Unravelling the links between agriculture and economic growth

a panel time-series approach for post-WW II Africa

MSc Thesis
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March 2015, Wageningen
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Preface
In front of you is the final version of my Master's thesis, which I conducted between August 2014 and February 2015 as part of my program in *Economics, Environment and Governance* at the Wageningen University. Working on this thesis enabled me to combine my interests in agricultural development and economics with my preference for quantitative methods.

Despite the attraction of such a quantitative approach, one should always bear in mind its limitations: the enormous uncertainty and shortcomings in the process of generating these data or the loss of the heterogeneity underlying these numbers, to name but a few. Working with quantitative methods therefore always requires a strong balance between the attraction and the power of numbers on the one hand and the loss of the underlying – and sometimes invisible – world beneath these numbers. In a way, numbers, to paraphrase Elinor Ostrom, are always simpler than the phenomenon to which they refer.

In order to deal with the complexity of such a large dataset and the different methods of analysis, the supervision of Mr. Gardebroek was of great help. Our meetings were always both constructive and productive. His ideas and advice really helped me in order to conduct the analyses that were carried out during this study. Furthermore, he was always willing to make appointments on short-term and look thoroughly through my writings, which I really appreciated throughout the process of writing this thesis.

Beyond, his way of supervising fitted perfectly within the wider atmosphere of Wageningen, which I have come to embrace as my second home in the past few years: intellectually challenging and highly motivated while maintaining a down-to-earth working sphere. It is this vision and working atmosphere that I hope to encounter in other places as well.

March 2015,
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Abstract

This study explores the interaction between patterns in agricultural development and economic growth in post WW-II Africa. The study covers the period of 1961-2010 for 52 African countries and applies panel co-integration and causality approaches in order to unravel the links between economic and agricultural development. Final results of panel co-integration regressions 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 a reallocation of labor from the agricultural sector 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, where the outflowing labor can be absorbed by other productive economic sectors. Besides, panel causality results show the existence of a bidirectional causal relation between agricultural and economic development.

Keywords

Content

1. Introduction
1.1 Introduction
The presumed relation between agricultural productivity 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 (e.g. 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 exact direction and causal connection of the relation between agricultural and economic development however is subject to debate (e.g. Gollin, 2010; Tiffin and Irz, 2006). On the one hand, one could argue that increases in agricultural productivity must precede any further process of economic growth, whereas on the other hand a process of economic growth can also positively influence agricultural productivity.

Most 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).

Furthermore, productivity increases in the agricultural sector are often seen as a precondition for the release of labor to other sectors in the economy (Tiffin and Irz, 2006; Self and Grabowski, 2007). Reallocating labor from the agricultural sector towards the industrial or service sector is often perceived as a prerequisite for modern economic growth (Humphries and Knowles, 1998). With respect to such developments in the structural composition of the economy, Mundlak argues that '*without the growth in agricultural productivity, the history of economic development would have taken a completely different course*' (Mundlak, 2005, p. 990). Beyond, historical research for example emphasizes the importance of a developed agricultural sector as essential condition for the take-off of the Industrial Revolution (Matsuyama, 1992; Federico, 2005).

The above-mentioned arguments all imply a causal direction that runs from agricultural productivity growth to economic growth. However, it is also very plausible that (non-agricultural) economic growth in turn can positively affect the productivity and the output in the agricultural sector. Agricultural productivity is to a large extent dependent on technology and inputs from other economic sectors (Hwa, 1988). These technological developments in turn can spillover to the agricultural sector and enhance further productivity and output growth. Therefore, agriculture might also benefit from wider processes of economic growth.

The exact relation between productivity increases in the agricultural sector and economic growth is therefore still unidentified. Is productivity growth in agriculture really a prerequisite for economic growth or should it rather be regarded as a side-effect of general economic growth? Important to note here, however, is that recent literature seems to question the strict relation between economic growth and agricultural development in a more

globalized context (Matsuyama, 1992). Tsakok and Gardner (2007) for example state that economies are in some cases even able to bypass the process of agricultural development. These countries could instead focus on investing in their industrial sector as a way to promote economic growth and in turn import food rather than develop their own domestic agricultural sector.[1] Therefore, the potential of trade can arguably heavily intervene in the relation between economic and agricultural development. In addition, the role of labor and the influence of outflowing labor out of the agricultural sector on further economic developments might lead to differences in the relation between agricultural and economic growth.

The recent economic growth in most developing African countries however 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). Furthermore, according to the Harvard Center for Economic Development, a list of the seven fastest expected growing economies until 2020 is fully composed out of African countries (Posthumus, 2012). According to the World Bank more investments, a growing world economy and higher prices for natural resources are the main drivers of this African economic growth (de Volkskrant, 2013). 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.

1.2 Problem Statement and Research Question
Concluding on the above, current literature emphasizes the uncertainty in the exact relation between agricultural development and economic growth. As the agricultural sector is a low productivity sector, questions arise whether expanding this sector is the best way to promote economic growth in developing countries. And more profoundly, as it is difficult to determine the causal direction between agricultural development and economic growth, endogeneity problems occur in empirical research (e.g. Gollin, 2010; Tsakok and Gardner, 2007).

The purpose of this research is to empirically assess the relation between agricultural development and economic growth for African economies between 1960 and 2010. As mentioned before, the recent growth of most African economies provides an opportunity to study this relation over a longer period. The main question that this research aims to address is

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[1] *Tsakok and Gardner (2007), e.g., show that the agricultural sector hardly played any significant role in the economic growth of South-Korea, where the yearly per capita income grew from under $100 in the early 1960's to over $10.000 in the late 1990's. Rather, the focus on export-driven industries was the main driver of this substantial economic growth.*

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how economic growth and agricultural development are mutually interacting in the current African context.

Furthermore, the role of trade in agricultural products might intervene in this relation. Arguably, in economies that are open with respect to trade in agricultural products, the agricultural output should not have to grow by definition, as these countries have more opportunities to import food in order to meet the dietary needs of the citizens.

In order to address these issues, the following general research question is formulated:
"*How did patterns in economic growth and agricultural development interact with each other in African countries in the period between 1960 and 2010?*"

Furthermore, the following sub questions are formulated:
- What underlying mechanisms can be identified that connect economic growth with agricultural development and vice versa?
- Did economic growth influence the agricultural productivity in African countries in the period between 1960 and 2010?
- Did changes in agricultural productivity influence the general economic growth level in African countries in the period between 1960 and 2010?
- Did the sectoral reallocation of labor contribute to economic growth of African countries in the period between 1960 and 2010?
- What is the role of trade in agricultural products in the relation between economic growth and agricultural development?

1.3 Scientific Relevance
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 will contribute to the existing empirical literature and arguably leads to additional insights in the relation between agricultural and economic development.

Besides, the research can contribute to the empirical assessment of the validity of the 'food problem-hypothesis' in a more globalized context. Most of the theorems from this branch of literature have been proposed in the 1950's and 1960's (e.g. Johnston and Mellor, 1961) and it is questionable whether these still hold under different circumstances in a more globalized context. Furthermore, the specific focus on the African context can give additional insights in the key determinants of economic development in developing countries during the late 20th and early 21st century.

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1.4 Societal Relevance

The debate on the alleged relation between agricultural development and economic growth might considerably influence the policies advocated in this field. If agricultural development is not found to be a prerequisite for economic growth, the role of the government with respect to intervening in and supporting the agricultural sector can be quite minimal. Moreover, in that situation, a government might even have good reasons to disadvantage the sector, by the means of heavy taxation (Timmer, 1992). If, the other way around, the agricultural sector does seem to play an active and positive role with regard to the economic development of African countries, the role of these governments should also be more active: providing rural infrastructure and modern technology as well as subsidizing the agricultural sector should in that case be seen as beneficial steps towards economic development (Timmer, 1992).

As especially African governments have used the agricultural sector in the past as a means to gain taxes through unfavorable price and tax policies (Wiggins, 2014; World Bank, 1981), the results provide policy makers with more insight in the relation between agricultural development and economic growth and its underlying mechanisms.

1.5 Overview

Chapter two of this study provides a detailed review of the current literature on the relation between agricultural development and economic growth. It will pay attention to all the possible relations and underlying mechanisms that drive the relation between agricultural and economic development. Both theoretical as well as empirical models and research will be discussed here. Furthermore, the specific context of the African case will be described more in depth.

Chapter three gives an overview of the data sources that will be used in the empirical analysis and provides an empirical overview of the developments in the agricultural sector of the African continent. Subsequently, chapter four presents the methodology that is used in order to empirically assess the research questions. Chapter five provides the main results of the panel time-series analysis. Lastly, chapter six presents the conclusions and implications of the findings of this research in light of the current scientific debate, as well as a contribution to the policy debate on African agricultural and economic development.

2. Theoretical Framework

2.1 Introduction

This chapter aims to provide a more detailed description of the relation and the underlying mechanisms between agricultural and economic development. It will start out with a historical perspective on the role of agriculture for economic development. Afterwards, section 2.3 explains more in-depth the underlying reasons for why a developed agricultural sector is often perceived as a necessary precondition for further economic growth. Section 2.4, in contrast, pays attention to the influence of trade and the so-called *agro-pessimistic* literature, which questions the importance of the agricultural sector for further economic development. Beyond, section 2.5 shows the reversed influence of wider patterns of economic development on the productivity and output of the agricultural sector. Contemporary empirical research in the field of agricultural and economic development is discussed in section 2.6. In addition, the specific context of the African continent will be presented and lastly section 2.8 provides an overview of the conceptual framework that is being derived upon the literature discussed in this chapter and which will be used as further directive for the following analysis.

2.2 Economic Development and the Agricultural Sector

Modern economic growth is defined by Kuznets as a process that is "*jointly featured by the growth in income per capita and by a change in the sectoral shares of GDP and employment*" (Federico, 2005 p. 222). The role of agriculture in the process of economic growth, however, has been looked upon from quite different perspectives over the years. In most early work on economic development, the role of agriculture is often ignored. Instead, industrial development is often emphasized as the main driver of economic growth (Self and Grabowski, 2007; Tiffin and Irz, 2006). Agriculture itself was often perceived as a traditional sector, which only passively contributed to development through the provision of labor and food to the industrial sector (Diao et al., 2010). Such a view on the role of agriculture in development implicitly assumes that labor could easily be subtracted from the agricultural sector without leading to a significant reduction in agricultural output. Timmer (1992) emphasizes that agriculture was often neglected in the 1950's and 1960's as a sector that could contribute to economic development. According to Timmer, the agricultural sector was by the nation-builders in developing countries often perceived as '*the home of traditional people [...] – the antithesis of what nation builders in developing countries [...] envisaged for their societies*' (Timmer, 1992, p. 27).

Furthermore, the agricultural sector seemed to be widely ignored in long-run economic growth models. Instead, manufacturing and industrialization were increasingly used and seen as factors that drive economic growth, while agriculture in fact disappeared from the forefront (Self and Grabowski, 2007). The use and popularity of one-sector growth models as the Harrod-Domar models to explain economic growth, implicitly emphasizes investment in the industrial sector as the main key to development (Thorbecke, 1970).

Through various reasons however, the paradigm shifted back towards a more agriculture-oriented perspective on economic development in the 1970's. For example, the results and the outcome of the Green Revolution in Asia emphasized again the potential of the agricultural sector to contribute in the wider process of economic growth (Diao et al., 2010). Furthermore, the poor economic growth rates of most African countries, which not long

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before that time regained their independence, challenged the view that industrial development was the main source of economic development (Tiffin and Irz, 2006). The idea that agriculture could also actively contribute to economic growth and development of these African countries was prominently stated in the Berg Report (World Bank, 1982).

As especially in these developing countries the majority of the people found employment in the agricultural sector (at the time the Berg Report was released, it was not uncommon that roughly four out of five people were employed in agriculture), it's relation with wider economic growth regained more importance again. 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).

2.3 Conventional Wisdom: Agricultural Productivity as Prerequisite

This section explores the different ways and underlying mechanisms in which the agricultural sector can contribute to the process of modern economic growth. It will address both direct as well as more indirect manners in which agricultural productivity increases can influence economic growth. According to Federico (2005) agriculture performs a key role in the process of economic growth. Federico identifies three essential tasks that the agricultural sector performs: the product role, the market role and the factor role. The product role refers to the goods provided by the agricultural sector and is twofold: on the one hand it feeds the population, whereas the exports of agricultural products also provide foreign currency. The purchase of manufactures for investments is identified by Federico as the market role, as a modernized agricultural sector has a higher demand for products from the manufacturing sector. Lastly, the factor role refers to the supply of manpower and capital to other sectors, such as the industry and the service sector.

In their seminal article published in 1961, Johnston and Mellor identify five roles for the agricultural sector with respect to economic development: increasing the supply of food for domestic use, releasing labor for industrial employment, increasing the supply of domestic savings, earning foreign exchange and enlarging the size of the market for industrial output (Timmer, 1992). This subsection will address and give a more detailed description of these different roles, with a special focus on the current context of (developing) African countries.

2.3.1 Direct Relation

As previously mentioned, a large share of the labor force in developing countries still finds employment within the agricultural sector. Although declining in the last few decades, according to FAO data still 65% of the total working population in the least developed countries is employed in agriculture. Gollin (2010) furthermore states that these numbers in a way even understate the importance of agriculture for employment, as people who are engaged in transporting and processing agricultural goods are not yet taken into consideration in such a definition.

Besides the importance of agriculture with respect to employment, the share of agriculture in the GDP of developing countries is also significant. Table 2.1 shows the share of the agricultural sector in GDP for different income groups between 1965 and 2010. As can be seen, in low income countries the share of agriculture in GDP was in 2010 still above 25%. With such significant shares, it is therefore not surprisingly that growth in agricultural output and increases in the agricultural value added will contribute directly to the GDP of low income countries (Tiffin and Irz, 2006). For higher income countries, this effect on the growth rate of the economy will be much smaller, as the share of agriculture in the economy of these countries has fallen below 2%. Because of its scale in developing countries, proponents of agricultural growth argue that only the agricultural sector has sufficient growth linkages in order to influence aggregate growth, as will be elaborated more in depth on in section 2.3.5 (Diao et al., 2010).

Table 2.1: Agriculture's share of GDP for different countries based on income-group from 1965 – 2010.

	1965	1970	1980	1990	2000	2005	2010
High income			4.0	3.3	1.9	1.6	1.4
Upper middle income	28.0	24.6	20.1	17.3	10.0	8.6	7.7
Lower middle income	41.6	39.8	30.2	26.4	21.1	17.9	17.3
Low income			37.7	37.5	33.2	28.6	27.6

Source: World Development Indicators, World Bank (2014).

2.3.2 Food Problem

Besides this direct relation between the agricultural sector and economic growth, a growing agricultural output can influence economic development in different manners. One profound argument in the literature on agricultural productivity and economic growth is what is being identified by Schultz (1953) as the *food problem* − and refers to the *product role* of the agricultural sector as identified by Federico (2005). According to Schultz, most low income countries are caught in a situation in which their income is on such a low level, that an extremely high percentage of their income must be attributed towards buying food. Since such large fractions of the resources (as labor) must be devoted to satisfy the subsistent dietary needs of the citizens, these countries are unable to develop (Xu, 2010). 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. Schultz saw a major role for the agricultural sector in the further process of modern economic growth, as this sector ensures subsistence for society, a precondition for any further growth (Dethier and Effenberger, 2012). This argument therefore profoundly states an idea of causality: increases in agricultural productivity must precede economic growth. Schultz argued that countries must produce the majority of their own food themselves, as imports were too costly for these low income countries (Gollin et al., 2007). Contemporary literature however questions the validity of the food-problem argument in a more globalized context, in which food could be more easily imported (e.g. Matsuyama, 1992). A more detailed description on the role of trade openness for the relation between agricultural productivity and economic growth will follow in section 2.4.

2.3.3 Sectoral Transformation

Next to facilitating the dietary needs of citizens, the increase in agricultural productivity plays a pivotal role in releasing labor to the other sectors in the economy (Tiffin and Irz, 2006). Also emphasized by Federico (2005) and Johnston and Mellor (1961), the growth in agricultural output is seen as a prerequisite for the release of any labor from the agricultural sector towards other sectors in the economy, such as the industrial or service sector.

The foundation under such reasoning lies in the work of Lewis. According to his work in the early 1950's on dual-sector models, a large share of the working population in developing countries has a marginal product of labor that is equal or close to zero. The majority of these so-called surplus laborers are employed within the agricultural sector. According to the Lewis model, a process of economic growth in developing countries is unable to take off as long as this labor is still allocated in sectors with a low marginal product of labor, such as agriculture (Humphries and Knowles, 1998).

These dual-sector models imply a productivity differential between the agricultural (subsistence) sector and the non-agricultural (capitalistic) sector, as the marginal product of labor – and therefore the reward of labor – must be higher in the non-agricultural sector compared to the agricultural sector, since otherwise labor would not reallocate towards other sectors. This assumption is often verified in empirical research: e.g. according to Dowrick (1989), labor indeed has a lower marginal product in the agricultural sector than in industrial or service sectors. His findings furthermore seem to hold for both developed, as well as for developing countries.

The existence of such a productivity differential emphasizes the importance of sectoral transformation for growth. This is also in line with the aforementioned definition of Kuznets of 'modern economic growth', in which the change in the sectoral shares of GDP is a key feature. Anderson (1987) furthermore states that a proportionate decline in the agricultural sector is among the most dominant characterizations of a growing economy. Two underlying reasons are often mentioned for this decline: 1) the demand for food rises slower compared to other goods and services (also known as *Engel's Law*) and 2) the development of new farm technologies leads to higher food supplies measured per hectare or per worker.

Engel's Law implies that the income-elasticity of demand for food is lower than one. This means that during a process of economic growth, the ratio of food to non-food will fall almost by definition: the demand for food products will grow slower than the demand for other products. Therefore the share of the agricultural sector in GDP will eventually fall as well (Anderson, 1987).

The second mentioned mechanism by Anderson is the development of new farm technologies that in turn allows labor to flow into other sectors of the economy. However, according to Lewis' model, most agricultural workers have a marginal product close or equal to zero: this would mean that – even without any new technologies that expand the food supply – their labor could be subtracted and allocated towards other sectors in the economy. The question that remains open then is whether the agricultural sector plays an active role in this sectoral transformation or whether this role is more passive. Both models address that the sectoral shift from labor to non-agricultural sectors is among the main drivers of economic

growth, yet there are different perceptions on whether the productivity increases in the agricultural sector *push* the labor towards other sectors or whether the wider economy *pulls* labor out of the agricultural sector without the requirement of any technological innovations that expand the food supply.

2.3.4 Capital Formation

Beyond, the agricultural sector performs several additional roles that contribute to economic growth. Widely acknowledged is the role of agriculture to serve as a source of savings that can finance the expansion and development of other (industrial) sectors in the economy (Self and Grabowski, 2007). If an underdeveloped country tries to achieve economic development, it will face requirements in terms of capital to finance the investments in e.g. infrastructure, education and manufacturing enterprises (Johnston and Mellor, 1961). Most developing countries (unless a country obtained large earnings from exporting natural resources as minerals or petroleum) will often lack these financial requirements. The agricultural sector however, as pointed out in section 2.3.1, is likely to be the only sector in the economy of these developing countries that is of sufficient size to function as a capital source for wider economic growth.

Johnston and Mellor (1961) mention the example of Japan in this case. Based on historical research, they state that "*consumption levels of the farm population increased much less than the rise in productivity in agriculture, so that a substantial fraction of the increment in product in agriculture could be used to finance capital formation in the capitalist sector of the economy*" (Johnston and Mellor, 1961, p. 578). Besides the function of the agricultural sector as a surplus for labor that was elaborated on in section 2.3.3, agriculture also seems to perform a key function in financing the development of the industrial sector in developing countries. The supply of both labor and capital to other sectors of the economy is identified by Federico (2005) as the *factor role* of agriculture.

For most governments, the agricultural sector was also an attractive sector to tax relatively heavily. Governments of developing countries often rely heavily on the agricultural sector for their tax-revenues. The incomes from the taxes on land and agriculture are often used to carry out programs for developing the industrial sector (Johnston and Mellor, 1961). For example, in the late 19th and early 20th century, agriculture's share in the tax-income of the Japanese government was about 80%. More recently, also in late 20th century Africa, the tax-incomes from the agricultural sector were still a significant source of income for national governments (Wiggins, 2014).

2.3.5 Production and Consumption Linkages

Besides supplying labor, food and capital to other sectors in the economy, the agricultural sector may also contribute to economic growth through both production and consumption linkages (Dethier and Effenberger, 2012). Higher agricultural productivity for example increases the income of the rural population (especially in developing countries) and can therefore contribute to increasing the demand for (domestic) industrial output. Through such linkages, increases in agricultural productivity can contribute to the development of the rural economy. The idea of 'agricultural demand-led industrialization' builds upon these linkages. Based on experiments with 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.

An implication of the findings of Adelman is that growth within the agricultural sector itself should preferably focuses on small and medium sized farms, rather than on large-scale producers, as these small and medium sized farms have stronger linkages with the local, rural economy (Dethier and Effenberger, 2012). Furthermore, this strategy seems to work best for developing countries that have a relatively closed economy with respect to trade in agricultural products, since the strength of these linkages is particularly evident in small and closed economies. According to Adelman (1984), mainly in countries in which the agricultural sector still holds a significant share in the total economy, the pivotal role of the agricultural sector for generating further economic growth and stimulating domestic demand should be recognized. The World Development Report of 2008 states that growth strategies, that focus on the agricultural sector as spindle for the wider economy, are especially relevant for much of sub-Saharan Africa, as it simultaneously spurs economic growth, enhances food security and contributes to alleviating poverty (World Bank, 2008).

The production and consumption linkages of the agricultural sector with the wider economy also hold a central place in the work of Mellor. According to the *Mellor hypothesis,* growth in agricultural productivity will have wider impacts that go beyond the boundaries of the agricultural sector: e.g. through higher productivity, food prices will eventually decline, which contributes to the purchasing power of both rural and urban consumers. These positive effects on the purchasing power in turn can also increase the domestic demand for industrial output. Furthermore, increases in agricultural productivity are said to increase the competitiveness of industrial and agricultural exports, with a positive influence on (foreign) currency earnings (Gollin, 2010).

The above discussed functions of the agricultural sector imply that, rather than only the direct effect of a growth in agricultural output on the level of the gross domestic product, there are additional underlying mechanisms that cause the positive influence of the agricultural sector on the wider economy also in more indirect ways.

2.4 Agro-pessimism and Agriculture in a Globalized Context

In contrast with most of the literature and research discussed in section 2.3, the literature on *agro-pessimism* holds a more critical stance towards the influence of increases in agricultural productivity on economic growth. In most developing countries, the share of the agricultural sector in employment exceeds the share in output, meaning that output per worker in agriculture is on average lower than output in other sectors (Gollin, 2010). Since in most developing countries the agricultural sector is a relatively low productivity sector, it is questionable whether expanding and stimulating growth in this sector will have positive effects on the overall economy. This so-called 'agro-pessimistic' view therefore questions the importance of the agricultural sector for economic growth and opts for investing in other (higher productivity) sectors in order to promote economic growth.

Most of the policy advocated in the 1960's and 1970's was influenced by this more agro-pessimistic development paradigm and was based on the idea that countries – in order to

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develop – are also able to bypass the process of agricultural development (Byerlee et al., 2005). The potential of trade in food products plays an important role in this discussion. According to the agro-pessimistic branch of literature, most theoretical models that advocated agricultural-led development did not take into account the possibility and potential of trade in agricultural products (Matsuyama, 1992). According to Byerlee et al. (2005) most of the least developed countries have abundant resources in e.g. mineral and oil, which 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.

Besides, it is often claimed that for most of the developing countries that still face an underdeveloped agricultural sector, a harsh and unfavorable natural environment reduces the advantage these countries could have from modernizing and developing their agricultural sector. The declining trend in agricultural commodity prices in the late 20th century furthermore makes such a strategy that focuses on importing food rather than modernizing the domestic agricultural sector even more plausible and profitable (Byerlee et al., 2005). At the same time, however, as food prices have become more volatile in recent years (FAO, 2014), such a strategy shows its dependence on and vulnerability towards the sometimes erratic international food markets.

In his influential article on *Agricultural productivity, comparative advantage and economic growth* Matsuyama (1992) compares the role of the agricultural sector in economic development for both open and closed economies. Matsuyama questions the view that changes in agricultural productivity must precede economic development when considering the case of open economies. According to different historical research there is actually a negative link between agricultural productivity and the potential for a flourishing industrial sector, due to the so-called *Law of Comparative Advantage*. This view states that both the manufacturing and the agricultural sector compete for labor. The lower the productivity in the agricultural sector, the more supply for cheap labor there will be for the manufacturing sector, as the marginal product of this labor is close to zero in the agricultural sector. The higher supply of labor in the manufacturing sector in turn enlarges the potential for economic growth.

Through simulations in which labor is the only mobile factor that is able to float between the industrial and agricultural sector and in which, in line with *Engel's Law,* the income elasticity of demand for agricultural goods is less than one and the productivity in the manufacturing sector will gradually rise due to learning-by-doing effects, Matsuyama finds that – in accordance with conventional wisdom – in closed economies agricultural productivity is positively linked to economic growth. In open economies, however, this link becomes negative, as economies with low-productivity agricultural sectors will allocate more labor in the manufacturing sector and will therefore grow faster and attain higher welfare levels (Matsuyama, 1992).

In accordance with the findings of Matsuyama, Dercon (2009) states that "agriculture is not the crucial constraint", meaning that for countries that can easily trade with other economies it would be more favorable to export other (industrial) goods and in turn import agricultural products. Dercon however furthermore emphasizes the heterogeneity among developing (African) countries: land-locked countries face a different situation, in which the

modernization and development of the agricultural sector might be more crucial, due to the lower potential of trade. In contrast, for resource-poor countries, due to their lower domestic agronomic potential, it might be more favorable to focus on importing agricultural products.

Recent work from economic historians furthermore seems to weaken the importance of the agricultural sector for the take-off of the Industrial Revolution in Europe. While some research emphasizes growth in agricultural output as a necessary precondition for the take-off of the Industrial Revolution and wider patterns of modern economic growth, other research questions its importance. Concerns have been raised since levels of agricultural productivity were much higher in other parts of Europe, compared to Britain, leading to the question why the Industrial Revolution did not started off elsewhere (Gollin, 2010). In turn, this also questions the importance of a modernized and developed agricultural sector for further economic development in today's developing economies, especially since these countries are said to have better access to international food markets.

Beyond, skeptics point out that the different growth-linkages (as described in section 2.3.6) related to the agricultural sector may become less pivotal in a global environment (Diao et al., 2010). According to Hart (1998) these production and consumption linkages may have been valid during the Green Revolution in Asia, but will not by definition hold true for other parts of the world. Hart states that the effectiveness of these growth linkages to a large extent depends on the social organization of production and the further access to resources. It therefore remains questionable whether such linkages will emerge in the current African situation.

Furthermore, concerns have been raised on the future possibilities of technological improvements in the agricultural sector (Byerlee et al., 2005). The success of Asia's Green Revolution and the subsequent economic growth in these countries was mainly generated by new developments and a technological breakthrough (e.g. the introduction of high-yielding varieties of wheat and rice) that allowed for an enormous increase in agricultural productivity. The yield growth in Africa is still relatively low, mainly due to the large dependence on rainfed farming and due to the poor access and use of fertilizer. With additional investments in agricultural R&D, the agricultural productivity in Africa's agricultural sector could be raised, yet it remains questionable whether Africa's agronomic potential on the short term is as large as was the case for the Asian countries during the Green Revolution (Byerlee et al., 2005).

2.5 Reversed Causality: Influence of Economic Growth on Agriculture

In contrast to conventional wisdom and the literature discussed in section 2.3, which viewed the development and the modernization of the agricultural sector as a prerequisite for the take-off of any further process of modern economic growth, it is important to acknowledge that several arguments in the literature also point out that the causality might run in the opposing direction, meaning that changing patterns in economic development in turn can also influence the productivity and the output of the agricultural sector.

One of the main reasons why the agricultural sector could profit from wider non-agricultural growth is due to the dependency of the modern agricultural sector on technology and inputs from the industrial sector (Hwa, 1988). As the industrial sector provides advanced technology and modern farm inputs to the agricultural sector, the growth of agricultural

output is to a large extent dependent on new technologies and development in the non-agricultural sector, which in turn spill over to the agricultural sector and raise the productivity. Based on the results of a case-study on the Chinese agricultural sector, Fan (1991) even states that wider technological change is a crucial factor for the further development of the agricultural sector, due to the small potential of output increases while using conventional inputs.

Gemmel et al. (2000) have found in a Malaysian case-study that an expansion of output in the manufacturing sector in the short-run leads to a reduced agricultural output, but will in the long run change to a positive relation, meaning that eventually effects will spill over from the manufacturing sector to the agricultural sector and in turn lead to increases in productivity. The authors argue that in the short-run the competition over resources will dominate, which disadvantages the output of the agricultural sector since labor and capital can reallocate towards other sectors. Yet in the long-run, the potential of spill-over effects and the sectoral complementarity between the agricultural and manufacturing sector will dominate. Therefore, it might prove to be beneficial to advocate policies that stimulate growth in the manufacturing sector, as in the long run these positive effects will spill over to the agricultural sector.

Beyond, adjustments in the labor market as a result of wider economic growth are often mentioned among the main sources of growth in the value added per worker in the agricultural sector (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 labor market adjustments. Due to economic growth and the resulting increases in wage rates in the non-agricultural sector, labor will get pulled to these sectors and move out of agriculture. This in turn increases the labor productivity per worker of the agricultural sector and raises living standards of the farm population. This however does not by definition imply that aggregate agricultural output will also increase as a result of these labor market adjustments, as it only implies that the labor that remains allocated in the agricultural sector will become more productive. It is however important to note that this sectoral reallocation of labor is not only occurring due to increases in agricultural productivity, that push the labor to other sectors (as was discussed under section 2.3.3), since this reallocation of labor could also be the result of wider processes of economic growth that in turn pull labor out of agriculture, regardless any preceding productivity increases in that sector.

When considering the incomes of farm households, Estudillo and Otsuka (1999) found that the incomes of rice-farming households in the Philippines have risen mainly due to growth and economic development in the non-agricultural sector. The rice production as source of income for these farmers in fact decreased considerably over the years, whereas the importance of off-farm jobs for rural household incomes increased (in the Philippian case even strengthened by the remittances from migrated family members). The increase in the importance of off-farm jobs for rural incomes however enlarges the dependency of farm incomes on the development and changes in the wider economy. Changes in the wider economic situation will therefore have a stronger influence on the farmer's financial position, implying a stronger connection between the wider economic situation and the farmer's income. Higher incomes in turn can have a positive influence on the access to new technology and modern inputs and the availability of capital, which in turn can positively affect the level

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of agricultural output. Although their results are somewhat contradictory, 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.

The above mentioned studies show the reversed effect that wider patterns in economic development can have on the productivity and output in the agricultural sector. This indicates that the relation between agricultural development and processes of wider economic growth is not only characterized by a single straight-forward 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 the agricultural sector (Hwa, 1988).

Beyond, it could be argued that the relationship has a more spurious character: in that case the alleged positive relation between growth in agricultural output and economic growth is not due to the fact that one factor is causally linked to the other factor, but rather due to an external factor that both influences agricultural output and economic growth (Gollin, 2010). Examples of these external factors are institutional and infrastructural quality. Antle (1983) finds that investments in the infrastructural quality help to explain the increases in aggregate agricultural productivity. His findings hold for a sample of both developed as well as developing countries. Furthermore, it seems to be the case that investments in agricultural research often target regions and countries that are known for having high quality institutions and effective governance. This in turn implies a problem of attribution: increases in agricultural productivity coincide with wider economic growth, but in such situations it seems reasonable to assume that the wider institutional characteristics were responsible for both the increases in agricultural productivity and the wider economic development (Gollin, 2010).

2.6 From Theory to Empirics

The above paragraphs mainly considered and focused on theoretical models. When looking at more empirically-oriented research in the field of agricultural development and economic growth, the ambiguity of the theoretical underpinnings seems to return in the somewhat contradicting empirical evidence.

Self and Grabowski (2007) e.g. elaborate on the role of agricultural technology for economic development. Through an empirical cross-country analysis they test whether improvements in the level of agricultural technology have an impact on the long-run economic growth. Based on data for the time period between 1960 and 1995, the authors study whether measures of agricultural technology influence the average change-rate in real per capita GDP from 1960 to 1995. Regarding the measures of agricultural technology, Self and Grabowski distinguish between fertilizer intensity (measured as kilograms of phosphate and nitrogen used per hectare), an interaction term of fertilizer intensity and tractor intensity and an interaction term that combines both fertilizer and tractor intensity with the average years of schooling, in order to incorporate the broader impact of human capital. Besides these specific variables for the conditions in the agricultural sector, the authors control for other variables that arguably influence the growth in GDP, such as institutional quality, state antiquity (indicating the long-term history of the type of state that existed, e.g. tribal level or

higher), a variable for average investment as well as different dummy-variables for different regions (Asia, Latin-America and Sub-Saharan Africa).

Their results show a positive relation between the different indicators for agricultural modernization and economic growth. Yet the effect of these variables in some cases is only very modest, although in all models it is positive and significant. Based on the estimates of the different equations, Self and Grabowski conclude that the modernization of the agricultural sector is important for determining overall economic growth. Beyond, the indicators for agricultural modernization are robust with respect to the inclusion of different other variables in the model.

Gollin et al. (2002) analyzed data for 62 developing countries over the time-span between 1960 and 1990. They conclude that increases in agricultural productivity were an important explanation for the growth in GDP per capita. According to the results of panel data analysis, 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. Both the studies of Gollin et al (2002) and Self and Grabowski (2007) however do not conclude anything with respect to the causality and the direction of this relation.

Gardner (2003) does take the issue of causality into account. In line with the results of Self and Grabowski (2007) he finds a significant positive relation between the growth in the value added per worker in the agricultural sector and national GDP per capita. This relation is investigated for 52 developing countries in the period between 1980 and 2001. The investigation of lags with respect to the 52 countries of the sample however does not point out that the indicator for agricultural output is the leading variable in the relation. Gardner therefore questions the conventional wisdom that increases in agricultural output must precede any process of further economic growth. When looking at data between 1960 and 2001, Gardner states that the value added in the agricultural sector grew at a faster rate in the second half of the time period (after 1980) compared to the first half (before 1980). This even suggests that increases in national GDP per capita preceded the increases in agricultural value added.

In contrast with the findings of Gardner (2003), Tiffin and Irz (2006) do identify the agricultural sector as the engine of further economic growth. They analyzed panel data for 85 developed and developing countries and applied Granger causality tests in order to investigate the direction of causality. Through the use of Granger causality tests, the authors aim to find out whether lagged values of the indicator for economic growth help to predict the current value of the variable for agricultural value added, or whether this is the other way around. After establishing the co-integration of their series, the authors conclude that five countries in their dataset exhibit a 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.

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A different, less econometric-centered approach is used by Tsakok and Gardner (2007). They conduct an analysis for 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. Based on these four different case-studies, Tsakok and Gardner conclude that countries are able to transform and develop their economies without the requirement of a modernized and developed agricultural sector. However, their main concern is that cross-sectional econometric studies are unable to sort out fundamental issues in economic growth. The authors, responding to the contradicting and sometimes inconclusive results of econometric analysis, state that "*economists will simply have to face the fact that econometric studies of country data will not be able to establish causality*" (Tsakok and Gardner, 2007, p. 1146).

2.7 The Context of Africa: Agricultural and Economic Development

Due to the sheer size of the agricultural sector in developing economies, most of the aforementioned empirical research focuses on developing countries in order to empirically assess the relation between growth in agricultural output and economic development. Some research also specifically focuses on the role of the agricultural sector for economic development in African countries (e.g. Diao et al., 2010; Wiggins, 2014). The recent growth of many African economies makes the specific focus on the African continent even more relevant. Roxburgh et al. (2008) state that between 2000 and 2008 African economies grew at an average rate of 4.9%. This even more profoundly raises the question on the role of the agricultural sector in this economic development.

After the success of the Green Revolution in Asia in the 1960's (where the application of agricultural research in combination with public investments in infrastructure and irrigation drastically increased the agricultural yields and formed a starting point for the further economic development), the focus of agricultural development moved to the African continent (Wiggins, 2014). Around that time, most of the African countries regained their independence. Due to the abundance of land and minerals in most African countries, the potential of economic development was highly prevalent in these countries. However agricultural productivity stagnated and could not follow up with population growth, eventually causing the African food production per person to go down in the 1960's and 1970's.

Wiggins (2014) distinguishes three different lines of reasoning in order to explain the stagnation in Africa's agricultural sector: geographical, structural and policy-related explanations. Geographical explanations for the stagnation in the agricultural sector are, among others, infertile soils, the prevalence of diseases for both humans and livestock and the highly fluctuating rainfall in the African continent. E.g. the introduction of new and improved varieties (such as in the Green Revolution) was hampered due to unreliable rainfall that hindered the growth of these crops. Moreover, the majority of African agriculture is rain-fed, in contrast to the agricultural context in Asia during the Green Revolution, which was to a large extent driven by irrigation (Dethier and Effenberger, 2012).

Others however emphasized the colonial past of the African continent as main explanation for its (agricultural) stagnation. According to such Marxian interpretations, the

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structures created by colonialism forced most African smallholder farmers into world markets, where they were confronted with falling output prices and rising production costs, eventually causing the stagnation in Africa's agricultural sector (Wiggins, 2014).

The most influential line of reasoning however puts emphasis on the poor domestic policies on the African continent. As discussed before, the agricultural sector was often heavily taxed in African countries, putting the agricultural sector at disadvantage. Due to the political weight of the growing urban population, the agricultural sector in these African countries was often negatively biased. Empirical research shows that farmers in Cote d'Ivoire, Zambia and Ghana were taxed at a rate of 52 % (Wiggins, 2014).

Through the liberalization of the African agricultural sector that followed in the 1990's the high taxation of the sector was reduced in order to attract investments. Due to the weakly developed financial and insurance services the access to additional seeds, inputs and capital however never occurred. Furthermore, high trading costs hindered the further development of the agricultural sector: not only transportation costs, but also additional storage and credit costs as well as both formal and informal taxes formed a barrier to trade. Empirical research shows that trading costs in the African continent are significantly higher compared to the rest of the world (Wiggins, 2014).

This makes the question on the role of trade in the relation between agricultural and economic development increasingly relevant in light of the current African context. As discussed before, Matsuyama (1992) showed the important role of trade and openness with respect to the role of the agricultural sector in stimulating further economic growth. With respect to these relatively high trading costs, the question arises whether African economies can be considered as open economies and whether that will eventually change the relation between growth in agricultural output and economic growth.

As discussed before, Dercon (2009) furthermore pointed out that the considerable heterogeneity of the African continent causes large differences in whether countries have potential to trade agricultural products or not. Transportation costs are considerably lower for coastal areas compared to the more difficult reachable land-locked areas that depend on the poorly developed infrastructure. It might very well be the case that these high trading costs lower the potential of trade in agricultural products. Beyond, it is important to note that, despite todays globalized context, the size of the global trade in food products should not be overestimated. Aside trade in commodities such as sugar, cacao and fish, the size of the world market for other food products in 2010 is only about 15% of the total global production, meaning the overwhelming majority of the agricultural products are produced and consumed domestically (Oosterveer and Sonnenfeld, 2012). E.g. for wheat, the trade was 18% of the total production, while for other crops as rice and cassava this was respectively only 10% and 7%. Given these numbers and the high transportation costs in most landlocked African countries, the assumption of fully open economies, in which agricultural products can be widely imported and exported, becomes more questionable.

2.8 Conceptual Framework

Based on the literature discussed in the previous subsections, figure 2.2 provides a conceptual framework that will be used as a further guideline for conducting the empirical analysis in this study.
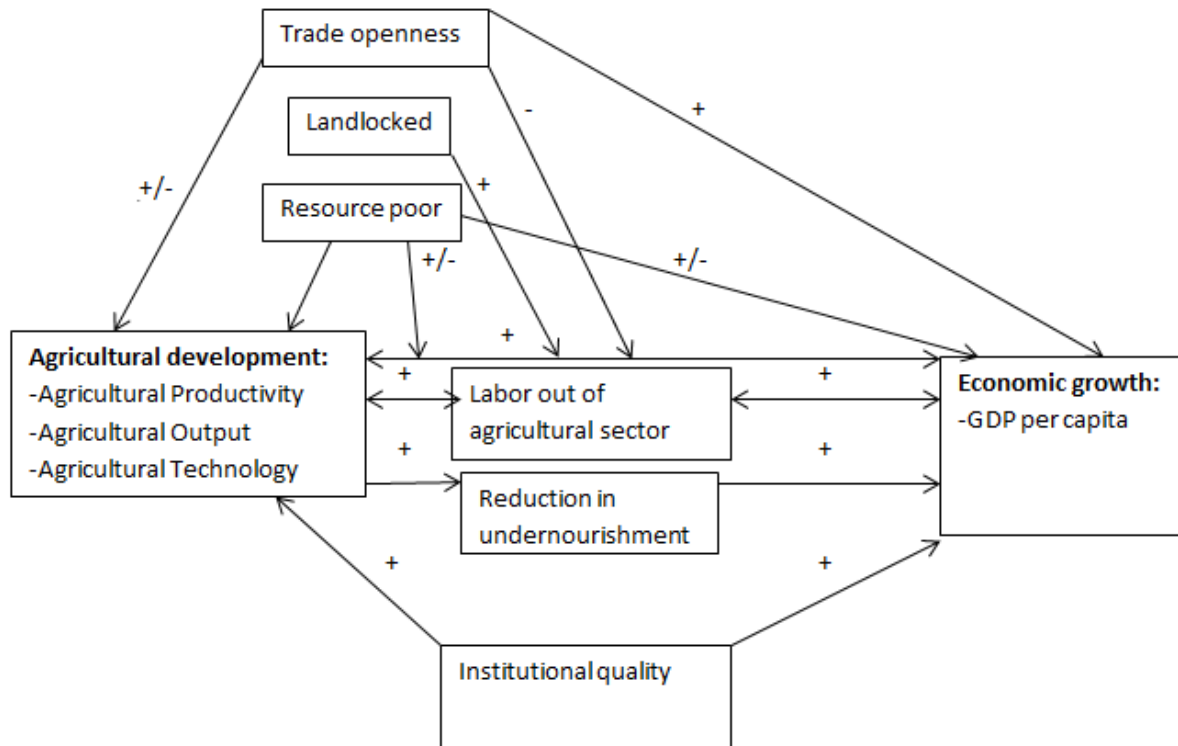
Figure 2.2: Conceptual Framework. Two-sided arrows indicate uncertainty in the direction of causality.

The main relation the framework is concerned with is the relation 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. Growth in total factor productivity measures the degree in which the total output of the agricultural sector is growing faster than the total inputs, indicating a higher productivity of the sector (Fuglie, 2012). Such a growth in total factor productivity however does not by definition imply a higher output, as e.g. value added per worker can also increase due to the reallocation of unproductive labor towards other sectors in the economy, without any subsequent growth in aggregate output. Therefore also an indicator on total output of the agricultural sector is taken into account, which measures the gross agricultural output. Beyond, the use and application of modern technology in the agricultural sector can be seen as an indicator for a modernized agricultural sector (Self and Grabowski, 2007). Direct measures of the application of technology in the agricultural sector are for example the use of fertilizer or tractor intensity.

As can be seen from figure 2.2, the relation between agricultural development and economic growth can run in both ways, indicating the aforementioned uncertainty on the direction of the causality between these factors (e.g. Gollin, 2010; Gardner, 2003). Beyond, the scheme stresses some of the underlying mechanisms that play 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 (referring to Schultz' (1953) ideas on the *food problem*). 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 is said to play a pivotal role in this relation (e.g. Federico, 2005; Johston and Mellor, 1961). It is important to note here however that this relation is again 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).

Beyond, there are several factors that intervene in the direct relation between agricultural development and economic growth: the geographical circumstances of a country (in terms of resources and its geographical location) and the wider access to international commodity markets. As indicated by Matsuyama (1992), the potential of trade in agricultural products can weaken 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 their own domestic agricultural sector (Dercon, 2009). This then would increase the importance of a well-developed domestic agricultural sector as pre-condition for further economic growth. Beyond, resource-poor countries face a lower agronomic potential (Dercon, 2009), which increases the importance of trade in order to meet the domestic dietary needs and arguably weaken the importance of the domestic agricultural sector.

Next to the influence of these factors on the relation between agricultural development and economic growth, 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. Harrisson, 1994). The direct influence of trade openness on the development of the agricultural sector however remains more questionable, as Matsuyama (1992) indicated that the potential of trade can lower the importance of the agricultural sector, which in turn could lower the investments in this sector. The influence of the amount of resources in a country on its economic development is also 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 their agricultural output.

Lastly, the institutional quality of a country could act as a spurious variable that both influences the agricultural development as well as the economic growth (Gollin, 2010). This would weaken the importance of the direct relation between agricultural development and economic growth, since the institutional environment acts as an external factor that addresses both the agricultural development and the economic growth.

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3. Data and Empirical Overview

3.1 Introduction

In order to unravel the links between agricultural development and economic growth, extensive data from a total of 52 African countries is collected. A full list of these countries can be found in Appendix 1.1. Data is gathered for the time-span between 1961 and 2010. During this period, most African countries regained their independence. Furthermore, in 1991 Eritrea separated from Ethiopia. Unless noted otherwise, data for Ethiopia represents the sum of both Ethiopia and Eritrea.

For all 52 African countries, several variables are observed for the period between 1961 and 2010 regarding both the economic and agricultural development, as well as the institutional quality and indicators of nutritional quality and the amount of resources available in a country. Section 3.2 gives an overview and description of these data and their original sources. In addition, section 3.3 provides an empirical overview of Africa's economic and agricultural development between 1961 and 2010.

For conducting the further analysis, all countries are furthermore grouped in different sub-samples. The countries are grouped based on their geographical location and on their economic status and additionally different subsamples have been created for landlocked and non-landlocked countries and for resource rich and resource poor countries. In order to group countries together based on their geographical location, the United Nations-geoscheme has been used. This scheme divides the African continent in five geographical locations: Eastern, Northern, Central, Western and Southern Africa. Important to note here is that for this sub-regional classification, Sudan is considered as a part of Northern Africa and Mozambique and Zimbabwe belong to the Eastern African region, despite the fact that they are often considered as a part of the Southern African region (Wiggins, 2014). Appendix 1.2 provides a full overview of this sub-regional classification.

Besides, a distinction is made between countries based on their income-level. In total, four different income classes are distinguished. This is done according to the 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 the definition of the World Bank. The parentheses behind the countries given in Appendix 1.1 indicate the income-class of the country.

Appendix 1.3 in turn shows the landlocked and the coastal countries, whereas Appendix 1.4 indicates which countries are resource poor and resource rich. Resource rich countries are defined as countries where the annual total per capita earnings derived out of natural capital are above $5000.

3.2 Data

3.2.1 Economic Variables

Economic growth is measured by the variable *gdp* that measures the per capita Gross Domestic Product, since dividing the total Gross Domestic Product by the total population

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allows for a comparison between countries of different population size. Data is derived from the Maddison Historical GDP database. 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 US$ in 1990 in the United States.

The openness of the different African economies is measured through various indicators. The variable *foodbvrage* measures the share of food and beverage imports as a percentage of the total economy (measured at PPP). It specifically measures the openness of a country in terms of its agricultural trade. This variable provides the development of the imports in food and beverages both over time and across countries. Data for this variable is derived from the Penn World Table, version 8.0 (Feenstra et al., 2013). Beyond, several variables are used to measure the wider openness of the different African economies. 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 are bigger than the overall production level. This can be the case if the majority of economic activity of a country involves the assembly and export of products made from imported materials. Data for this variable is obtained from Penn World Tables 7.1 (Heston et al., 2012).

3.2.2 Agricultural variables

Several variables will be used in order to measure different concepts of agricultural development: output growth, productivity growth as well as the use and application of agricultural technology. *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. Data is derived from the International Agricultural Productivity database from the USDA (Fuglie, 2012).

Another variable that measures the agricultural output is the food production index. This *foodprod* variable covers all food crops produced in a country that are considered both edible and containing 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 recalculated in such a way that the year 1961 has become the new base year with a value of 100, this has been done in order to enable comparison with other indices.

Furthermore, several indicators of agricultural productivity are taken into account. The variable *avapw* measures the agricultural value added per worker and takes into account the output of the agricultural sector minus the value of all intermediate inputs. Data of this variable are in constant 2005 US$. For this variable, only data after 1980 is available (World Bank Database, 2014d).

Crlyield measures the cereal yield in kilograms per hectare of harvested land. Besides wheat, rice and maize it also includes barley, oats, rye, millet, sorghum, buckwheat and mixed grains. Crops harvested for hay or feed are excluded from this list. Due to the fact that this variable measures the yield in kilograms per hectare, it allows for comparison between the different countries, since its values are unrelated to the size of the total agricultural sector in a country. It is however important to note that it is by no means an indication of the

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productivity of the total agricultural sector, as it only takes into account cereal yield, thereby neglecting other forms of agricultural output. Data for this variable is obtained from the World Bank Database (2014e).

Beyond, Total Factor Productivity (*tfp*) measures the ratio of total agricultural outputs to total inputs. Output here 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 seen as 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 rather 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.

Next to indicators of output and productivity, some variables that measure the level of agricultural technology are taken into account. Besides total agricultural inputs, which are constructed in the same way as the input equation of the aforementioned total factor productivity, machinery and fertilizer use are used as indicators of agricultural technology. All data comes from the USDA Database on International Agricultural Productivity (Fuglie, 2012). Machinery data measures the total stock of farm machinery measured in 40-CV tractor equivalents. This means it forms a weighted sum of all 2-wheel tractors, 4-wheel tractors and combine-harvesters. 2-Wheel tractors have been given a weight of 12 CV, whereas combine-harvesters have a weight of 20CV and 4-wheel tractors a weight of 40CV.

Data on fertilizer use measures the fertilizer consumption in metric tonnes of nitrate-fertilizer equivalents. This means the different fertilizer types (nitrate, P_2O_5, K_2O) are aggregated with weights based on their relative prices. Nitrate therefore has a weight of 1 in this equation, whereas P_2O_5 has a slightly higher weight of 1.3576 and K_2O has a weight of 0.8532.

For both data on fertilizer and machinery, it is however important to note that these are aggregate, national data. This implies that for large countries, with a large agricultural sector in terms of labor or land, this number will, almost by definition, be higher. In order to enable a comparison between countries of unequal size, these numbers will therefore be 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 (varying 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* indicates all 'economically active' adults in the agricultural sector in the different countries. One should however be cautious with interpreting the data of this variable, as it does not distinguish between different kinds of labor. In order to calculate the percentage of the population that is employed in the agricultural sector, *agrlabor* is divided by the total population. Due to a considerable amount of missing values on the indicator for the total working population of African countries, the choice has been made to divide agricultural labor by total population and not by the working population in order to

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estimate the percentage of people working in the agricultural sector. It is important to note that this ratio therefore does not represent the official percentage of the labor population working in the agricultural sector.

3.2.3 Institutional variables

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. The scores on this scale are the average of both the Amnesty International Report and the State Department Report for each country (Political Terror Scale, 2014). Scores for Eritrea are not taken into consideration.

3.2.4 Nutrition and Health variables

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. The data for this variable is obtained from a joint database of the World Bank, WHO and UNICEF (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.[2]

3.2.5 Resource variables

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 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.

Beyond, a wide range of different other variables were considered. However, due to a considerable amount of missing values or due to other measurement problems, these are not taken into account for further analysis.

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

3.3 Empirical Overview: Economic and Agricultural Development in Modern Africa

3.3.1 Introduction

When taking a closer look at the recent development of the agricultural sector in Africa, Wiggins (2014) states that the interest in the sector revived after 2000. Both donors and governments stressed the importance of developing the agricultural sector in order to alleviate poverty and hunger. The question however remains whether such paradigm shifts become visible when looking at data from these African countries. When interpreting these data, however, it is important to take into account that *"African data comes with a health warning"* (Wiggins, 2014, p. 538). Most of this data relies on assessments done by staff of agricultural ministries, and it is very plausible that most data is a modification of the previous data corrected for some weather changes and for the incidence of pests and diseases (Wiggins, 2014). With due consideration of the limitation of these data, this section will present an overview of the Africa's post WW-II agricultural and economic development. In order to be able to address the considerable heterogeneity of the African continent, countries are grouped together in different sub-groups. Section 3.3.2 groups countries based on their income classification, while section 3.3.3 gives an overview of the differences between landlocked and non-landlocked countries. Subsequently, section 3.3.4 groups the African countries together based on their geographical region.

3.3.2 Empirical overview: countries grouped on income classification

Figure 3.1 shows the development of the GDP per capita for the African economies for the period between 1961 and 2008. The blue line is the average for all the low-income countries (based on the UN-classification where low-income countries are defined as countries with a GNI per capita below $1045 in 2013), whereas the red and green line show the pattern for respectively lower middle income (economies with a GNI per capita between $1045 and $4125) and upper middle income countries, which are defined as economies with a GNI per capita between $4125 and $12,746). When grouping the individual countries in larger groups of countries based on their average GNI, the aforementioned heterogeneity remains. With respect to economic growth in the most recent years, the average annual growth between 2000 and 2007 for the lowest income countries was 1.6%, whereas the average annual growth for both lower and upper middle income countries was respectively 2.7 and 2.5%. Note that for individual countries these growth rates may be much higher, as grouping individual countries together levels off the more fluctuating individual growth rates.
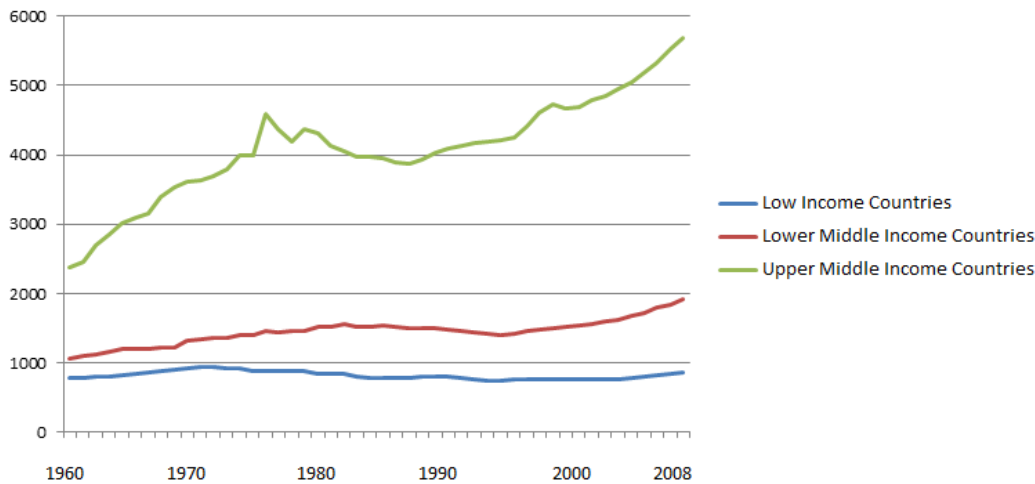
Figure 3.1: GDP per capita between 1960 and 2008 for African countries based on income groups. Left-axis indicates GDP per capita. Based on Madison (2013).

Based on figure 3.1, there is however again no sign of any convergence within the African continent, as the countries that were already among the relative wealthy countries are still among the countries with the highest growth rates.
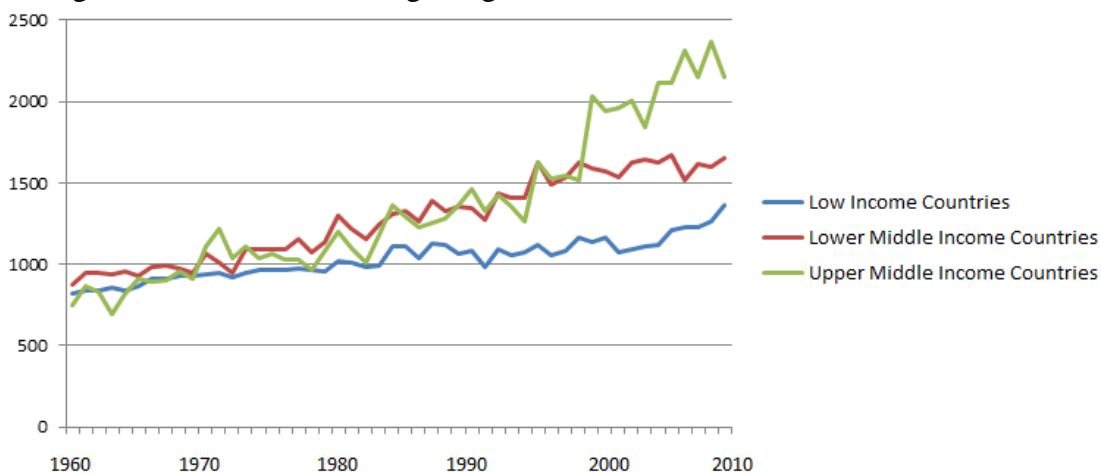

Figure 3.2: Annual cereal yield between 1960 and 2010 for African countries based on income groups. Left-axis indicates cereal yield in kg per hectare. Based on World Bank (2014e)

Figure 3.2 gives an overview of the cereal yield, measured in kilograms per hectare and includes the harvest of wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat and mixed grains. All income groups start with roughly the same value of around 800kg per hectare in 1960. Despite the strong yearly fluctuations, it is clearly visible that the relatively higher income countries have undergone a pattern of faster growth in cereal yield compared to the other African countries. When looking at the most recent decade, the fluctuations in cereal yield however seem to increase and the average growth decreases. In the period between 2000 and 2007, the lowest income countries grew with an annual average of 1.0%, whereas the cereal yield for the lower- and upper middle income countries annually grew with less than 1% in this period.
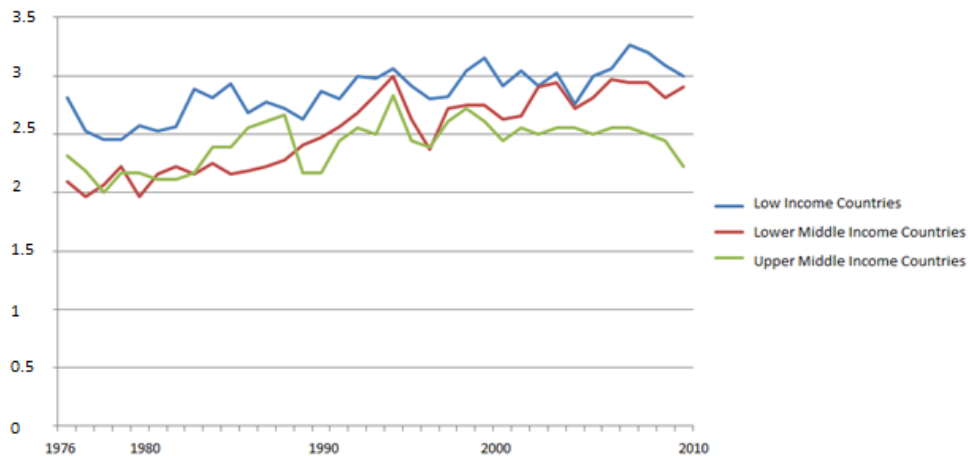
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Figure 3.3: Institutional quality. Left-axis indicates score on the Political Terror Scale from 1 to 5. High values indicate a low institutional quality. Based on PTS (2014).

When considering the institutional quality between different countries based on their income group, the differences are less clearly observable. Upper middle income countries do, on average, score better than their lower income counterparts, yet the differences are rather small. Furthermore, it is interesting to note that the institutional quality in the different African countries, as measured by the Political Terror Scale, in the last ten years has hardly improved. The upper middle income countries do show a sign of improvement in terms of their institutional quality, as the average score for these countries is approaching two, which does not yet mean that countries are under a secure rule of law, but political imprisonment and unlimited detention are becoming rarer. The lower middle and low income countries have hardly increased their institutional quality. For individual countries, this however may be different, as figure 3.3 only shows the average results of the different income groups.
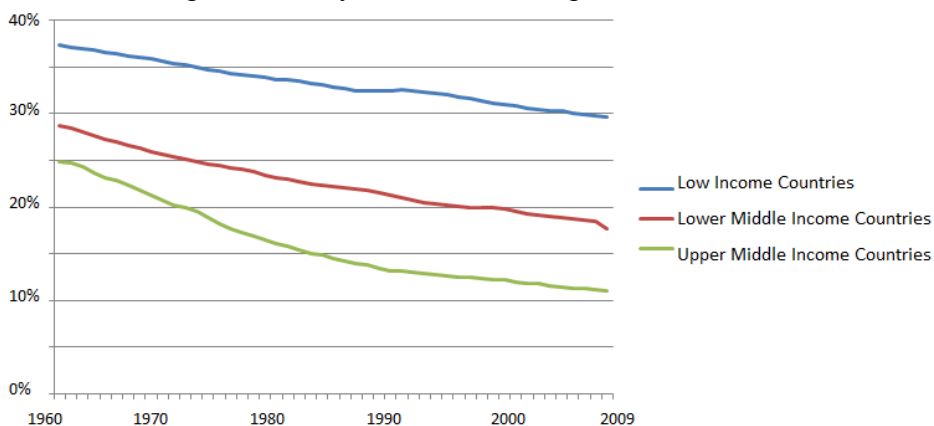

Figure 3.4: Agricultural Labor. Left-axis indicates the share of agricultural labor in the total population. Agricultural Labor is based on Fuglie (2012). Total population is derived from Madison (2013).

Figure 3.4 shows the development in the agricultural labor share for both low, lower middle and upper middle income countries. Note that the lines in the above graph do not represent the percentage of the working population employed in the agricultural sector, as the denominator is the total population and not the working population. However, two separate trends are clearly observable: a) the gradual decline of the population employed in the agricultural sector between 1961 and 2009 and b) the on average lower share of agricultural labor relatively in

the higher income countries. Moreover, the decline in agricultural labor is strongest visible in the relatively wealthy upper middle income countries. In these countries, the share of agricultural labor in the total population decreased with over 50% between 1961 and 2009.

The falling shares of agricultural labor as shown in figure 3.4, however, are not only the result of declining labor in the agricultural sector (a lower numerator), but also due to strong growing population numbers in most African countries (viz. a higher denominator). Nevertheless, the declining trend of agricultural labor is clearly visible over time, which is in line with the findings of, among others, Anderson (1987). As mentioned before in section 2.3.3, the demand for food rises on a lower level compared to the demand for other goods and services and due to the development of new farm technologies, the agricultural sector becomes less labor-intensive in more developed economies, hence the falling shares of agricultural labor in these economies.

3.3.3 Empirical overview: landlocked vs non-landlocked countries

Figure 3.5 shows the difference in trade between landlocked and non-landlocked countries. The red line shows the share of food and beverage imports in GDP for all the non-landlocked countries, whereas the blue line indicates this for all the landlocked countries. On average, the non-landlocked countries traded more than their landlocked counterparts, indicating a more open economy of non-landlocked countries. Landlocked countries are cut off from a direct access to seaborne trade, which - especially when considering trade in food and agricultural products - is responsible for a considerable amount of trade, since products as wheat, rice and maize are often transported in bulk-cargoes by ship. This makes transportation for landlocked countries more expensive and unattractive, hence their – on average – lower trade numbers. This implies that the potential for trade in agricultural products will be lower for landlocked countries.

Remarkable in figure 3.5 however is the peak in the line for non-landlocked countries just after 1990. This is due to an extreme increase in the share of food and beverage imports in Equatorial Guinea during the early 1990's with a peak of 1.9 in 1991, which implies that the food and beverage imports in this period for Equatorial Guinea were almost twice as large as the total size of the countries' economy. This severely affects the average value shown in the above graph, as countries – regardless of their economic size – have an equal weight in this. Again, it should be taken into account that African data comes with the aforementioned 'health warning', as no clear explanations for such an enormous increase are at hand.
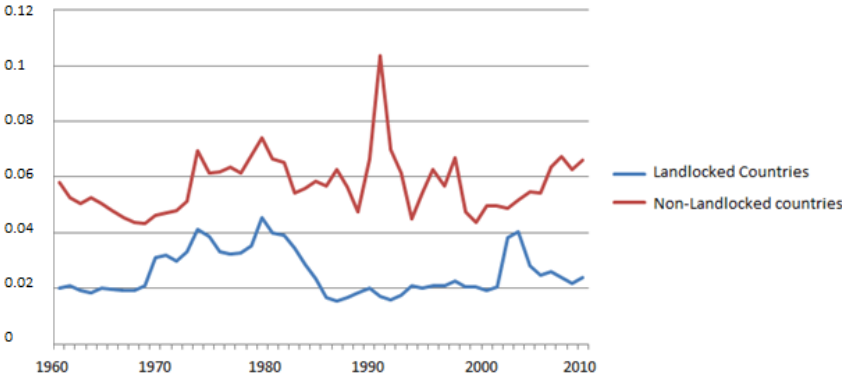

Figure 3.5: Share of food and beverage imports. Left-axis indicates percentage of food and beverage imports in GDP. Based on Feenstra et al.(2013).

3.3.4 Empirical overview: Africa's different regions

As shown in sections 3.2.2 and 3.2.3, clear differences arise between landlocked and non-landlocked countries and between various countries based on income-levels. The different patterns in development also become visible when considering the different geographical regions in the African continent. Figure 3.6 shows the development in the agricultural total factor productivity for five African regions: Eastern, Middle, Northern, Southern and Western Africa. In the period between 1961 and 2010 the Northern African countries have increased their agricultural total factor productivity with more than three times, whereas the Eastern, Central and Western African states (on average) increased their total factor productivity in the agricultural sector with less than a quarter compared to the level of 1961. In line with the analysis of Wiggins (2014) especially the period between the 1960's and the 1980's can be considered as a lost decade in terms of agricultural productivity. For the Central African countries, the total factor productivity of agriculture even decreased with over 20% between 1961 and 1980. More recently, the productivity in the agricultural sector seems to have risen again, although there seems to be no clear sign of any convergence in terms of agricultural productivity. The average annual growth rates between 2000 and 2007 were highest for the already relatively productive Northern African countries, with an annual growth rate of 4.5%. In the same period, the other African regions had an average annual growth rate between 0 and 2%, indicating a growing gap in terms of agricultural productivity between the Northern African countries and the rest of the continent.
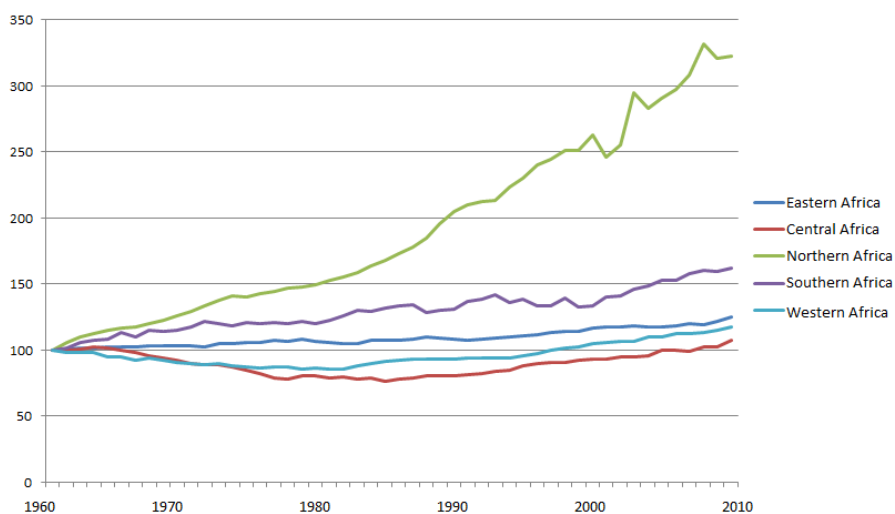

Figure 3.6: Total Factor Productivity in the agricultural sector for African countries based on UN-region classification. Left-axis indicates the TFP-index, 1961 functions as a base year (value=100). Based on Fuglie (2012).

Figure 3.7 in turn shows the use of fertilizer input in the African agricultural sector for every specific African region. The left-axis shows the weighted sum of all NPK-fertilizers, divided by the total amount of agricultural land available in a country measured in rainfed cropland equivalents. Western and Central Africa again seem to be lagging behind in terms of their development in agricultural technology and input use. The average country in these regions was already behind in the early 1960's, yet their relative position has only grown worse

during the rest of the 20th century. The agricultural sector in Western and Central African countries is to a large extent still dependent on low input farming systems and rainfed agriculture. These farming systems are extremely prone to changing weather conditions (e.g. drought) and tropical diseases (Abdulai et al., 2005). The low fertilizer and input use in these countries are among the main reasons for the large yield gaps, implying that agricultural output has the potential to increase if fertilizers were more widely available and accessible for farmers in Central and Western African countries (Nin-Pratt et al., 2011).

The use of NPK-fertilizers in the agricultural sector of most African countries in the other regions of the continent however did increase in this period. In line with the results of figure 3.6 on factor productivity, again the Northern African countries have undergone the fastest growth pattern in the recent period.
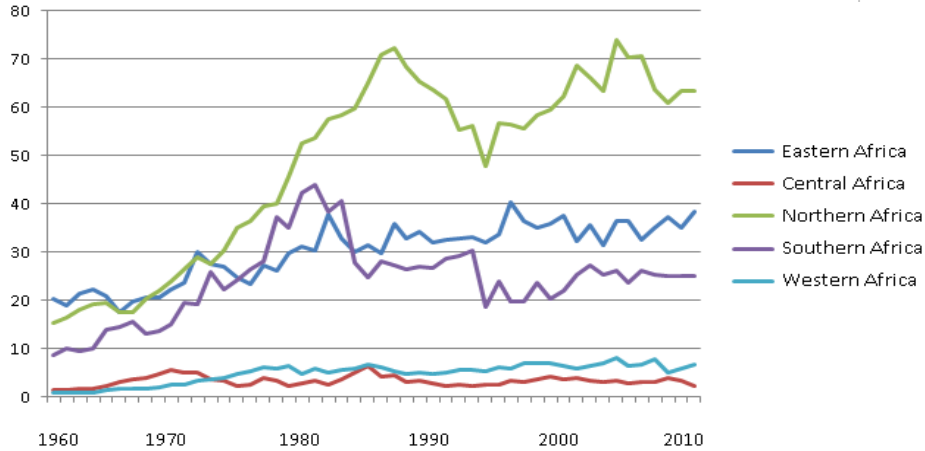

Figure 3.7: Fertilizer use in the agricultural sector for African countries based on UN-region classification. Left-axis indicates the weighted sum of NPK-fertilizers. Based on Fuglie (2012).

Figure 3.8 shows the economic development of African countries grouped in the UN-region classification, measured in GDP per capita. Especially in the period after 2000, all different regions were growing in terms of their GDP per capita. Mainly central African countries grew rapidly in this period, with an average annual growth of 7.4% between 2000 and 2007. Important to note however, is that according to the UN-region classification, Sudan belongs to Northern Africa. This slightly levels off the growth of the other Northern African countries in figure 3.8.

Despite the growth of these African countries in the period after 2000, it should be kept in mind that the economic performance of most African countries is still lagging behind in a global context. According to Bloom and Sachs (1998), at the end of the 20th century, of the world's poorest twenty countries, fifteen were located in Africa. In terms of the UN's Human Development Index (that, beyond per capita GDP also takes into account the life expectancy and literacy), most of the lowest ranked countries are African countries. Despite the recent economic growth in the early 21st century, the majority of African countries are still at the bottom of this list: of the 40 lowest ranked countries, only 6 were non-African (Human Development Report, 2014).
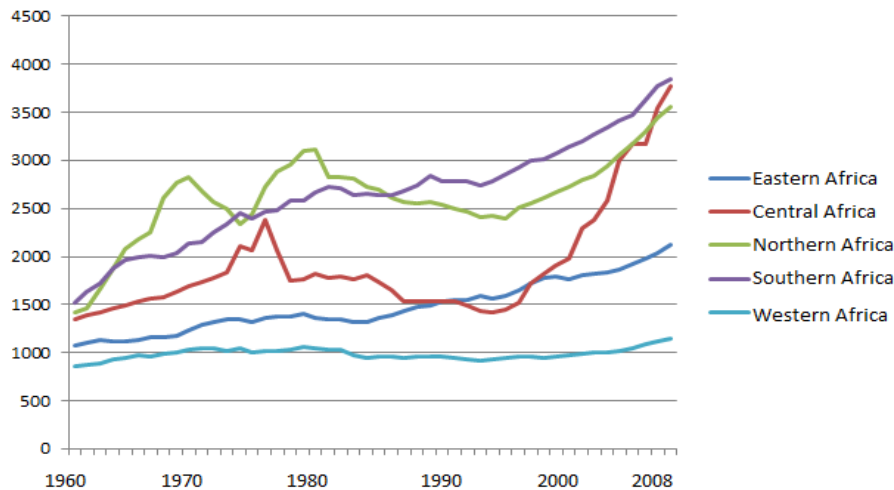
Figure 3.8: GDP per capita for African countries based on UN-region classification. Left-axis indicates GDP per capita. Based on Madison (2013).

Despite the fact that the relative situation of the most underdeveloped African countries has not increased in the 20th and early 21st century, there does seem to be an increase in the absolute living circumstances in these countries when considering, e.g., the mortality-rate of newborn babies. Figure 3.9 shows the amount of newborn-babies that will die before reaching the age of five (per 1000 newborn-babies). In 1960, roughly 3 out of every 10 children that were born in Western African countries died before they reached the age of five. As can be seen in the figure below, this number steadily decreased throughout the years for almost all African regions. In 2010, only in very few countries this mortality-rate was above 100.
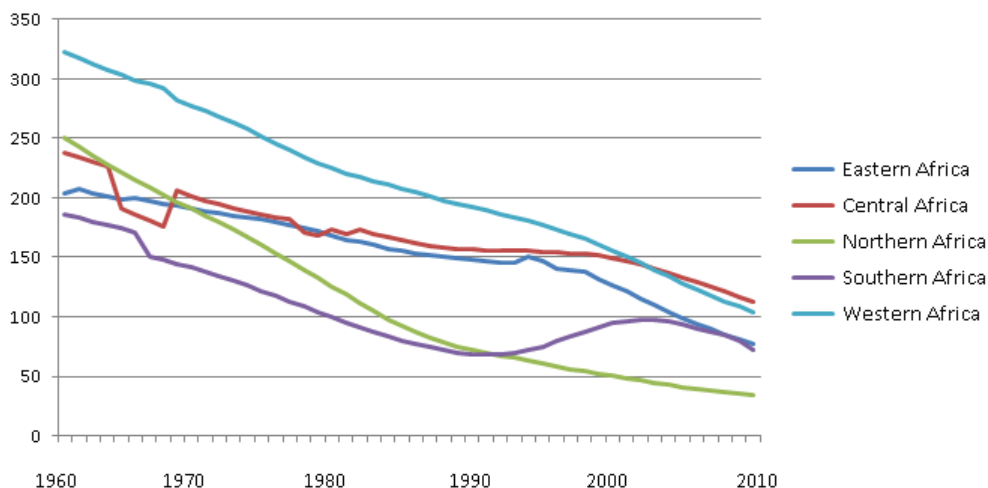
Figure 3.9. Under-5 mortality-rate for African countries based on UN-region classification. Left-axis indicates the number of children (per 1000) who died before they reached the age of five. Based on World Bank (2014g).

3.3.5 Empirical Overview: Africa's Economic and Agricultural Development
When taking into account the empirical data presented in section 3.2.2, 3.2.3 and 3.2.4, the difference between the various African countries becomes strikingly visible. Both in terms of agricultural and economic development, the Northern African countries seem to be among the African countries that underwent the fastest growth rates. When taking into account that, according to the UN-region classification, Sudan (a relatively weak-performing country in

terms of agricultural development) is also considered as part of this Northern African region, the distinct position of the other Northern African countries (Morocco, Tunisia, Egypt, Libya and Algeria) only will become more apparent.

In order to characterize the development of Africa's agricultural sector in the post-colonial period, Wiggins (2014) distinguishes three separate phases. The first period distinguished is the so-called lost decade of the 1970's, just after most African countries regained their independence, in which infertile soils and a high prevalence of diseases (for both human and livestock) hampered the development of the agricultural sector. Secondly, the general neglect of the sector in the 1990's. The liberalization of markets led to lower interest and investments of both governments and other donors in the agricultural sector. The last phase Wiggins distinguishes concerns the period after 2000, in which the agricultural sector was again perceived as a vital and crucial sector for alleviating poverty and hunger.

When looking at the empirical data on agricultural development for Sub-Saharan African countries (hereby neglecting the Northern African countries for a moment), we can, to a certain extent, indeed distinguish separate phases based on the above presented figures. When considering the total factor productivity in the sector, as presented on Figure 3.6, the productivity for most Western, Eastern and Central African countries indeed seems to stagnate, or even decline, until the 1990's and seems to increase slightly in the period after 2000, which is in line with the different phases discerned by Wiggins (2014). The average cereal yield (measured in kilograms per hectare) also increases after 2000; however the average annual growth rates are mostly moderate.

Furthermore, the low input-use in especially Central and Western Africa causes a high dependency on rainfed agriculture and low input farming systems. Beyond, there seems to be little indication of progress in terms of fertilizer use or the application of other inputs in these countries after 2000. When considering the performance of African agriculture in an international context, it furthermore should be kept in mind that Sub-Saharan African countries have much lower agricultural output and productivity rates compared to other regions in the world. Especially in combination with a rapid growth in population in most African countries, the relatively low growth in agricultural output is worrisome (Alston and Pardey, 2014).

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. Initially, econometric techniques and theory for panel data were mostly developed for and applied to situations where the number of observations over time (T) was relatively small. However, due to a growing availability of datasets that covered a longer time-span for different sets of regions or countries, the use of panel time-series techniques became increasingly relevant in recent decades (Smith, 2001). Due to the larger time-span (T) in panel data, concerns have been raised on issues such as non-stationarity, spurious regressions and co-integration, which are issues normally dealt with within the realm of conventional time-series, which lack any cross-sectional dimensions. Panel time-series, also referred to as 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 investigate 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 order to conduct the further non-stationary panel analysis properly, several steps need to be conducted:

1) Specify the preferred model based on the conceptual framework presented in section 2.8. This model specification is shown in section 4.2. A summary of the main variables is given in section 4.3.

2) As different indicators for agricultural development are used in the specified equations, it is necessary to check for possible multicollinearity among these variables. These tests are shown in section 4.4.

3) Determine the order of integration of all separate variables included in the models specified in section 4.2. With the help of panel unit root tests, the order of integration of the variables can be determined. The different panel unit root tests and their results are presented in section 4.5.

4) The next step is to find out whether all variables with the same order of integration also form a co-integrating relation. In this case, the non-stationary variables combined have a residual term which is stationary. This can be tested through panel co-integration tests. Results for these tests are shown in section 4.6

5) With the results of the panel unit root and panel co-integration tests in mind, our preferred model specifications might need to be adjusted in order to remove all variables that are not integrated to the same order. Therefore, adjusted equations will be presented. These adjusted equations in turn can be estimated with the use of PDOLS and FMOLS techniques in order to determine the long-run relation between the independent and the different dependent variables. Section 4.7 gives a short overview of the estimation techniques, and additionally Appendix 1.7

provides a further background on the intuition behind these techniques. The results of the different estimations can be found in chapter 5.

6) Lastly, in order to be able to address issues concerning the short-run causality between the indicators for agricultural and economic development, several panel causality tests are performed. The equations for these tests are presented in section 4.8 and chapter 5 provides the final results of these estimations.

4.2 Model specification

Based on the conceptual framework shown in figure 2.2 in section 2.3.8, the following equations are formulated in order to identify the links between agricultural and economic development:

$$\Delta LogGDP_{it} = \alpha_{1i} + \beta_{11}\Delta LogGDP_{it-1} + \beta_{12}\Delta AgrProd_{it-1} + \beta_{13}\Delta AgrOutput_{it-1}$$
$$+ \beta_{14}\Delta AgrMach_{it-1} + \beta_{15}\Delta AgrLabor_{it-1} + \beta_{16}\Delta InstQual_{it} + \beta_{17}\Delta Openness_{it} + \varepsilon_{1it} \qquad (4.1)$$

$$\Delta Agrprod_{it} = \alpha_{2i} + \beta_{21}\Delta LogGDP_{it-1} + \beta_{22}\Delta AgrLabor_{it-1} + \beta_{23}\Delta InstQual_{it}$$
$$+ \beta_{24}\Delta NatResource_{it} + \beta_{25}\Delta FoodImports_{it} + \varepsilon_{2it} \qquad (4.2)$$

$$\Delta AgrOutput_{it} = \alpha_{3i} + \beta_{31}\Delta LogGDP_{it-1} + \beta_{32}\Delta AgrLabor_{it-1} + \beta_{33}\Delta InstQual_{it}$$
$$+ \beta_{34}\Delta NatResource_{it} + \beta_{35}\Delta FoodImports_{it} + \varepsilon_{3it} \qquad (4.3)$$

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.

Equation 4.1 expresses the changes in GDP a function of the changes in agricultural productivity, output and technology in the previous period. Furthermore, a lagged version of agricultural labor is taken into account in order to test whether the push of labor out of the agricultural sector contributes to economic growth. In line with the conceptual framework in figure 2.2 furthermore several additional variables are 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 any outliers in this variable. This is also done for all the subsequent equations.

Equations 4.2 and 4.3 in contrast estimate the influence of changes in GDP on the indicators for agricultural development. Growth of GDP is therefore now used in its lagged form in order to predict changes in agricultural productivity and agricultural output.

Furthermore, indicators for agricultural labor, institutional quality, the amount of natural resources and food imports are taken into account.

Beyond, in order to control for the differing influences of trade, having an abundance of resources and being landlocked, the above equations are estimated separately for different sets of countries. In these equations landlocked countries will be distinguished from non-landlocked countries and resource abundant countries from resource scarce countries. Furthermore, separate equations are estimated for different country groups depending on their gross national income, as was done in the empirical overview in section 3.2. This chapter first provides an overview of the data used in estimation and continues with a description of the issues involved with panel-time series: panel unit root and panel co-integration testing.

4.3 Data summary

The table below gives a rough overview of the main variables included in equations 4.1, 4.2 and 4.3[3]. Per variable, the first row presents the observations for the total period (1961-2010); the second row the observations in the first twenty years (1961-1980) and the third row for the period after 1981. Clearly, some variables have a relatively high number of missing values: most data for institutional quality (*pts*-variable) is only available after 1980 and the *malnutrition*-variable has a high amount of missing values throughout the whole time period. Note that for conducting the final analysis, all variables are rescaled in such a way that all values are in a range between 1 and 10. This is being done in order to obtain coefficients in the same range.

Table 4.1: Summary Statistics of Main Variables.

Variable	Obs	n	T	Mean	SD	Min	Max
GDP							
1961-2010	2496	52	48	1644.18	1755.35	206.54	22048.51
1961-1980	1040	52	20	1472.93	1338.17	340.75	12339.93
1981-2010	1456	52	28	1766.50	1992.28	206.54	22048.51
Openness							
1961-2010	2512	52	48.31	65.59	37.24	1.86	263.88
1961-1980	957	51	18.77	60.55	33.40	10.97	176.90
1981-2010	1555	52	29.90	68.70	39.10	1.86	263.88
Total Factor Productivity							
1961-2010	2600	52	50	112.84	59.86	45	802
1961-1980	1040	52	20	101.16	23.69	52	305
1981-2010	1560	52	30	120.63	73.80	45	802
Food Production Index							
1961-2010	2586	52	49.73	195.84	119.01	45	1054
1961-1980	1038	52	19.96	128.90	35.51	45	388
1981-2010	1548	52	29.77	240.72	133.41	51	1054
Cereal Yield							
1961-2010	2480	50	50	1159.75	942.15	63.20	9453.70
1961-1980	980	49	20	956.65	589.37	63.20	4094.50
1981-2010	1500	50	30	1292.44	1093.86	110.10	9453.70
Total Input Index							
1961-2010	2600	52	50	170.85	67.02	75.12	567.36

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[3] See section 3.1 for a broader definition of these variables and their original data-sources.

1961-1980	1040	52	20	127.46	42.88	75.12	236.72
1981-2010	1560	52	30	199.78	70.57	90.13	567.36
Machinery							
1961-2010	2600	52	50	2.31	3.59	0.01	25.21
1961-1980	1040	52	20	1.63	2.45	0.01	17.03
1981-2010	1560	52	30	2.77	4.13	0.01	25.21
Political Terror Scale							
1961-2010	1788	52	34.38	2.72	1.02	1	5
1961-1980	238	52	4.58	2.33	0.90	1	5
1981-2010	1550	52	28.80	2.77	1.02	1	5
Natural Capital*							
1961-2010	50	50	1	5161.91	6355.67	836.59	39659.19
% Agricultural Labor							
1961-2010	2548	52	49	27.43	11.11	1.17	54.37
1961-1980	1040	52	20	30.26	10.03	5.49	48.49
1981-2010	1508	52	29	25.47	11.39	1.17	54.37
<5-Mortality Rate							
1961-2010	2434	52	46.81	162.24	80.58	14.20	484.50
1961-1980	876	50	17.52	213.64	79.05	30.50	484.50
1981-2010	1558	52	29.96	133.34	65.67	14.20	335.70
Malnutrition							
1961-2010	230	52	4.42	20.27	9.32	3.30	45
1961-1980	8	7	1.14	19.66	4.29	13.90	25
1981-2010	222	52	4.27	20.29	9.45	3.30	45

Note that Natural Capital is a time-invariant variable.

4.4 Multicollinearity

Table 4.2 gives an overview of the correlation between the main variables that will be used in the estimation equations. As can be seen, none of the selected variables shows an extreme correlation with any other variable (none of the correlation coefficients is above 0.7).

Table 4.2: Correlation Table of Main Variables.

Variable	Log GDP	TFP	Food Prod	Mach inery	Agr Labor	PTS	Open- ness	Nat capital	Mor- tality	Cereal yield
Log GDP	1.00									
TFP	0.41	1.00								
Food Production	0.06	0.60	1.00							
Agr Machinery	0.56	0.59	0.16	1.00						
Prct Agr Labor	-0.68	-0.49	-0.18	-0.48	1.00					
PTS	-0.27	0.03	0.17	-0.03	0.12	1.00				
Openness	0.42	0.12	-0.08	0.36	-0.40	-0.25	1.00			
Natural Capital	0.50	0.02	-0.01	0.31	-0.26	-0.06	0.29	1.00		
Mortalityrate	-0.64	-0.47	-0.25	-0.45	0.60	0.12	-0.25	-0.24	1.00	
Cereal Yield	0.38	0.37	0.23	0.47	-0.29	-0.02	0.02	0.12	-0.31	1.00
Food Beverage Imports	-0.09	0.10	0.21	0.04	0.07	0.32	-0.29	0.04	0.06	0.14

However, as it is plausible that the different indicators for agricultural development (Total Factor Productivity, the Food Production Index and Agricultural Machinery) show a strong correlation with each other, and since these variables are used together, e.g. in equation 4.1 in

order to estimate the influence of changes in agricultural development on economic growth, this could cause multicollinearity problems.

For checking multicollinearity in panel data, no specific tests are available. However as multicollinearity only concerns the mutual relation of independent variables, it is not necessary to control for individual effects attributed to the use of panel data. The table below therefore provides an overview of the VIF (Variance Inflation Factor) scores for the variables *foodprod, machinery* and *TFP*. A high VIF-value would imply that the explanatory variables have a high mutual correlation that in turn enlarges the standard errors in the final estimation. It furthermore complicates interpreting the final results, as it becomes difficult to separate the (predictive) effects of the different explanatory variables (Ott and Longnecker, 2010).

Table 4.3: Multi-collinearity tests between different indicators of agricultural development.

Variable	VIF	Tolerance (1/VIF)
Food Production Index	2.21	0.45
Agricultural Machinery	1.65	0.60
Total Factor Productivity	1.45	0.69
Mean VIF	**1.77**	

When considering the VIF-scores, it can be seen that the values for all variables are below 2.5. These values are therefore still below the often mentioned threshold level of 10 (e.g. Ott and Longnecker, 2010). This implies we can assume that the data are not affected by multicollinearity. Beyond, the observations vary both over time and over countries, therefore reducing the likelihood of any problems related to multicollinearity.

4.5 Panel Unit Root Testing

Time-series data are often non-stationary, implying that the data in its original form may have stochastic trends in common (Verbeek, 2012). Especially when considering multivariate time-series, this can lead to severe additional problems: two different (non-stationary) variables might show a high correlation with each other, yet in non-stationary cases this correlation is often due to an omitted (time) effect that influences these variables. Eventually, this could imply that two non-stationary variables are only 'related' due to the fact that they have the same trend, yet the real relation between the variables remains unidentified. In the case of the relation between economic growth and agricultural development, such a spurious relation might very well be existent, since the empirical overview in section 3.2 showed that both the indicators for economic growth as well as the indicators for agricultural development to a certain extent seem to grow over time. Obtaining stationarity is therefore crucial in order to study the patterns between economic growth and agricultural development.

A variable is said to be stationary if its mean, variance and covariance are no longer a function of time. Often, stationarity can be obtained after differencing the original variable[4]:

$$\Delta y_{it} = y_{it} - y_{it-1}$$

We therefore test for the presence of a unit root in both the original form of the variable (y_t), as well as in its differenced form (Δy_t). Next to the tests for conventional unit root testing (see

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[4] See Appendix 1.5 for an example of differenced and non-differenced time-series with the GDP of Algeria.

e.g. Verbeek, 2012), some specific tests have been developed for panel unit root testing. Panel unit root tests have higher power than a normal ADF (Augmented Dickey Fuller) test, due to the increase in sample size as a result of pooling the observations of various cross-sections. In this section, both the LLC-test (Levin-Lin-Chu) and the IPS-test (Im-Pesaran-Shin) will be applied to the main variables included in the model (Levin & Lin, 1992; Im et al., 2003). Both the IPS and the LLC-unit root tests are widely used in other contemporary research that makes use of non-stationary panels (see 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 these tests are rejected at least some of the panels are stationary, but not by definition all panels (Baltagi, 2013).

The LLC-test follows the same procedure as the ADF test does for conventional unit root testing[5]. 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 final (pooled) OLS 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 Levin-Lin-Chu 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 (Im-Pesaran-Shin) test is taken into consideration, as this test does allow for heterogeneous coefficients. Beyond, this test allows for unbalanced data (meaning it allows for some missing values on some variables), whereas the Levin-Lin-Chu test requires strongly balanced data. The IPS-test computes an average of

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[5] Verbeek (2012) provides an overview of the steps involved in conventional (non-panel) unit root testing.

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 the following:

H_0: $p = 1$; in the 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. A large portion of the recent empirical work on panel time-series analysis uses the IPS-test (see e.g. Neal, 2013; Bittencourt, 2010) in order to test for the presence of unit roots in panel data. Important to note however 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 4.4 Panel Unit Root Tests

Tests	Levin, Lin & Chiu		Im, Peasaran & Shin	
Variables	*Level*	*Differences*	*Level*	*Differences*
GDP n=52; t=48	3.55	-16.45**	1.15	-25.94**
LOGGDP n=52; t=48	0.23	-16.25**	-1.53	-26.05**
TFP n=52; t=50	1.44	-18.11**	-1.82*	-31.16**
Agricultural Output n=52; t=50	-12.75**	-22.01**	17.15	3.37
Food Production n=52; t=50	+	+	0.21	-32.70**
Machinery n=52; t=50	-3.51**	-18.97**	1.37	-29.70**
Total Inputs n=52, t=50	2.50	-19.82**	5.01	-25.65**
Agr Labor n=52; t=49	-7.27**	-6.09**	2.13	-12.54**
Mortality n=52; t=47	+	+	6.54	5.31
Mortality (T-1) n=52; t=46	+	+	-23.09**	-7.01**
PTS n=52; t=34	+	+	-13.88**	-27.17**
Natcapital	-	-	-	-
Openness n=52; t=48	+	+	-8.39**	-31.84**
Food Imports n=48; t=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.

Table 4.4 provides an overview of the test-statistics of the different tests[6]. For every test, every variable is tested twice: once in its original form (level) and once after the first differences were obtained (differences). 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.

When considering the results of the IPS-test, all variables are stationary after obtaining their first differences, except for *agroutput* and *mortality*. Therefore, instead of using the gross agricultural output as indicator for agricultural output, the Food Production Index variable will be used in further regression analyses as the indicator for agricultural output, as this variable is stationary after obtaining first differences. With respect to the variable that measures the under-5 mortality rate of the different African countries over time, this variable is neither in its original form nor in its differenced form stationary. However when adding a lag to the test regression, it becomes stationary in its level-form.

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)).

These results, however, have strong implications for the further analysis conducted in this chapter. As will be elaborated on in section 4.4 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 4.1, 4.2 and 4.3 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:

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

(4.1 Adjusted)

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

(4.2 Adjusted)

$$\Delta AgrOutput_{it} = \alpha_{3i} + \beta_{31}\Delta LogGDP_{it-1} + \beta_{32}\Delta AgrLabor_{it-1} + \varepsilon_{it}$$

(4.3 Adjusted)

4.6 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 is used. Co-integration tests for individual time-series are said to have low power in the case of relatively small T's, which is often the

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[6] 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.

case for post-war annual data (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. If we consider the following estimation:

$$Y_{it} = \alpha_i + \beta_i X_{it} + \varepsilon_{it}$$

Both the dependent variable (Y) as well as the independent variables (X) should be integrated to the same order I(1). A cointegrated relationship implies that the error term (ε_{it}) is stationary for each i. A cointegrated relationship therefore exists out of multiple non-stationary variables that combined have a stationary residual term (Verbeek, 2012).

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. Pedroni (1999) uses the cointegration equation shown below:

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

As mentioned above, both the dependent variable (X_{it}) and the independent variables (Z_{it}) are assumed to be I(1). The slope coefficients (β_{mi}) can vary for individual countries. The same goes for the individual specific intercept term (α_i). The null hypothesis (which assumed no co-integration) states that $\rho_i = 1$ for every country (i) (Nasreen and Anwar, 2014). Rejecting H_0 therefore implies the presence of a co-integrated relation, which assumes that there is a long-run relation between the I(1)-variables included in the model (Kirchgassner et al., 2013).

In total, the Pedroni test calculates 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.

The results of the panel unit root tests described in section 4.3 however showed that some of the variables included in the model equations are stationary in their original from, while other variables are only stationary after obtaining first differences. Therefore, only the I(1)-variables will be included in the Pedroni test in order to see whether there is co-integration between these I(1)-variables. In the adjusted 4.1 equation, *LogGDP* is used as the dependent variable and *TFP, FoodProd, Machinery* and *AgrLabor* are the other variables taken into account. The table below provides an overview of the different Pedroni test statistics:

Table 4.5: Pedroni panel cointegration test results.

Variables: LogGDP, TFP, FoodProd, Machinery, AgrLabor	Panel	Group
V	0.63	
Rho	0.75	2.44
T	-3.17***	-2.59***
ADF	-2.77***	-3.31***
Number of observations: 2483	Panel Units: 52	Regressors: 4

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

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 dependent and independent I(1)-variables. Both 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. It furthermore implies that the residuals of the above equation are stationary.

In order to gain more insight in the exact underlying cointegrating relations between these variables, the Johansen Cointegration Rank test is applied as well. The results of this test, given in table 4.6, indicate that there is at least 1 (based on the Maximum Eigenvalue test) – and possibly 2 (based on the Trace test) co-integrating vectors.

Table 4.6: Unrestricted Cointegration Rank Test.

Hypothesized no. of CE(s)	Fisher stat (Trace test)	Fisher stat (Max-eigen test)
None	647.0***	437.1***
At most 1	300.6***	182.3***
At most 2	172.8***	113.2
At most 3	114.5	83.5
At most 4	95.7	95.7
Number of observations: 2600	Panel Units: 52	

Dependent Variable: LogGDP. Regressors: TFP, FoodProd, Machinery and AgrLabor.
Note that a trend-term was added in the equation. ***=P<0.01, **=P<0.05, *=P<0.10

The question however remains how this cointegrating vector is actually shaped. The results of the Pedroni and Johansen test imply the presence of co-integration between the aforementioned variables, yet it remains unclear between which variables the co-integration exists. In order to shed more light on these co-integrating relations, several additional Pedroni panel co-integration tests are conducted on subsets of variables. For every variable of the adjusted 4.1 Equation 4.1, namely *LogGDP, TFP*, *FoodProd*, *Machinery* and *Agricultural Labor,* separate tests for each regressor are conducted. The results of these tests, which can be found in Appendix 1.6, indicate that while using *LogGDP* as dependent variable, the variables that are co-integrated in a separate test as well are *Machinery* and *TFP*. The results for a co-integrating relation between *LogGDP* and *FoodProd* and *Agricultural Labor* are less clear.

Beyond the adjusted equation 4.1, the other adjusted equations were also tested on cointegration among the I(1)-variables that are included in the respective equations. Note that for these equations, again only the variables that were found to be integrated of order one in the panel unit root test are included in these panel cointegration tests. For equation 4.2 this means *TFP* acts as the dependent variable and *LogGDP* and *AgrLabor* are the other relevant variables.

Table 4.7: Pedroni panel cointegration test results.

Variables: TFP, LogGDP, AgrLabor	Panel	Group
V	2.38***	
Rho	-1.69*	-0.41
T	-3.31***	-2.54***
ADF	-2.88***	-3.25***
Number of observations: 2496	Panel Units: 52	Regressors: 2

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

The results of Pedroni's panel cointegration test for the adjusted 4.2 equation give roughly the same results as the Pedroni test for equation 4.1, implying that there exists a cointegrating relation between the dependent variable (agricultural total factor productivity) and the independent I(1)-variables. Especially when considering the V, T and ADF tests, the H_0 gets rejected at the 0.01 significance level.

When considering the cointegration test for the adjusted equation 4.3, where *FoodProd* is the dependent variable with *LogGDP* and *AgrLabor* as the other variables, the following results are obtained:

Table 4.8: Pedroni panel cointegration test results.

Variables: FoodProd, LogGDP, AgrLabor	Panel	Group
V	0.14	
Rho	-2.27***	-3.37***
T	-4.37***	-6.24***
ADF	-2.42***	-1.80**
Number of observations: 2483	Panel Units: 52	Regressors: 2

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

Again, there seems to be evidence of the existence of a cointegrating relation between the variables in this equation. All tests, except for the Panel V test, seem to point at the existence of a long-run relation between *FoodProd, LogGDP* and *Agricultural Labor*.

4.7 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 are widely used in other, current empirical research (see 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 Chaing (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 problems (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 of the above mentioned estimation methods will be conducted. The results of these panel co-integration regressions can be found in chapter 5.[7]

4.8 Panel Causality

As discussed extensively in chapter 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 (see section 4.4), 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:

$$\Delta LogGDP_{it} = \alpha_{1i} + \sum\nolimits_{m=1}^{p} \beta_{1im} \Delta LogGDP_{it-m} + \sum\nolimits_{m=1}^{p} \vartheta_{1im} \Delta Agrprod_{it-m}$$
$$+ \sum\nolimits_{m=1}^{p} \kappa_{1im} \Delta AgrOutput_{it-m} + \sum\nolimits_{m=1}^{p} \theta_{1im} \Delta AgrMach_{it-m} + \sum\nolimits_{m=1}^{p} \xi_{1im} \Delta AgrLabor_{it-m} \qquad (4.4)$$
$$+ \psi_1 ECT1_{it-1} + \varepsilon_{1it}$$

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[7] It is beyond the scope of this study to present a full derivation of these estimation techniques; however Appendix 1.7 gives a concise background on the intuition behind both the PDOLS and the FMOLS estimator.

$$\Delta Agrprod_{it} = \alpha_{2i} + \sum_{m=1}^{p} \beta_{2im} \Delta Agrprod_{it-m} + \sum_{m=1}^{p} \vartheta_{2im} \Delta LogGDP_{it-m}$$

$$+ \sum_{m=1}^{p} \kappa_{2im} \Delta AgrLabor_{it-m} + \psi_2 ECT2_{it-1} + \varepsilon_{2it} \qquad (4.5)$$

$$\Delta Agroutput_{it} = \alpha_{3i} + \sum_{m=1}^{p} \beta_{3im} \Delta Agroutput_{it-m} + \sum_{m=1}^{p} \vartheta_{3im} \Delta LogGDP_{it-m}$$

$$+ \sum_{m=1}^{p} \kappa_{3im} \Delta AgrLabor_{it-m} + \psi_3 ECT3_{it-1} + \varepsilon_{3it} \qquad (4.6)$$

The Error-Correction term (ECT) is used in the above equations in order to distinguish the long-run causality between the variables. For equation 4.4, 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 4.5, 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 4.6. 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 4.4, 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 4.4, 4.5 and 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 Introduction

This chapter provides an overview of both the results of the PDOLS and FMOLS estimators as well as the results on the different tests for causality. First, section 5.2 provides the results of the different panel co-integration regressions. As elaborated on in section 3.1, the full sample is for several analyses divided in different sub-samples. For the adjusted long-run co-integrating equation 4.1, first the PDOLS and FMOLS results for the full sample and the different subsamples based on income-class are presented. Afterwards, the PDOLS results for both landlocked and non-landlocked countries as well as the results for resource poor and resource rich countries are shown. Subsequently, the PDOLS and FMOLS results for the adjusted 4.2 and 4.3 equations are discussed. Section 5.3 in turn presents and discusses the results of the Panel Causality tests that were formulated in equations 4.4, 4.5 and 4.6 in order to study how short run changes in the indicators of agricultural development influence the indicator for economic growth and vice versa.

5.2 Panel Co-Integration Regression Results

Table 5.1 first presents the results of the different PDOLS estimations for the above adjusted long-run co-integrating equation 4.1.[8]

Table 5.1: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

Note that a trend term was considered in the co-integration deterministic.
***=P<0.01, **=P<0.05, *=P<0.10. Standard errors between parentheses.

The first row in the above table presents the results for the full sample of 52 African countries over the period 1961-2010. For the whole sample of African countries, the only variable that is significantly related to the Gross Domestic Product is the Food Production Index. A higher food 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 Gross Domestic Product of the African countries.

When grouping countries of the same income class together 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

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

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 on the above 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 chapter 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 further 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. Arguably, a growth generating effect of labor that flows out of agriculture is missing in these countries, implying that a sectoral reallocation of labor from agricultural towards other sectors in the economy is only beneficial for further economic growth if countries are already in a more developed economic situation.

Table 5.2:Fully Modified OLS results for full sample and different income groups

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

Note that a trend term was considered in the co-integration deterministic.

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

Next to the PDOLS estimation, table 5.2 presents the results of the FMOLS regression. Albeit slightly different, these results are to a large extent comparable to the results obtained in table 5.1. 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 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 5.3 in turn shows again the results of the adjusted 4.1 equation, yet now the countries are 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. A method to assess the differences in parameters between these subsets of countries is to see whether the estimated coefficient of the landlocked countries falls within the confidence interval of the non-landlocked countries and vice versa. When applying this method, one sees that for most variables no significant differences between landlocked and non-landlocked countries appear. However, when looking at the coefficient of *Machinery* for non-landlocked countries, it is significantly higher compared to the landlocked countries, since the coefficient of landlocked countries for machinery (-0.139) does not fall within the confidence interval for non-landlocked countries (0.233 – 0.793).

Beyond, the coefficient of *FoodProd* is significantly higher for landlocked countries (0.244) than the confidence interval for non-landlocked countries (0.119 – 0.237). This would imply that food production is more crucial for determining economic growth in landlocked than in non-landlocked countries. This result seems to be somewhat 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, implying that – based upon the results from table 5.3 – real empirical evidence for this different relation seems to be lacking.

Table 5.3:DOLS Panel results for landlocked and non-landlocked countries

Dependent variable: LogGDP	Landlocked countries	Non-landlocked countries
TFP	-0.013	-0.034
	(0.138)	(0.118)
FoodProd	0.244***	0.178***
	(0.080)	(0.059)
Machinery	-0.139	0.513*
	(0.569)	(0.280))
AgrLabor	-0.147	-0.119
	(0.132)	(0.121)
Obs	628	1748
N	14	38

Note that a trend term was considered in the co-integration deterministic.
***=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 – in the conceptual framework in figure 2.2 – also identified as a possible factor that could interfere in this relation. Table 5.4 therefore shows the results of the PDOLS regression for separate 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 derived out of natural capital are above $5000.

Table 5.4:DOLS Panel results for resource rich and resource poor countries

Dependent variable: LogGDP	Resource rich	Resource poor
TFP	-0.100	-0.013
	(0.198)	(0.106)
FoodProd	0.221**	0.189***
	(0.009)	(0.005)
Machinery	0.372**	0.286
	(0.133)	(0.396)
AgrLabor	-0.068	-0.064
	(0.052)	(0.106)
Obs	598	1502
N	13	33

Note that a trend term was considered in the co-integration deterministics
***=P<0.01, **=P<0.05, *=P<0.10. Standard errors between parentheses.

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, the amount of agricultural machinery is 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 however again apply the aforementioned method of assessing the differences in parameters, there is no clear difference visible between resource rich and resource poor countries with respect to agricultural machinery (partly due to the relatively large standard errors). A difference between resource rich and resource poor countries with respect to the *FoodProd*-variable now however appears, as the coefficient for resource rich countries is significantly higher than for their resource poor counterparts.

Table 5.5 shows the results for the adjusted equation 4.2. 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 equation of this co-integrating relation is furthermore estimated because its residuals are used to construct the ECT term in equation 4.5.

Table 5.5:PDOLS and FMOLS results for the adjusted 4.2 equation.

Dependent variable: TFP	PDOLS	FMOLS
LogGDP	0.008**	0.059***
	(0.037)	(0.026)
AgrLabor	0.115**	0.113***
	(0.054)	(0.035)
Obs	2340	2444
N	52	52

Note that a trend term was considered in the co-integration deterministic.
***=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 5.5. *LogGDP* and *TFP* are, although the effect is quite modest in terms of its strength, positively related in the long-run. Remarkable however is the positive effect of *AgrLabor* on *TFP* in both estimators. The result namely implies that the more labor engaged in the agricultural sector, the higher the productivity in the sector is. This result 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.

Table 5.6 in turn shows the results for the adjusted equation 4.3. Here, *FoodProd* is the dependent variable and *LogGDP* and *AgrLabor* are the remaining variables in this co-integrating relation. Again, the residuals of this equation are furthermore used to construct an error-correction term, namely the ECT term in equation 4.6.

The results of the adjusted 4.3 equation however do show that both the amount of labor engaged in the agricultural sector as well as the GDP-level are positively related to the food production level. Combined with the results of the adjusted 4.2 equation shown in table 5.5, there seems to be evidence of a positive relation between the amount of labor employed in the agricultural sector and indicators for agricultural productivity and output. On average,

labor therefore still can be considered as a factor that contributes to the productivity and output of the agricultural sector.

Table 5.6:PDOLS and FMOLS results for the adjusted 4.3 equation.

Dependent variable: FoodProd	PDOLS	FMOLS
LogGDP	0.676***	0.551***
	(0.009)	(0.071)
AgrLabor	0.365***	0.481***
	(0.129)	(0.096)
Obs	2328	2432
N	52	52

Note that a trend term was considered in the co-integration deterministic.
***=P<0.01, **=P<0.05, *=P<0.10. Standard errors between parentheses.

5.3 Panel Causality Results

Table 5.7 provides the results for equations 4.4, 4.5 and 4.6 in order to address the issue of short-run causality between agricultural development and economic growth. This table shows the results for the all the three equations. The first column shows the results for equation 4.4, with *LogGDP* as dependent variable, whereas the second and third column respectively show the results for equation 4.5 (*TFP* as dependent variable) and 4.6 (*FoodProd* as dependent variable).

Table 5.7: Arellano-Bover/Blundell-Bond dynamic panel estimation

Dependent Variable:	LogGDP	TFP	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 version of the 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 (and in the case of *LogGDP* even slightly above 1). This would imply 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.[9]

The further results regarding the causal relation between the indicators for agricultural development and economic growth however 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 on the other hand the previous values of *LogGDP* 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 Error-Correction-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), this term is of significant influence. 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 5.7 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.

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[9] 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 presented in section 4.5.

6. Discussion and Conclusions

6.1 Conclusions

Based upon the results from the previous chapter, the main research question (*How do patterns in economic growth and agricultural development interact with each other in African countries in the period between 1960 and 2010*) and the accompanying sub-questions posed in the first chapter can be answered. One of the sub-questions was to identify the underlying mechanisms between economic and agricultural development. As discussed in the theoretical framework in chapter two, there are severable mechanisms 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 towards other economic sectors. 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.

When considering the sub-question on the role of the sectoral reallocation of labor for enhancing further economic growth, some interesting conclusions can be drawn. Anderson (1987) stated that growing economies can be characterized by a decline in the agricultural sector in terms of both contributions to the GDP as well as contributions in terms of employment. Often, labor productivity in the other sectors of the economy is said to be higher compared to the labor productivity in agriculture, suggesting that reallocating labor towards other sectors is beneficial for economic growth (e.g. Humphries and Knowles, 1998).

The results shown in chapter five provide useful additional insights in how this relation is largely dependent on the wider economic context. For the more developed upper middle income countries, the aforementioned reasoning indeed seems to hold: here, 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 seen, 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 presented in chapter five 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 and the earlier formulated sub questions 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 shown in the empirical overview in section 3.3, 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.

6.2 Critical Reflection

The chosen approach to use panel modelling has some severe limitations: as was visible in the empirical overview in section 3.3, there is a 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.

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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 mentioned before, 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 provided useful insights in the interaction between economic growth and agricultural development. Clearly, agricultural and economic development 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.

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Appendix 1.1: 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 (and 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 (Democratic Republic of Congo) (1)
51. Zambia (2)
52. Zimbabwe (1)

Appendix 1.2: 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 1.3: 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 1.4: 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

Appendix 1.5: Example of stationary and non-stationary time-series: GDP per capita of Algeria

| 1961	1799,434	
1962	1433,057	-366
1963	1767,757	335
1964	1805,88	38
1965	1869,676	64
1966	1725,159	-145
1967	1824,17	99
1968	1977,431	153
1969	2105,494	128
1970	2249,22	144
1971	1999,654	-250
1972	2349,833	350
1973	2356,541	7
1974	2427,528	71
1975	2521,953	94
1976	2608,24	86
1977	2758,687	150
1978	3018,661	260
1979	3192,184	174
1980	3151,825	-40
1981	3131,141	-21
1982	3227,648	97
1983	3288,602	61
1984	3363,257	75
1985	3431,033	68
1986	3301,182	-130
1987	3191,804	-109
1988	3043,111	-149
1989	3066,722	24
1990	2946,865	-120
1991	2843,717	-103
1992	2822,05	-22
1993	2696,597	-125
1994	2613,559	-83
1995	2658,073	45
1996	2709,407	51
1997	2694,065	-15
1998	2788,129	94
1999	2834,707	47
2000	2862,675	28
2001	2894,769	32
2002	2968,433	74
2003	3130,409	162
2004	3250,516	120
2005	3374,002	123
2006	3399,865	26
2007	3459,518	60
2008	3520,378	61
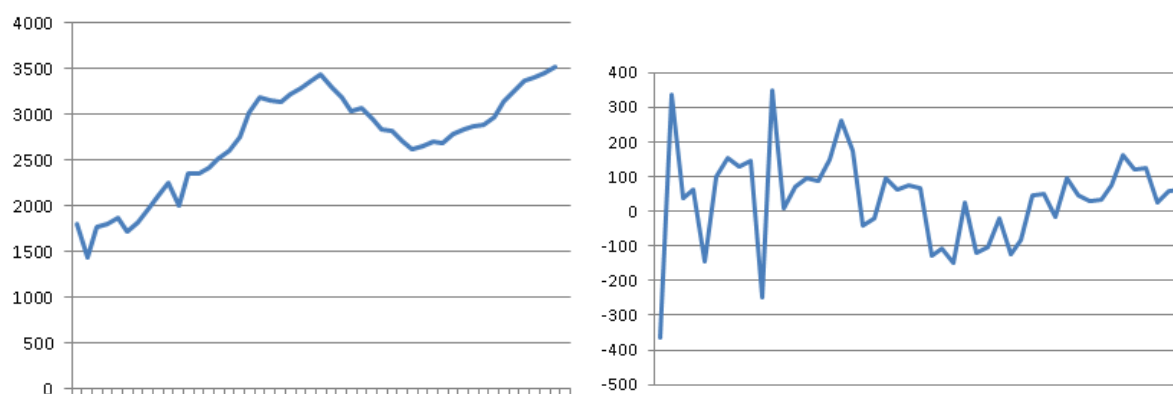
Figure A1: Left panel shows development of GDP of Algeria in levels. Right panel shows development of GDP of Algeria in first-differences.

The left panel in the above figure gives a representation of the development of the GDP in Algeria over time. What can be clearly seen, is that – except for a decrease in the late 1980's and early 1990's – the graph overall shows an increasing trend. This variable therefore is dependent of time, as it increases over time. The right panel in contrast shows the GDP of Algeria in first-differences, meaning it shows the yearly deviations instead of the annual values. The data in the right panel is independent of time. Deviations, both positive and negative, follow each other up and there is no longer a clearly visible trend to be seen (although the yearly fluctuations seem to be larger at the beginning of the sample compared to the latter half of the sample). We can therefore assume that the right panel follows a more stationary pattern, whereas the variable in its original form – as shown on the left panel – still contains a unit root, which can be removed after differencing the variable.

Appendix 1.6: Additional Pedroni tests

The table below provides a short overview of the outcomes of the different Pedroni tests for panel co-integration between different subset of variables. Below the overview table, the separate results for each additional test can be found.

Table A1.4a: Overview table on Pedroni tests for panel co-integration

	LogGDP	TFP	Foodprod	Machinery
TFP	Yes			
FoodProd	No	Yes		
Machinery	Yes	Yes	Yes	
AgrLabor	No	Yes	Inconclusive	No

"Yes" assumes the presence of a co-integrating relation between the two concerning variables.

Table A1.4b: Additional Pedroni panel cointegration test results.

Test	Panel	Group
V	0.23	
Rho	-0.41	-0.99
T	-2.02***	-1.57*
ADF	-1.57*	-2.34***
Number of observations: 2496	Panel Units: 52	Regressors: 1

Variables: LogGDP and TFP. Note that a trend-term was added in the equation.
***=P<0.01 **=P<0.05 *=P<0.10

Table A1.4c: Additional Pedroni panel cointegration test results.

Test	Panel	Group
V	0.47	
Rho	-0.41	-0.236
T	-1.88**	-2.035***
ADF	-0.77	-1.47
Number of observations: 2483	Panel Units: 52	Regressors: 1

Variables: LogGDP and FoodProd. Note that a trend-term was added in the equation.
***=P<0.01 **=P<0.05 *=P<0.10

Table A1.4d: Additional Pedroni panel cointegration test results.

Test	Panel	Group
V	1.88**	
Rho	-1.60*	0.12
T	-2.85***	-2.20***
ADF	-2.63***	-3.50***
Number of observations: 2496	Panel Units: 52	Regressors: 1

Variables: LogGDP and Machinery. Note that a trend-term was added in the equation.
***=P<0.01 **=P<0.05 *=P<0.10

Table A1.4e: Additional Pedroni panel cointegration test results.

Test	Panel	Group
V	0.77	
Rho	-0.09	1.35
T	-1.12	-0.35
ADF	-1.34	-2.29***
Number of observations: 2496	Panel Units: 52	Regressors: 1

Variables: LogGDP and Agricultural Labor. Note that a trend-term was added in the equation.
***=P<0.01 **=P<0.05 *=P<0.10

Table A1.4f: Additional Pedroni panel cointegration test results.

Test	Panel	Group
V	4.33***	
Rho	-6.47***	-6.42***
T	-7.09***	-7.80***
ADF	-4.24***	-5.18***
Number of observations: 2586	Panel Units: 52	Regressors: 1

Variables: TFP and FoodProd. Note that a trend-term was added in the equation.
***=P<0.01 **=P<0.05 *=P<0.10

Table A1.4g: Additional Pedroni panel cointegration test results.

Test	Panel	Group
V	3.68***	
Rho	-3.58***	-1.99***
T	-4.07***	-3.10***
ADF	-4.53***	-4.17***
Number of observations: 2600	Panel Units: 52	Regressors: 1

Variables: TFP and Machinery. Note that a trend-term was added in the equation.
***=P<0.01 **=P<0.05 *=P<0.10

Table A1.4h: Additional Pedroni panel cointegration test results.

Test	Panel	Group
V	2.13***	
Rho	-2.22***	-1.52
T	-2.97***	-2.49***
ADF	-1.98*	-2.72***
Number of observations: 2586	Panel Units: 52	Regressors: 1

Variables: TFP and AgrLabor. Note that a trend-term was added in the equation.
***=P<0.01 **=P<0.05 *=P<0.10

Table A1.4i: Additional Pedroni panel cointegration test results.

Test	Panel	Group
V	3.95***	
Rho	-6.13***	-5.26***
T	-5.40***	-5.39***
ADF	-3.55***	-5.04***
Number of observations: 2586	Panel Units: 52	Regressors: 1

Variables: FoodProd and Machinery. Note that a trend-term was added in the equation.
***=P<0.01 **=P<0.05 *=P<0.10

Table A1.4j: Additional Pedroni panel cointegration test results.

Test	Panel	Group
V	1.06	
Rho	-3.74***	-4.28***
T	-4.35***	-4.90***
ADF	-0.59	-0.55
Number of observations: 2586	Panel Units: 52	Regressors: 1

Variables: FoodProd and AgrLabor. Note that a trend-term was added in the equation.
***=P<0.01 **=P<0.05 *=P<0.10

Table A1.4k: Additional Pedroni panel cointegration test results.

Test	Panel	Group
V	-2.22	
Rho	2.33	3.09
T	1.08	2.10
ADF	1.62	1.45
Number of observations: 2548	Panel Units: 52	Regressors: 1

Variables: AgrLabor and Machinery. Note that a trend-term was added in the equation.
***=P<0.01 **=P<0.05 *=P<0.10

Appendix 1.7: The PDOLS and FMOLS estimation techniques

This appendix provides a short background of the intuition behind the PDOLS and FMOLS estimation techniques. Important to keep in mind is that, based upon the results from the panel co-integration tests, we can assume that the u_{it} processes are stationary, implying the presence of co-integration among the chosen variables (Wagner and Hlouskova, 2006).

Concerns on endogeneity and serial correlation can be addressed with several methods. First, it is important to note that estimating regular time-series data in a standard OLS, this will lead to biased estimators and additional concerns of a spurious regression (Neal, 2013). There are two different ways to deal with these concerns: one is to estimate a 'fully modified OLS' and the other is to conduct a 'panel dynamic' OLS estimation.

The intuition behind the PDOLS test is to correct for any possible correlation between u_{it} and ε_{it} through the inclusion of both leads and lags of ΔX_{it} as extra regressors in the estimated cointegrating regression. This means that for all the explanatory variables, not only current, but also previous and future values of the changes are taken into account and used as additional regressors. In this way, the PDOLS estimator is able to solve for concerns on endogeneity (Wagner and Hlouskova, 2007). Subsequently, information obtained on the co-integrating vectors is in the PDOLS pooled for the different cross-sections. This enables a more precise estimation and a more powerful test when comparing it to conventional, single time-series analysis, due to the higher number of observations gained from the different cross-sections (Carlson et al, 2007). The PDOLS estimator then tests the hypothesis of $H_0 : \beta_i = 1$ for all i against the alternative of $H_A : \beta_i \neq 1$ with the use of t-statistics.

In short, the PDOLS estimator is about removing the correlation between u_{it} (the equilibrium error) and the leads and lags of ΔX_{it} by augmenting the original equation with lags and leads of the first differences (Eberhardt, 2006).

The FMOLS estimator in contrast depends on non-parametric methods in order to solve for the aforementioned concerns of endogeneity and serial correlation, which implies that it doesn't make any assumptions on the probability distributions of the respective variables. In the FMOLS, the dependent variable is corrected by using the long-run covariance matrices in order to remove the nuisance parameters. Subsequently, a standard fixed-effects panel OLS regression is being used for the corrected variables. Afterwards, in order to remove the effects of dynamics and endogeneity, non-parametric methods are applied to the errors of the estimates of the parameters (Neal, 2013).

It is important to note that long-run covariance matrices are used in order to deal with concerns on endogeneity. This namely implies that this estimator is not valid for estimating and interpreting any short-run dynamics. Therefore, in addition to the long-run co-integration estimators presented in section 4.7, section 4.8 will introduce panel Granger causality methods in order to be able to interpret the short-run dynamics between agricultural and economic development.