth. When testing for parameter differences, it appears there are no statistically significant differences between landlocked and non-landlocked countries. However, when looking at the coefficient of *Machinery* for non-landlocked countries, it is significantly higher compared to the landlocked countries. The coefficient of *FoodProd* is significantly higher for landlocked countries (0.244) compared to non-landlocked countries. This would implies that food production is more crucial for determining economic growth in landlocked than in non-landlocked countries. This result seems to be in line with the theoretical expectations of e.g. Matsuyama (1992), as landlocked countries with a smaller potential to trade are more reliant on their own domestic food production. However, one should notice that these differences between landlocked and non-landlocked countries are rather small.

Table 5: PDOLS results for landlocked and non-landlocked and resource rich and resource poor countries

Dependent variable: LogGDP	**Landlocked countries**	**Non-landlocked countries**	**Resource rich**	**Resource poor**
TFP	-0.013	-0.034	-0.100	-0.013
	(0.138)	(0.118)	(0.198)	(0.106)
FoodProd	0.244***	0.178***	0.221**	0.189***
	(0.080)	(0.059)	(0.009)	(0.005)
Machinery	-0.139	0.513*	0.372**	0.286
	(0.569)	(0.280))	(0.133)	(0.396)
AgrLabor	-0.147	-0.119	-0.068	-0.064
	(0.132)	(0.121)	(0.052)	(0.106)
Obs	628	1748	598	1502
N	14	38	13	33

****=P<0.01, **=P<0.05, *=P<0.10. Standard errors between parentheses.*

Next to the possible intervening effect of trade in the relation between agricultural and economic development, the availability of natural resources in a country was also identified as a possible factor that could interfere in this relation. The last two columns of table 5 show the results of the PDOLS regression for subsets of resource rich and resource poor countries. In this case, resource rich countries are defined as countries where the annual total per capita earnings from natural resources are above $5000. The most clearly observable difference between the resource rich and poor countries is the differing effect of agricultural machinery on GDP. For resource rich countries, agricultural machinery has a strong long-run relation with growth in GDP, whereas this effect is not significant for the resource poor countries. Arguably, the lower agronomic potential in resource poor countries causes that additional investments in agricultural machinery and technology do not have strong influences on the further economic growth. This in contrast to the resource rich countries, where agricultural technology does have a strong influence on GDP growth.

When we consider differences in parameters statistically, there are no clear differences between the two set of countries with respect to agricultural machinery (partly due to the relatively large standard errors). For the *FoodProd*-variable there is however a statistically significant difference, with the coefficient for resource rich countries being higher than for their resource poor countries.

Table 6 shows the results for the adjusted equations 2 and 3. Now, *LogGDP* is no longer the dependent variable, but is used – together with *AgrLabor* – in an equation where the total agricultural factor productivity is the dependent variable. The residuals of this equation are used to construct the ECT terms in equations 5 and 6.

Table 6: PDOLS and FMOLS results for the adjusted equations 2 and 3.

	Adjusted equation 2 Dependent variable: TFP		**Adjusted equation 3 Dependent variable: FoodProd**	
	PDOLS	***FMOLS***	***PDOLS***	***FMOLS***
LogGDP	0.008**	0.059***	0.676***	0.551***
	(0.037)	(0.026)	(0.009)	(0.071)
AgrLabor	0.115**	0.113***	0.365***	0.481***
	(0.054)	(0.035)	(0.129)	(0.096)
Obs	2340	2444	2328	2432
N	52	52	52	52

****=P<0.01, **=P<0.05, *=P<0.10. Standard errors between parentheses.*

Only slight differences between the PDOLS and FMOLS estimation techniques appear in table 6. In equation 2 *LogGDP* and *TFP* are positively related in the long-run, although the effect is quite modest in terms of its size. The long-run relation between *LogGDP* and *Foodprod* in equation 3 is much stronger and also significantly different from zero. Remarkable is the positive effect of *AgrLabor* on *TFP* and *FoodProd* in all cases, since this implies that the more labor engaged in the agricultural sector, the higher the productivity in the sector is. This is quite in contrast with earlier formulated expectations based on the Lewis-model, which assumed that labor in the agricultural sector is often *surplus labor* (Humphries and Knowles, 1998). For the whole sample of African countries, this assumption therefore does not seem to hold, since – at least in some of the studied countries – agricultural labor has a positive relation with productivity in the agricultural sector and economic growth.

5.2 Panel Causality Results

Table 7 provides the results for error correction models 4-6 in order to address the issue of short-run causality between agricultural development and economic growth.

Table 7: Arellano-Bover/Blundell-Bond dynamic panel estimation

	Equation (4) LogGDP	**Equation (5) TFP**	**Equation (6) FoodProd**
$LogGDP_{t-1}$	1.007***	0.038***	0.015*
	(0.006)	(0.003)	(0.009)
TFP_{t-1}	0.098***	0.924***	X
	(0.016)	(0.007)	
$FoodProd_{t-1}$	-0.020***	X	0.993***
	(0.005)		(0.008)
$AgrLabor_{t-1}$	-0.235**	-0.592***	-0.432**
	(0.108)	(0.064)	(0.194)
$Machinery_{t-1}$	-0.012	X	X
	(0.012)		
ECT	-0.001	-0.035***	0.002
	(0.006)	(0.003)	(0.002)
Obs	2324	2340	2327

****=P<0.01, **=P<0.05, *=P<0.10. Standard errors between parentheses.*

The lagged dependent variable is in all cases by far the best predictor for the dependent variable. Important to note here, however, is that the coefficients for all lagged dependent variables in their respective equations are close to 1. This implies that, despite the method of the Arellano-Bover/Blundell-Bond estimation which uses the differences of the included variables, the current values of the dependent variables are still to a large extent dependent on their previous value. This in turn could indicate that the I(1)-variables are arguably still non-stationary, which questions the results of the panel unit root tests.

The results regarding the short-run causal relation between the indicators for agricultural development and economic growth are somewhat inconclusive. Lagged values of *TFP* have a positive influence on *LogGDP* in the short run, but the other way around, lagged values of *LogGDP* also positively affect *TFP*. Beyond, the link between *FoodProd* and *LogGDP* is fairly indistinct. In the short-run, lagged values of *FoodProd* negatively influence the GDP, whereas the previous values of *LogGDP* do have a positive effect on *FoodProd*. It remains however important to note that the strength of these effects are relatively small, as the main variance in the different dependent variables are explained by their own lagged values.

When considering the influence of the ECT-term in the different tests for causality, it is interesting to note that only in the second equation (where total factor productivity is the dependent variable), the adjustment parameter is significantly different from zero. The long-run relation between economic growth and agricultural development, as identified by the co-integrating equation, does not seem to play a significant influence for determining the GDP. This in turn implies the GDP-level is to a large extent determined by other, external factors and is not tightly bounded to developments in the agricultural sector. Due to the declining size of agriculture in growing economies, this is not completely unexpected. Based upon the results from table 7 we therefore cannot conclude that economic growth Granger causes productivity or output growth in the agricultural sector, or the other way around. The relation between agricultural development and economic growth therefore cannot be perceived as a straight-forward relation where a change in the one always must precede an increase in the other. Rather, the relation between economic and agricultural development seems to be characterized by mutual interdependent relations and a bidirectional causality that in different phases can run in different directions.

6. Discussion and Conclusions

This study aims to empirically asses how economic growth and agricultural development interact in African countries in the period between 1960 and 2010. As discussed in the theoretical framework in section two, severable mechanisms are identified that potentially cause a relation between agricultural and economic development. Among the major underlying causes for this relation is the role the agricultural sector can play in alleviating the so-called *food problem* as well as its importance for the sectoral reallocation of labor. The so-called factor-role of the agricultural sector – which assumes that through productivity increases in agriculture, the supply of labor to other economic sectors can increase (see e.g. Federico, 2005) – is of major importance here.

In line with the propositions stated by a.o. Schultz (1953), we find that, mainly in the least developed African countries, increases in food production play an important role in generating economic growth, as increases in food production coincide with further economic development in these countries. In the more developed countries however, this effect is missing. Arguably, food is, in these countries, no longer a crucial constraint for generating further economic growth. Beyond, the relative economic size of the agricultural sector has declined in most (upper) middle income countries, which causes a decrease in the direct effect between economic and agricultural development.

The results show that the relation between economic growth and agricultural development is largely dependent on the wider economic context. For the more developed upper middle income countries, an outflow of labor out of the agricultural sector is indeed coinciding with further economic growth levels. In the lower income countries, however, this effect was less clear. It therefore remains highly questionable whether transferring labor out of agriculture is unconditionally beneficial for economic growth. It might very well be the case that labor markets and other economic sectors in these countries are not yet developed enough in order to absorb the labor that flows out of agriculture into other productive sectors. Urban unemployment is increasingly becoming a major concern in the large cities in sub-Saharan Africa. A growing rural-urban migration as a result of labor flowing out of the agricultural sector towards the urban areas will lead to more pressure on these already vulnerable markets, causing a further increase in unemployment (Potts, 2000).

One should therefore be cautious with advocating policies aimed at increasing the productivity in agriculture through more capital-intensive and less labor-intensive development strategies. As we have found, increases in food production are beneficial for further economic growth (indicating the importance of the agricultural sector for economic growth in the least developed African countries), yet it seems of utmost importance to create agricultural development strategies that are inclusive when it comes to employment. Based upon our results, capital intensive strategies that drive labor towards urban areas are mainly positive for the more developed countries. In the low income countries however, labor in the agricultural sector is arguably still relatively more productive and beneficial for economic growth than an outflow of this labor towards urban areas. The results are therefore to a large extent in line with Adelman's ideas on agricultural demand-led industrialization (ADLI), where she states that development strategies should put more emphasis on the agricultural sector, mainly due to its beneficial effect on the employment-rate compared to other development strategies that are more based on export-led industrialization (Adelman, 1984).

Additional research that focuses on the lowest income countries however is necessary in order to study whether such a productivity differential between the agricultural and non-agricultural sectors is indeed present in these countries and what further implications this has on economic development.

Other issues raised in the conceptual framework were the impact of available resources and the differing potential with respect to trade in agricultural products. According to Matsuyama (1992), the agricultural sector plays a less important role in more open economies, as these economies are less dependent on their own domestic agricultural sector in order to ensure sufficient food provision. As became clear in the data, non-landlocked countries are more open in terms of food imports, due to their direct access to seaborne trade. Landlocked countries in turn face greater barriers to trade. Trade, however, does not seem to play a crucial interfering role in the relation between agricultural and economic development. For resource poor and resource rich countries, some notable differences appear, as investments in agricultural technology are mainly beneficial for resource rich countries.

The clear evidence of the presence of a co-integrating relation between the indicators for agricultural and economic development furthermore implies the existence of a stable long-run relation between the two. In accordance with the somewhat ambiguous results of previous research (e.g. Tsakok and Gardner, 2007), this study however is unable to identify a convincing causal relation in the short-run between agricultural and economic development. The results show that previous values in the indicators for agricultural development are related with economic growth and the other way around, previous values of economic growth indicators are also connected to levels in agricultural output and productivity, indicating the existence of a two-way causality.

In this study we applied novel panel time series techniques. Whereas the benefits of this approach are often stated in the literature, the methodology also has some limitations, mainly due to the considerable amount of heterogeneity present in the African continent. Countries have their own individual characterizations and differ e.g. in terms of their economic development and agricultural productivity. Pooling all these countries together in one single estimation does not always reflect these idiosyncrasies. After grouping similar countries together, e.g. based on their income class, significant differences appeared. This in turn implies that the use of non-stationary panel techniques might be beneficial in terms of its larger testing power and increase in the amount of useable observations, yet it also comes with a cost, namely the loss of the underlying heterogeneity.

Furthermore, we should be somewhat cautious with the origin of the data used in this study, as historical African data often comes with the so-called *health warning.* Yearly observations might be missing, which in turn are filled up with rough estimations on yield and productivity levels in the original data sources. Moreover, a political dimension comes into play as local informants might have incentives to overstate the actual yield levels in order to please the agricultural ministry (Wiggins, 2014). All these limitations and uncertainties in the process of generating the original data should be kept in mind when interpreting the results of this study. Lastly, due to the fact that not all variables were integrated to the same order, some possibly important factors were not taken into consideration. E.g. the role of institutional quality in the relation between economic and agricultural development was not taken into account.

Despite these limitations, this study however provides useful insights in the interaction between economic growth and agricultural development. These two processes do not follow each other up in a clearly defined path, but are to a large extent connected to the wider social and economic conditions. Copying development strategies that worked for 19th century Western Europe or for Asia's Green Revolution into the current context of the African continent is therefore not an advisable strategy, as the economic and social context in which the agricultural sector is embedded are strongly different. Where for example outflowing labor of the agricultural sector in 19th century Western Europe could easily be absorbed by the new flourishing industrial sectors, the results of this study point out that such an outflow of labor towards other economic sectors and urban areas is not beneficial for most African low income countries. Its wider embeddedness and interlinkages with other economic sectors and labor markets are therefore of utmost importance for creating further agricultural development strategies.

Literature

Adelman, I. (1984). Beyond Export-Led Growth. *World Development,* vol. 12 (no. 9), pp. 937 – 949.

Alston, J.M. & Pardey, P.G. (2014). Agriculture in the Global Economy. *Journal of Economic Perspectives,* Vol. 28 (1), pp. 121 – 146.

Baltagi, B.H. (2013). *Econometric Analysis of Panel Data*. Wiley & Sons: Fifth Edition.

Baltagi, B.H. & Kao, C. (2000). Nonstationary Panels, Cointegration in Panels and Dynamic Panels: A Survey. *Centre for Policy Research: Paper 136.*

Bittencourt, M. (2010). Inflation and Economic Growth in Latin America: Some Panel Time-Series Evidence. *Economic Modelling,* vol. 29 (no.2)., pp. 333 – 340.

Byerlee, D., Diao, X. & Jackson, C. (2005). Agriculture, Rural Development and Pro-Poor Growth: Country Experiences in the Post-Reform Era. *Agriculture and Rural Development Discussion Paper 21,* The World Bank.

Dercon, S. (2009). *Rural Poverty: Old Challenges in New Contexts*. International Bank for Reconstruction and Development / The World Bank, 2009.

Dethier, J.J. & Effenberger, A. (2012) Agriculture and Development: A Brief Review of the Literature. *Economic Systems,* vol. 36, pp 175 – 205.

Diao, X., Hazell, P. & Thurlow, J. (2010). The Role of Agriculture in African Development. *World Development,* vol. 38 (n. 10), pp. 1375 – 1383.

Eberhardt, M. & Teal, F. (2011). Econometrics for Grumblers: A New Look at the Literature on Cross-Country Growth Empirics. *Journal of Economic Surveys,* vol. 25, pp. 109 – 155.

Estudillo, J.P & Otsuka, K. (1999). Green Revolution, Human Capital and Off-Farm Employment: Changing Sources of Income among Farm Households in Central Luzon, 1966 – 1994. *Economic Development and Cultural Change,* vol. 47 (no. 3), pp. 497 – 523.

Fan, S. (1991). Effects of Technological Change and Institutional Reform on Production Growth in Chinese Agriculture. *American Journal of Agricultural Economics,* vol. 73 (no. 2), pp. 266 – 275.

Fayad, G., Bates, R.H. & Hoeffler, A. (2011). Income and Democracy: Lipset's Law Inverted. *OxCarre Research Paper 61.*

Federico, G. (2005). *Feeding the World: An Economic History of Agriculture, 1800-2000.* Princeton University Press.

Gardner, B. (2000). Economic Growth and Low Incomes in Agriculture. *American Journal of Agricultural Economics* 82(5): 1059-1074.

Gardner, B. (2003). Causes of Rural Economic Development. *Proceedings of the 25th International Conference of Agricultural Economists,* 16-22th August, Durbin: South Africa.

Gemmel, N., Lloyd, T.A. & Mathew, M. (2000). Agricultural Growth and Inter-Sectoral Linkages in a Developing Economy. *Journal of Agricultural Economics,* vol. 51, (no. 3), pp. 353 – 370.

Gollin, D. (2010). Agricultural Productivity and Economic Growth. *Handbook of Agricultural Economics,* vol. 4, pp. 3825 – 3866.

Gollin, D., Parente, S. & Rogerson, R. (2002). The Role of Agriculture in Development. *American Economic Review,* vol. 92 (2), pp. 160 – 165.

Gollin, D., Parente, S. & Rogerson, R. (2007). The Food Problem and the Evolution of International Income Levels. *Journal of Monetary Economics,* vol. 54, pp. 1230 – 1255.

Hayami, Y. & Ruttan, V.W. (1971). Induced Innovation in Agricultural Development. *Center for Economics Research: Discussion paper No. 3.,* University of Minnesota, May 1971.

Humphries, H., & Knowles, S. (1998). Does agriculture contribute to economic growth? Some empirical evidence. *Applied Economics*, vol. 30(6), pp. 775 – 781.

Hwa, E.C. (1988). The Contribution of Agriculture to Economic Growth: Some Empirical Evidence. *World Development*, vol. 16 (100), pp 1329 – 1339.

Im, K.S., Pesaran, M.H. & Shin, Y. (2003). Testing for Unit Roots in Heterogeneous Panels. *Journal of Econometrics,* vol. 115, pp. 53 – 74.

Kao, C. & Chiang, M.H. (2000). On the Estimation and Inference of a Cointegrated Regression in Panel Data. *Nonstationary Panels, Panel Cointegration and Dynamic Panels*, Vol. 15, pp. 179 – 222.

Lewis, W.A. (1954). Economic Development with Unlimited Supplies of Labour. *The Manchester School* 22(2): 139–191.

Johnston, B.F. & Mellor, J.W. (1961). The Role of Agriculture in Economic Development. *The American Economic Review,* vol. 51, pp. 566 – 593.

Levin, A. & Lin, C.F. (1992). Unit Root Tests in Panel Data: Asymptotic and Finite-sample Properties. *University of California: Discussion Paper 92-93.*

Matsuyama, K. (1992). Agricultural Productivity, Comparative Advantage and Economic Growth. *Journal of Economic Theory*, vol. 58, pp. 317 – 334.

Nasreen, S. & Anwar, S. (2014). Causal Relationship between Trade Openness, Economic Growth and Energy Consumption: A Panel Data Analysis of Asian Countries. *Energy Policy*, vol. 80, pp. 82 – 91.

Neal, T. (2013). Using Panel Co-Integration Methods To Understand Rising Top Income Shares. *Economic Record*, vol. 89(284), pp. 83 – 98.

Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and Statistics* 61, pp. 653-678.

Pedroni, P. (2000). Fully-modified OLS for Heterogeneous Cointegration Panel. *Advanced Econometrics,* vol. 15, pp. 93 – 130.

Potts, D. (2000). Urban Unemployment and Migrants in Africa: Evidence from Harare 1985-1994. *Development and Change*, vol. 31 (4), pp. 879 – 910.

Reardon, T., Crawford, E. & Kelly, V. (1994). Links between Nonfarm Income and Farm Investment in African Households: Adding the Capital Market Perspective. *American Journal of Agricultural Economics,* vol. 74 (no. 5), pp. 1172 – 1176.

Roxburgh, C., Dörr, N., Leke, A., Tazi-Riffi, A., Wamelen, A. van, Lund, S., Chironga, M., Alatovik, T., Atkins, C., Terfous, N. & Zeino-Mahmalat, T. (2010). Lions on the Move: The Progress and Potential of African Economies. *McKinsey Global Institute: June 2010*.

Sachs, J.D. & Warner, A.M. (1995). Natural Resource Abundance and Economic Growth. *National Bureau of Economic Research.*

Schultz, T. W. (1953). *The Economic Organization of Agriculture*. New York: McGraw-Hill.

Self, S. & Grabowski, R. (2007). Economic Development and the Role of Agricultural Technology. *Agricultural Economics*, vol. 36(3), pp. 395 – 404.

Tiffin, R. & Irz, X. (2006). Is Agriculture the Engine of Growth? *Agricultural Economics,* vol. 35, pp. 79 – 89.

Tsakok, I. & Gardner, B. (2007). Agriculture in Economic Development: Primary Engine of Growth or Chicken and Egg. *American Journal of Agricultural Economics*, vol. 89(5), pp.1145 – 1151.

Verbeek, M. (2012). *A Guide to Modern Econometrics.* John Wiley & Sons, Ltd.

Wagner, M. and Hlouskova, J. (2007). The Performance of Panel Cointegration Methods: Results from a Large Scale Simulation Study. *Economic Series, No. 210,* Institut fur Hohere Studien (HIS).

World Bank (1981). *Accelerated Development in Sub-Saharan Africa: An Agenda for Action.* International Bank for Reconstruction and Development / World Bank: Washington, USA.

World Bank (2008). *World Development Report: Agriculture for Development.* International Bank for Reconstruction and Development / World Bank: Washington, USA.

Wiggins, S. (2014). African Agricultural Development: Lessons and Challenges. *Journal of Agricultural Economics,* vol. 65(3), pp. 529 – 556.

Data sources

Feenstra, R. C., Inklaar, R. & Timmer, M.P. (2013). *The Next Generation of the Penn World Table*. Available for download at www.ggdc.net/pwt

Fuglie, K. O. (2012). Productivity Growth and Technology Capital in the Global Agricultural Economy. In: Fuglie K., Wang, S.L. and Ball, V.E. (eds.) *Productivity Growth in Agriculture: An International Perspective.* CAB International, Wallingford, UK, pp. 335-368. Available for download at http://www.ers.usda.gov/data-products/international-agricultural-productivity.aspx

Heston, A., Summers, R. & Aten, B. (2012). *Penn World Table Version 7.1*. Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, November 2012.

Madison Historical GDP Data (2013). Obtained on 10-09-2014 from http://www.worldeconomics.com/Data/MadisonHistoricalGDP/Madison%20Historical%20GDP%20Data.efp

Political Terror Scale (2014). PTS Data Online. Obtained on 12-10-2014 from http://www.politicalterrorscale.org/ptsdata.php

World Bank Database (2014a). Imports of Goods and Services (% of GDP). Obtained on 12-10-2014 from http://data.worldbank.org/indicator/NE.IMP.GNFS.ZS

World Bank Database (2014c). Food Production Index. Obtained on 12-10-2014 from http://data.worldbank.org/indicator/AG.PRD.FOOD.XD

World Bank Database (2014f). Malnutrition prevalence, weight for age. Obtained on 12-10-2014 from http://data.worldbank.org/indicator/SH.STA.MALN.ZS

World Bank Database (2014g). Mortality-rate, under five. Obtained on 12-10-2014 from http://data.worldbank.org/indicator/SH.DYN.MORT

World Bank Database (2014g). The Changing Wealth of Nations: Subsoil and Forest Rents. Obtained on 11-11-2014 from http://data.worldbank.org/sites/default/files/subsoil_and_forest_rents.xls

WGI (2014). Worldwide Governance Indicators: Government Effectiveness. Obtained on 12-10-2014 from http://info.worldbank.org/governance/wgi/index.aspx#home

Appendix 1: Country list (Number between parentheses indicates income group; 1=low income, 2=lower middle income, 3=upper middle income, 4=high income)

1. Algeria (3)
2. Angola (3)
3. Benin (1)
4. Botswana (3)
5. Burkina Faso (1)
6. Burundi (1)
7. Cameroon (2)
8. Cape Verde (2)
9. Central African Republic (1)
10. Chad (1)
11. Comoro Islands(1)
12. Congo Brazzaville (2)
13. Cote d'Ivoire (2)
14. Djibouti (2)
15. Egypt (2)
16. Equatorial Guinea (4)
17. Ethiopia (including Eritrea) (1)
18. Gabon (3)
19. Gambia (1)
20. Ghana (2)
21. Guinea (1)
22. Guinea-Bissau (1)
23. Kenya (1)
24. Lesotho (2)
25. Liberia (1)
26. Libya (3)
27. Madagascar (1)
28. Malawi (1)
29. Mali (1)
30. Mauritania (2)
31. Mauritius (3)
32. Morocco (2)
33. Mozambique (1)
34. Namibia (3)
35. Niger (1)
36. Nigeria (2)
37. Rwanda (1)
38. San Tome & Principe (2)
39. Senegal (2)
40. Seychelles (3)
41. Sierra Leone (1)
42. Somalia (1)
43. South-Africa (3)
44. Sudan (2)
45. Swaziland (2)
46. Tanzania (1)
47. Togo (1)
48. Tunisia (3)
49. Uganda (1)
50. Zaire (Dem. Rep. of Congo) (1)
51. Zambia (2)
52. Zimbabwe (1)

Appendix 2: Countries divided by regions (According to UN-Geoscheme)

Eastern Africa
Burundi, Comoros, Djibouti, Eritrea and Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, Seychelles, Somalia, South Sudan, Uganda, United Republic of Tanzania, Zambia, Zimbabwe
Not included: Réunion, Mayotte

Central Africa
Angola, Cameroon, Central African Republic, Chad, Democratic Republic of the Congo, Equatorial Guinea, Gabon, Republic of the Congo, São Tomé and Príncipe

North Africa
Algeria, Egypt, Libya, Morocco, Sudan, Tunisia

Southern Africa
Botswana, Lesotho, Namibia, South Africa, Swaziland

West Africa
Benin, Burkina Faso, Cape Verde, Cote d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo
Not included: Saint Helena.

Appendix 3: Landlocked and non-landlocked countries

Landlocked countries
Botswana, Burkina Faso, Burundi, Central African Republic, Chad, Ethiopia, Lesotho, Malawi, Mali, Rwanda, Swaziland, Uganda, Zambia, Zimbabwe

Non-landlocked countries
Algeria, Angola, Benin, Cameroon, Cape Verde, Comoro Islands, Congo-Brazzaville, Cote d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Libya, Madagascar, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Sao Tome & Principe, Senegal, Seychelles, Sierra Leone, Somalia, South-Africa, Sudan, Tanzania, Togo, Tunisia, Zaire (Democratic Republic of Congo)

Appendix 4: Resource rich and resource poor countries

Resource rich countries
Algeria, Angola, Botswana, Cameroon, Cape Verde, Central African Republic, Lesotho, Namibia, Nigeria, South-Africa, Sudan, Swaziland

Resource poor countries
Benin, Burkina Faso, Burundi, Chad, Comoro Islands, Congo-Brazzaville, Cote d'Ivoire, Egypt, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Niger, Rwanda, Senegal, Seychelles, Sierra Leone, Togo, Tunisia, Uganda, Zaire (Congo-Kinshasa), Zambia, Zimbabwe

Value missing:
Tanzania, Somalia, San Tome & Principe, Libya, Equatorial Guinea, Djibouti