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Title: Rural Economic Transformation In the Senegal River Delta

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[1] The opinions expressed herein are those of the authors and do not necessarily reflect the views of the U.S. Agency for International Development.

Abstract

Existing low-income economies are based largely on subsistence agriculture, many of which were bypassed by the Industrial and Green Revolutions. Over the past 50 years, attempts modeled on the Green Revolution to catalyze transformation in these countries have met limited success—and global political, economic and social forces have rapidly changed the development context. This begs the question: what does successful structural transformation of an agricultural economy look like today? This paper contributes to answering this question through an empirical case study of what is the beginning of a contemporary rural economic transformation process in the Senegal River Delta. The paper includes and adds to the traditional measures of transformation -- agricultural technology adoption and staple-crop productivity increases—to include measures of institutional change, business development and rural non-farm employment. Three conclusions emerge. First, the Senegal River Delta shows evidence of agricultural transformation from subsistence to commercial farming. Second, the area shows evidence of increasing business activity, employment and population growth in rural towns and small cities. Third, the nature of the transformation cannot be captured adequately with only agricultural technology and productivity indicators.

Text

1. Introduction

Existing low-income economies are based largely on subsistence agriculture, many of which were bypassed by the Industrial and Green Revolutions. Over the past 50 years, attempts modeled on the Green Revolution to catalyze agricultural transformation in the remaining low-income countries have met limited success (Djurfeldt, Holmen, Jirstrom, & Larsson, 2005; Pingali, 2012). Contemporary social, economic and political realities are even more complex than during the Green Revolution, which has led many to suggest a new paradigm of structural transformation (Barrett, Carter, & Timmer, 2010; Byerlee, de Janvry, & Sadoulet, 2009; McMillan, Rodrik, & Verduzco-Gallo, 2014; Reardon & Timmer, 2014; Richards et al., 2016; World Bank, 2007). Though technical progress is a critical component of transformation, it remains a systemic process that includes and is enabled by policy, institutional, and socio-cultural changes. For example, today's rural and urban local economies are much more interlinked via value chains and provide a wider variety of income generating opportunity and labor migration patterns that were previously characterized by uni-directional migration to primary cities (Christiaensen, De Weerdt, & Todo, 2013; Christiaensen & Todo, 2014; Potts, 2012). Yet, even these advances are not fully comprehensive in covering the breadth of today's unfolding transformations. Socio-political processes including the Paris Agreement (COP21), Sustainable Development Goals, and World Health Assembly, among others, both constrain available structural transformation processes and open new opportunities. Global economic phenomena such as deindustrialization may affect the way in which transformation unfolds (Gollin, Jedwab, & Vollrath, 2013; McMillan et al., 2014; Rodrik, 2014). These and other aspects of the modern era beg the question: what does successful structural transformation of an agricultural economy look like today?

On a theoretical level, today's successful agricultural transformation encompasses the traditional concepts of moving labor out of low-return, subsistence agriculture into remunerative manufacturing and other non-agricultural jobs through the commercialization of agriculture, along with non-agricultural growth processes including the structural transformation of the broader economy. The definition of "success" has been somewhat fluid. E.g. while Lewis (1945) focused on job creation to the neglect of unemployment, Lewis (1954) recognized that unemployment compromised success, a concept with even more credence in today's developing capitals with growing slum populations that often do not support the current political powers (Resnick). Proxies for agricultural transformation include staple crop productivity and the share labor employed in agriculture (Timmer, 1988, 1998; Timmer and Akuus 2008); these are often associated with the 'farm problem' of pushing labor out of agriculture (Gardner and Lesser). With Africa's youth explosion, robust 'push' factors will compromise success. Environmental issues did not detract from Brazil's success despite significant clearing in the Amazon basin, nor from China's success despite water availability issues and significant urban pollution. Additionally, the Paris agreement (COP 21), the World Health Targets, and geopolitics indicate that success also includes sustainability, minimization of overnutrition and hypertension, and development that mitigates the emergence of terrorist activity are also characteristics of success. Within today's African context, success is best defined by the African Union's Malabo Declaration. Via commitments, Malabo defined a successful agricultural transformation in terms of both non-quantitative goals such as strengthened policies and institutions, and quantitative targets including ending hunger and halving poverty by 2025; reducing the prevalence of stunting to 10% and underweight to 5%; tripling intra-African agricultural trade; creating jobs for 30% of youth in agricultural value chains; establishing resilience to climate and weather for 30% of farmers, fishers and pastoralists.

The empirical research question is thus whether emerging African agricultural transformation processes are making progress against this broad set of criteria for success. The current paper contributes to answering this question within the context of an apparently emergent transformation in the Senegal River Delta. Because the Senegal River Delta is home to important Government of Senegal (GoS) actions, as well as multiple donor programs, the paper addresses the question of whether the data indicate more rapid transformation in the areas most highly served by GoS relative to areas that are less well served. This says neither that development programming has caused a transformation, nor that transformation is not happening in less-served areas. Rather, the current focus is on documenting what is emerging in both the highly-served and less-served areas. Comparisons across time and space are drawn to provide a more detailed, quantitative understanding of the nature and characteristics of this potentially emerging transformation.

The study area is rural and hence the paper examines only rural aspects of agricultural and structural transformation: urbanization, urban employment and other urban components of structural transformation are neglected, save for how they are linked to food systems.

The next section of the paper provides a conceptual background and develops several testable empirical hypothesis that inform the research question. The third section provides an overview of the study area, followed by a section describing data and methods. Results are presented in the fifth section. The final section draws conclusions.

2. Conceptual development of testable hypotheses

Classical development thought associates increases in national income with the movement of surplus labor out of farming and into urban manufacturing or service sectors, driven by dynamic and innovative urban manufacturing or sometimes the service sector (Fei & Ranis, 1964; Lewis, 1965; Malthus, 1803; Marshall, 1890; J. Mill, 1821; J. S. Mill, 1848; Ricardo, 1891; Rostow, 1959; Smith, 1776). To date, empirical validation of this ‘structural transformation’ process has

focused on quantifying labor migration and the share of farm labor in total employment relative to the share of agricultural value added in national income. There is overwhelming evidence that declines in the shares of farm labor and agricultural value added are associated with growth in national incomes (Irz, Lin, Thirtle, & Wiggins, 2001; World Bank, 2007). Similarly, structural transformations are associated with several societal goals, among them income growth, poverty reduction, and providing caloric sufficiency to the hungry (Bershteyn, Lyons, Sivam, & Myhrvold, 2015; Carletto, Ruel, Winters, & Zezza, 2015; Lin, 2012; Masters, 2015; Ruel & Alderman, 2013; Syrquin & Chenery, 1989; Timmer & Akkus, 2008).

Neo-classical development thought recognized the importance of rural economies in contributing to the structural transformation process (D. G. Johnson, 1993; Johnston & Mellor, 1961). The agricultural sector itself undergoes a systemic change from a subsistence basis to a commercial basis. This systemic change, or agricultural transformation, is typically quantified by farm productivity increases that generate commercial market surpluses. There is ample evidence of the association of farm productivity increases with the declining share of farming in labor employment and GDP (Byerlee et al., 2009; Timmer, 1988). Farm productivity in turn has depended on agricultural research and ensuing technical change. Technology embodied in seeds, fertilizers, and machines is credited with catalyzing the Green Revolutions in India, Pakistan, the Philippines, and parts of Latin America (Gollin, Byerlee and Morris 2005). Until recently conventional wisdom was that even in the face of changing market dynamics, African agricultural transformation would be catalyzed and characterized by technical change (Boughton et al 1997, Oehmke 1992, Oehmke and Crawford 1996, Staatz et al 1993)

However, despite a half-century of investment in agricultural research since the onset of the Green Revolutions in India, Pakistan and Latin America, much of Africa and some south Asian areas have neither realized the rate of technical change nor the increases in agricultural productivity and value added necessary to catalyze transformation on national or continental

levels. The lack of transformation is not necessarily due to lack of research success—e.g. African agricultural research has generated reasonably high returns and led to poverty reduction (Masters, Bedingar, & Oehmke, 1998; Oehmke, Anandajayasekeram, & Masters, 1997; Oehmke & Crawford, 1996; Pingali, 2012; Thirtle, Lin, & Piesse, 2003). Concurrently, a deeper understanding is emerging: contemporary transformation is a more complex process than previously thought (Barrett et al., 2010; Byerlee et al., 2009; Reardon & Timmer, 2014). While technical progress is a critical component, transformation is a systemic process that includes and is enabled by policy, institutional, and socio-cultural changes.

Thus an important first empirical question is to determine whether there is evidence of technical change and productivity increases in key commodities that would indicate a potential start to or catalyst for the transformation process. The compound hypothesis is that technology use and staple crop productivity are higher in the target (transforming) area than in the control area.

A second, critical part of agricultural transformation is the development of input and output markets that can provide modern inputs and absorb the smallholder surplus from increased productivity and production. The Green Revolution in the Mexican Altiplano was delayed by a decade because of ineffective land markets (Byerlee & de Polanco, 1986). Lack of input markets for improved seed varieties, fertilizer and other modern inputs has been cited as a constraint to African agricultural development (Crawford, Kelly, Jayne, & Howard, 2003; Kelly, Adesina, & Gordon, 2003). Credit and financial services are an important input market that enables use of these modern inputs (Dorward, Kydd, & Poulton, 1998; Kelly et al., 2003). Comparisons of Asian Green Revolution and African output markets have pointed to the existence of functioning output markets in Asia as contributing to the adoption of high-yielding varieties, and the lack of African markets as contributing to the lack of African adoption of high-yielding varieties (Diao, Headey, & Johnson, 2008; M. Johnson, Hazell, & Gulati, 2003).

Market development may also be associated with greater specialization in a single cropping system because of economies to scale, comparative advantage, and reliance on markets as food sources. More generally Collier and Dercon (2014a) and Gollin et al. (2013) argue that transformation is initiated by growing urban demand for food. But this does not seem to be the case with Senegal, which at least since 1961 has imported over half of its rice consumption. Within the study area, PCE emphasized linking smallholders with input and output markets, including food retail outlets in Dakar and other coastal cities. The empirical null hypothesis is that output market improvement is no different in the target area than in the control area. Rejection of this hypothesis would be interpreted as evidence corroborating the broader conception of agricultural transformation.

A third contentious issue in structural transformation relates to the location and role of non-farm employment. Collier and Dercon (2014a) argue for "a vast reduction in the number of [smallholders]", leading to "a massive increase in the urban population and coastal population" (p. 92). A contrasting line of thought emphasizes African demographic patterns suggesting that African rural populations will exceed urban populations for the next three decades and that even then rural populations will rise, that increases in rural populations today are mostly among the rural poor, and that African urban manufacturing employment options are limited and likely to remain so (Ghosh, 2016; Masters et al., 2013; McMillan et al., 2014). The policy implication is to support smallholder emergence from poverty in situ (as well as growth-increasing urban migration), buttressed by supportive farm policy and diversified livelihoods including higher farm income, farm wage labor and rural non-farm employment (RNFE) and entrepreneurial activity (Johnston & Mellor, 1961; Lipton, 2006; Sitko & Jayne, 2014). RNFE is an established empirical phenomenon that is critical to smallholder income diversification (Haggblade, Hazell, & Reardon, 2010; Lanjouw, Murgai, & Stern, 2013). D.G. Johnson (1993) pointed out that "the experience of all the market economies has been that a

large part of the adjustment of the farm population to economic growth has been through part-time farming—the combining of farm and nonfarm employment in the same household and often for the same person" (D. G. Johnson, 1993). In 65 low-middle income countries with Demographic and Health Survey (DHS) data, rural-urban and urban-rural migration largely offset in numbers but successful urban populations have higher earning power. (Young, 2013) This is consistent with an increasing role for RNFE, but data relevant to causality are not yet available (Christiaensen & Todo, 2014). There is a call for the development of a 3-sector model to better understand RNFE, but such models are not well developed (although see (Diao & McMillan, 2015; Mellor & Gavian, 1999; Mellor & Ranade, 2002). In Tanzania, evidence suggests that rural-urban migration by the poor may trap them in urban poverty, while rural-middle-urban migration provides a route to emerge from poverty (Christiaensen & Todo, 2014). The issue becomes one of whether the future is one of rapid congregation of populations in a few megacities, or the emergence of sustainable rural small towns and small cities integrated into the agricultural landscape, or both. Thus three related empirical hypotheses arise, representing the traditional view. First, population growth national and in large cities will be faster than population growth in rural small towns in the treatment area. Second, RNFE is not a significant contributor to rural household income in either target or treatment areas. Third, the number and growth of commercial businesses in the treatment area will be the same as in the control area.

A fourth empirical issue centers on the role of rural institutions in supporting agricultural and structural transformation. Within agriculture, Awotide et al. find that membership in a farmers' organization increased smallholder adoption of improved rice varieties in Nigeria (Awotide, Karimov, Diagne, & Nakelse, 2013). They also find that efforts devoted to improved varieties increase the likelihood of market participation and improved household welfare. Economy-wide, Acemoglu and Robinson argue that weak governance institutions limit private-

sector investment, thereby inhibiting the structural transformation process and keeping Africa poor (Acemoglu & Robinson, 2012; Acemoglu & Robinson, 2010). The empirical hypothesis is that there is no difference between the target and control areas in terms of supportive rural institutions.

Similarly, a lack of gendered institutions has been flagged as the cause of lagging development. Landes argues that the lack of social institutions for gender equality is the critical factor limiting economic growth. The World Development Report 2012 demonstrates the link between poverty and lack of women's' empowerment (ref). There is very limited work on the evolution of women's rights in association with structural transformation, and the existing work has unclear implications (Duflo, 2012; Fox, 2016). For example, in India, the phenomenon of 'missing girls' continued through the Green Revolution and public, physical violence against women persists today (Bhatla et al., 2013; Mehra, 1997). The empirical hypothesis is that there is no difference in women's participation in supportive social institutions in the target and control areas.

A fifth important question is whether unfolding rural transformations are consistent with broader societal and development goals such as the full set of Sustainable Development Goals (SDGs) and the Paris Agreement (Conference of Parties 21). As their name implies, the SDGs emphasize sustainability. Structural transformation is clearly linked to SDG 8 (economic growth and employment) as a vehicle to achieving SDG 1 (ending poverty) and SDG 2 (ending hunger). Similarly, the Paris Agreement emphasizes reductions in greenhouse gas (GHG) emissions. Previous structural transformations including the Industrial Revolution in the developed world and the Green Revolution have unclear track records on these issues. For example, China and Brazil are the highest emitters of agricultural GHG; Brazil also has higher emissions of agricultural GHG per unit of agricultural value added than most African countries (based on WDI data). Much of China's transformation depended on manufacturing

employment; in coastal cities the manufacturing activity has contributed to extreme levels of air pollution. While the politics of developing country contributions to control of global agricultural GHG emissions has yet to be worked out, the empirical question remains: how do agricultural GHG emissions affect possibilities for today's agricultural transformation with its focus on sustainable intensification? The empirical hypothesis is that there is no difference in the GHG emissions in the target and control areas. We note immediately that we will be able to bring only indirect evidence to bear on this hypothesis.

Finally, since an emergent transformation should be associated with improved household income and food security, the empirical question is whether and how rapidly are poverty reduction and increased food security happening in the transforming area? Since the target and control areas were selected to have the same rates of measured poverty, for comparability, the empirical hypothesis is reformulated in terms of a quality of life indicator (refs): there is no difference between the target and control areas in quality of life or prevalence of hunger.

The next section provides a brief description of the transformation study area in the Senegal River Delta. The following section comprises methodology, followed by a section on results. The final section summarizes the evidence on transformation and draws conclusions.

3. Overview of Senegal and the Senegal River Delta

Senegal had a 2015 population of 15.1 million; 56.3% of the population resided in rural areas and 23.0% lived urban areas of over 1 million people (United Nations, 2016a, 2016b; World Bank, 2016a). The World Bank projects that Senegal's urban population will exceed its rural population in 2030, but that rural population will continue to increase in number at least through 2050 (World Bank, 2016). In 2010 (most recent available) the national poverty rate was 46.7% at the national poverty line, comprising 33.1% in urban areas and 57.1% in rural areas. (World Development Indicators (World Bank, 2016)) Senegal's GDP growth rate has ranged from

1.8% to 4.9% over the past ten years, and is regarded as well below the rates necessary for significant poverty reduction. Agriculture provided 46.1% of total employment with an average value added per worker below the poverty line, and contributed 15.8% of GDP according to the World Bank that uses a definition of agriculture basically equivalent to farming (World Bank, 2016b). The contribution of the agricultural sector including agricultural value chains to GDP in 2014 was 34% (World Bank, 2016b).

The study area is within the Senegalese portion of the Senegal River Valley. The Senegal River has headwaters in Guinea and flows through Mali before becoming part of the Senegal-Mauritania border, eventually emptying into the Atlantic Ocean at the city of St. Louis, Senegal. The study area extends from the Matam district on the upstream end to the Diama dam on the downstream end. The Diama dam is located 27km inland from the river mouth and prevents salt water from pushing upstream. Rainfed agriculture is limited: there is a small amount of upland rice but the primary focus is on subsistence farming of drought-tolerant grains such as millet, with a small amount of livestock production. Rice has been the major crop in the irrigated Delta. Since the 1970s, the Government of Senegal and donors have invested in irrigation schemes to increase rice production. The limited effectiveness of these irrigation schemes was due in part to limited ability to control river flow. The Manatali Dam, located 1200km upstream in Mali and completed in 1988, now provides flood control and water retention for release during the irrigation period. The hydrological potential for irrigation is 375,000 ha (World Bank, 2016b). This could provide over 1.6 million tonnes (mt) of rice based on single-cropping basis at global average rice yields on 4.3 t/ha, more than the 1.5 mt consumed in 2014/2015 (USDA, 2016). However, Senegal became increasingly dependent on rice imports for twenty years after the Mantali Dam was completed and a recent analysis showed a negative net present value (Manikowski & Strapasson, 2016).

Rice is the basic staple grain of the Senegalese diet. The average urban Senegalese eats ¾ cup of rice per day (Anderson et al 2010). Between 1961 and 2007 the ratio of imported rice to domestically produced paddy rice fluctuated around a rising trend (figure reference), peaking in 2007 at five to one (imported to domestic). Rice varieties traditionally grown in the Delta were considered by urban consumers to be of low quality and received only low prices in the marketplace. Coupled with low yields, this provided little incentive to farmers to increase rice production.

Since the food price crisis in 2008 the Government of Senegal and various development agencies have elevated attention to improving rice production in the Delta. The Millennium Challenge Corporation invested $540 million between 2010 and 2015 for irrigation rehabilitation and expansion and road improvement in Senegal with a focus on the Delta although MCC reports a relatively modest 8% increase in rice production in its target areas in the Delta (Millennium Challenge Corporation, 2016). The World Bank had a major irrigation project from 2008-2013 in the Delta to refurbish and expand irrigation infrastructure. A 2013 reinvestment in the second phase of this project is designed to bring 13,000 ha into irrigation (World Bank, 2013). The US Government's Feed the Future Initiative supported the Projet Croissance Economique to strengthen rice value chains in the Delta (inter alia). The Plan Senegal Emergent was adopted by the Government of Senegal and development partners in 2012, with the vision of an economically emergent Senegal in 2035. The first pillar of this plan is structural transformation of the economy. Actions to support agriculture's contribution to this structural transformation include the development of commercial agriculture value chains, and halving the trade deficit on cereal crops in part by producing one million tonnes of rice by 2018 (Republique du Senegal, 2014).

4. Data and Methods

This paper relies on collection and analysis of primary household data collected in the study area in 2012, supplemented in some instances by secondary data. A household survey instrument was developed for the express purpose of measuring rural transformation as described in the previous section, and was pre-tested at the University of Gaston-Berger in St. Louis, Senegal. To provide additional information on job creation, the interviewers used an additional survey instrument to solicit information on employment from local enterprises. Both the household and enterprise survey instruments had been previously developed and validated for use in southeast Senegal (Moss, Mbaye, & Oehmke, 2016).

Because this survey was conducted after the apparent beginning of the transformation process, 5-year recall questions were included where feasible. The recall questions were more qualitative in nature, such as a question on whether the output markets had improved.

Based on sample size calculations (see Appendix), a sample of 200 target households and 200 control households was desired for the household data collection exercise. To determine the sampling frame it was necessary to define a geographic area with significant development activities and a potentially emergent transformation. The USAID funded Project Croissance Economique (PCE) provided such an opportunity. PCE is involved in strengthening the rice value chain from farm credit and input supply to processing and finally marketing of rice in Dakar. Additionally, multiple other donors including the World Bank, the Millennium Challenge Corporation and others as well as the Government of Senegal are active in the area. Within the Senegal River Valley PCE operates in the Departments of Podor, Matam, Kanel and Dagana, there are 51 villages within these Departments. 20 of the 51 villages were selected randomly. The control group was selected from the villages along the Senegal River

that were not the 51 villages forming the target group sample frame. From the set of possible control group villages, 10 were selected on the basis of matching the poverty levels and income activity levels of the target villages (Stuart, 2010). Within these 10 control villages, 20 farming households per village were randomly selected from the rolls of the village producer organizations. We matched villages on a similar level of poverty and similar village activities.

To select the sample we relied on Senegal's very structured system of producer organizations in which virtually every farmer is a member of some producer organization. From the rolls of the producer organizations serving the 20 target and 20 control villages, 10 farm households from each village were randomly selected. This resulted in a sample of n=400 farm households split evenly between target and control groups. To implement the enterprise survey, in each village all companies found were surveyed with the enterprise survey instrument.

Important secondary data accessed to strengthen the analysis include Census data including data on population of towns and cities with populations over 5,000 that were taken from the website citypopulation.com, and village-level zoning and construction data for the sample villages that were obtained from village government or key informants.

Analysis of the relationship between transformation and the financial well-being of the poor we quantify well-being based on household assets (Filmer & Pritchett, 1999; Filmer & Pritchett, 2001; Hewett & Montgomery, 2001; Montgomery, Gragnolati, Burke, & Paredes, 2000; Pritchett, 2011). We constructed an indicator of the quality of life based on household ownership an iron, a sewing machine, a television, a car, a refrigerator, a radio, a watch, a bed

or a mattress, a bike, a motorcycle, a table, a chair, a VCR, an air conditioner, a computer and a cellphone. It also included certain characteristics of the housing (type of walls, toilets, ground, etc.) Multiple correspondence analysis—analogous to principal components for categorical variables—was used to construct the indicator (Van Kerm, 1998). Multiple correspondence analysis of assets has been used to assess African poverty trends (Booysen, van der Berg, Burger, Maltitz, & Rand, 2008). The indicator was scaled to range from 0 to 100, with a higher value indicating a better quality of life.

Comparison of the distribution of work activities across different categories of employment uses the information metric developed by Moss, Mbaye and Oehmke (2015). The information metric is a comparison using all employment categories as shares, essentially comparing the distributions of employment across categories in the target group with the distribution of employment in the control group.

5. Results

In this section we report on the differences between the control and target groups for a variety of attributes associated with agricultural transformation.

4.1. Crop Production and Productivity

Innovation

There is little difference between the control and target area in the prevalence of new seed or new fertilizer use (Table 1). However, 41% of farmers in the target area reported using new methods or production standards, compared to 21% for the control area. Additionally, the purchase of fertilizer is 15 percentage points higher in the target area than in the control area.

(Table 1)

Yield

The difference between the control and target rice yield is 999 kg/ha (P= 0.081). For corn the yield difference is 435 kg/ha (P= 0.354), for millet 134 kg/ha (P= 0.213) and for onion 2405 kg/ha (P= 0.351).

(Table 2)

Crop Diversity

A comparison of the control and target area shows differences in crop specialization. In the recall of crop allocations five years prior to the survey, the top four crops in the target area covered 90% of the area while the top four crops in the control area covered 77% (Table 3). At the 2013 survey date the top four crops covered 86% of target area and 68% of control area.

(Table 3)

The composition of the top four crops for the target area changed from the recall date to the survey date. Onions replaced rice as the most widely grown crop, moving from 20% of area to 49% of area. Fruit was not widely grow at the recall date (5% of area) but was the second most widely grown crop at the time of the survey (16%). Rice area fell from the most popular crop to third as area slipped from 52% to 11%. Millet, with 7% of the area (third) in the recall fell out of the top four at the survey date with 3% of area. In other words, in the target area the cropping system switched from based on largely on rice (which is the staple food in Senegal but also a cash crop) to one based on cash crops, namely onions or fruit.

4.2. Markets

Output Markets

Target area households are more likely to participate in output markets (Table 4) rather than keep production for own consumption (54% to 44%, P= 0.000). They are also more likely to

report good marketing conditions (68% v. 52%, P= 0.002), better prices due to standards (48% v. 36%, P= 0.003) and noticeable market improvement over the past five years (49% v. 29%, P= 0.008).

(Table 4)

Financial Markets

Target area households are more likely to have a member who had accessed credit (52% v 39%, P= 0.000) and the amount of credit was higher (449,426 v. 285,390, P= 0.453; Table 5). The most common used of credit in the target households was to support agricultural production (53% v. 36%, P= 0.074). The most common use of credit in the control households was for food purchases (38% v 20%, P= 0.028). This difference is corroborative of a situation in which control households are subject to poverty traps that keep them in subsistence agriculture, but target households are able to access agricultural growth trajectories. For both control and target groups, over the past five years access to credit improved (45%, 60%, P= 0.031).

(Table 5)

4.3. Rural Non-Farm Employment

The survey of households provided information on jobs and on household revenue originating in various sectors including RNFE. Survey results show that more members of target households have regular jobs than do members of control households (1.09 v. 0.55).

The sectoral composition of household earnings including job earnings is calculated as the ratio of group-average sector earnings to sample-average total earnings. This ratio controls for higher earnings in the target households. Agricultural income for households in the target area

amounted to 50% of the sample average total income (not own household income), relative to 42% for control households (P= 0.055) (table reference). The difference in these ratios is a combination of different shares in household income plus higher household incomes. Target households also received a greater share of income from commerce (20% vs. 11%, P= 0.000) and services (9% and 4%, P= 0.000). Commerce and services are components of rural non-farm employment or entrepreneurship. There was no statistical difference in the shares of income from construction or remittances. The association of higher agricultural income ratios with higher commerce and service ratios but not with higher remittance ratios is consistent with a Johnston-Mellor local linkages conception of rural economic transformation.

(Table 6)

The enterprise survey provides data on the number of employees reported by businesses. Of the agriculturally based enterprises responding to the survey, 36% of enterprises in target areas had production employees compared to 20% in control areas (P= 0.000) (Table 7). Over the past five years, the number of agricultural production employees in target area businesses increased from 2.1 to 3.7; in control areas it increased from 2.5 to 3.4.

(Table 7)

Consistent with the numbers on numbers of jobs created, the proportion of businesses in the target area creating jobs was higher than in the control area (Table 8).

(Table 8)

4.4. Institutions

Farmer Organizations

Farmer organizations are both a place of expression of farmer interests and a means of achieving set goals. They play an important role in the construction of farmer power in the definition and

implementation of rural policy. They also determine the place in which farmers should occupy in a society under construction.

In this study, we have noted the emergence of many producer organizations (Table 9). What appears from the social network point of view is that economic interest groups, tontines, and women's rights groups are the most represented. In the target area, membership in an economic interest group is higher and significant (31.9% vs 11.4%, P= 0.000). Membership in a women's interest group is higher and significant in the target area compared to the control area (29.9% vs 21.2%, P= 0.004). This is consistent with existing theories that suggest a mutually beneficial relationship between gender equity and economic growth, however there is mixed evidence regarding the effect of economic growth of gender equity (Bjerge & Rand, 2011; Kabeer & Natali, 2013). Women's interest groups help to ensure female involvement in growth processes, which has a positive effect on economic growth; this is due in part to women constituting roughly 50% of the population, but also their access to economic resources improving the dispersion dynamics within households (Kabeer, 2012). This positive relationship between women's interest group involvement and national support suggests that policies targeting women's involvement in agricultural decision-making could have promising results if such policies were enforced (Salcedo-La Viña, 2015).

(Table 9)

In the target areas, 34% of households reported having a member that plays a leadership role in the organizations, in comparison to only 22% in the control areas (Table 10). A difference of 11%, significant at 1%, was obtained. Additionally, 53% of households have declared benefiting from group services in the target areas, compared to 40% in control areas, making a difference of 12 points, significant at 1%.

(Table 10)

Among the received services, financial support, as well as marketing support, are the most frequent (Table 11). In the control area, the financial support is the most important, while in the target area. Along with evidence presented momentarily of greater income and resilience in the target area, these results are consistent with the idea that the target area is more highly engaged in agricultural transformation with reliance on financial services to support agricultural production and growth. Along with the evidence presented earlier on greater use credit to support consumption in the control area, these financial service results are consistent with the idea that the control area is less engaged in agricultural transformation and more reliant on subsistence agriculture.

(Table 11)

4.5 Rural Transformation and SDGS

Climate Change Adaptation and Mitigation

It is beyond the scope of the current study empirically to quantify GHG emissions, but the study is able to provide indirect evidence on both adaptation and mitigation. The evidence on adaptation relates to shocks and resilience. The contribution to mitigation comes from looking at the evolution of cropping patterns.

Water shortages were reported to be the most likely shock in the control population (44% of respondents) (table reference). In contrast the target population subjectively perceived a lower likelihood of a water shortage (23% v 44%, P= 0.000), a less severe event when it does happen (5 v 6, P= 0.709), and more target respondents reported improved resistance in the past five years (20% v 13%, P= 0.087) relative to the control population. However, these effects are most

likely heavily influenced by the irrigation and thus attribution of lower shocks and improved resilience to water shortages to the transformation process per se is questionable.

(Table 12)

Climate-change mitigation action is implicit in the evolving cropping pattern, notably the switch from rice to onions (table reference). Rice has a relatively high environmental footprint including both water use and methane (CH4) emissions; moreover, as global temperatures rise so too do the CH4 emissions from rice. In comparison, onions have a relatively low environmental footprint and relatively low GHG emissions. While evolving cropping patterns are certainly part of rural transformation, the cropping pattern is location specific and the switch from a high-footprint crop to a low-footprint crop is not a necessary part of transformation. Switching from rice or high-input (nitrogen)-corn systems to fruits and vegetables may lower GHG and other environmental footprints, but not all fruits and vegetables have small footprints. It has been more typical in the past that agricultural commercialization processes were associated with increasing mechanization and higher GHG emissions. In the Senegal River Delta there is increasing use of fossil-fuel based mechanization for land preparation and harvesting, which increases the GHG emissions ceteris paribus.

Women

A decomposition of women's time allocation by activity shows two statistically significant differences (Table 13). Women in the target area spend more time on household revenue generations (10% v 7%, P= 0.731) and more time on leisure (11% v 9%, P= 0.031) than do women in the control area. Women in the target area also spend more time on their own revenue generation, although the difference is small time-wise and not statistically significant. The greater allocation of women's time to revenue-generating activities is consistent with the

concept of structural transformation that both provides a greater level of revenue-generating options and/or helps empower women to take advantage of these opportunities. Women in the target area are less likely to participate in women's advocacy groups (49% v 61%, P= 0.000).

(Table 13)

These results support previous notions that indicators of inclusive growth include economic infrastructure, gender equity, and social protection (McKinley, 2010; Ranieri & Ramos, 2013). The African Development Bank's 2012 measures of inclusive growth include access to basic infrastructure and social services as well as regional integration, indicated in this study by a significantly larger portion of the population with leadership roles within and receiving services from group organizations (Kanu, Salami, & Numasawa, 2014).

4.6. Societal Welfare Results

This section investigates some of the societal welfare impacts associated with a structural transformation. Specifically, it presents data on household resilience, household food security, income growth, and poverty reduction.

Resilience

The shocks reported most likely to affect the target populations were an increase in the price of purchased inputs, and a decrease in the output price (Table 14). These were subjectively perceived as more likely in the target population than the control population (sale price: 34% v 27%, P= 0.562; input price: 38% v 35%, P= 0.451). They occurred with the same magnitude across populations (sale price: 5 v 5; input price 5 v 5). But more of the target population has seen improvement in resilience over the past five years than has the control population (sale price: 16% v 11%, P= 0.321; input price 20% v 14%, P= 0.431). The greater importance of price shocks in the target population may well be associated with transformation as a process of farm commercialization including greater use of input and

output markets. The reasons for greater resiliency were not investigated, but may be related to higher overall income, greater access to diversified income sources including rural non-farm wage or entrepreneurial income, from improved ability to manage market fluctuations, or for other reasons

(Table 14)

Beyond these performances, it is necessary to analyze the behavior of the producers in the face of external shocks. In a dynamic of agricultural transformation, diversification, just as the development of non-agricultural activities, makes producers less vulnerable.

In Africa generally, and in Senegal in particular, there is a growing debate on whether this form of agricultural transformation, intensive in capital factor, is adaptable in the context of rural family production (Sitko & Jayne, 2014). However, the trend that we observe is an attempt by rural agriculture to exit its traditional sphere to better satisfy the needs of large cities, as is the case in the beneficiary areas of the PCE.

(Table 15)

Nutrition and Food Security

The target area has a hungry season that is 0.6 months shorter than the control area hungry season. The most popular coping strategy in either area is starting a new crop, for example planting short-cycle vegetables such as legumes that can be eaten while the rice is ripening. More households use this strategy in the target area (50.8%) than in the control area (43.0%, Table 16). Of the coping strategies practiced, hungry season cropping represents 71% of the strategies in the target area (71%) and 52% in the control area. Nearly a quarter of households in the control area sell livestock as a coping strategy, compared to less than 11%

in the target area. 11.5% of households in the control area had a member leave during the hungry season, more than twice the rate in the target area (4.6%).

(Table 16)

The difference in coping strategies during the hungry season may be indicative of a movement away from poverty traps associated with subsistence agriculture. Poverty traps occur when shocks or seasonality require the household to diminish its productive assets, e.g. by selling livestock or durable goods, or reallocating labor away from the household. Recurrent loss of productive assets inhibits wealth accumulation, trapping the household in poverty (Hoddinott, 2006). In contrast, emergence from the poverty trap is more likely to occur when the household has productive coping strategies, e.g. growing a short-cycle crop for the hungry season. While the current evidence is insufficient to draw firm conclusions, a movement from asset sales to increased production as a coping strategy could have very significant implications for household emergence from poverty and a sustained acceleration of agricultural growth.

Income

The target group reported higher growth in agricultural revenue over the past five years than did the control group (58.3% v. 46.1%). This income growth appears to be associated both with increased physical productivity especially in rice production, but also a switch from rice and grain production to high-valued fruits and vegetables particularly onions.

The target group also reports higher non-farm revenues and net income than does the target group, and higher income growth over the 2011-2013 period, although the within-year differences are not statistically significant (Table 17). In 2001 target household average agricultural revenues were almost 200,000 CFA per year, almost 1/3 again as much as control

household average agricultural revenues of just over 150,000 CFA per year. By 2013 target household average revenue had more than doubled to over 400,000 CFA per year, compared to an increase of just over 50% to 229,000 CFA per year in the control households. Interestingly, gross margins (income/revenue) fell in both groups, from 84% to 60% in control households and 55% to 39% in target households. The survey did not contain sufficient financial data to determine the cause of these declining margins, but lower margins are consistent with higher levels of entrepreneurial activity (because wage employment requires relatively little worker cost income more closely matches revenue; entrepreneurial activity typically requires investment and so margins will be lower).

(Table 17)

Subjective Poverty Reduction

In a subjective analysis of poverty fewer target households than control households self-reported being very poor (10.3% v 11.1%, P= 0.792) or poor (61.5% v 66.2%, P= 0.454). More target households than control household self-reported being rich (27.2% v 22.7%, P= 0.521) or very rich (1.0% v 0.0%, P= 0.337).

(Table 18)

Welfare

Table 19 shows the percentage of households in the target and control groups by Quality of Life quartiles. This distribution shows a greater proportion of very poor (first quartile) among the individuals of the control group and a much larger proportion of well-off households (fourth quartile) in the target group. In effect, only 20% of the households from the target groups figure in the poorest quartile of the entire sample, whereas this rate is 30% in the control group. In addition, more than 30% of the individuals of the target group are in the highest quartile while it is less than 20% for the control group.

(Table 19)

It is also important to note that the poor in the target groups are less poor than the poor in the control groups, and that in a similar manner, the rich in the target groups are much richer than the rich in the control groups (Figure 1). For low quality-of-life scores (<=35) the proportion of control group households with that score is higher than the proportion of target group households. For high quality-of-life scores (>=65) the proportion of target group households is higher than the proportion of control group households.

(Figure 1)

Analysis of changes in household revenue by quality-of-life quartiles indicates that the lowest quartile is realizing the greatest increase in household revenue. Control-group households in the first quartile increased their revenue by 11,440 CFA from 2011 to 2013 (Table 20), compared to an increase of 39,000 CFA for target group households. That is, among the least well-off quarter of the population, household revenue in the target group grew 3.4 times as much as in the control group. In the second, third and fourth quartiles the ratios are 1.61, 1.33 and 1.62, respectively.

(Table 20)

5. Summary and Conclusion

This paper has presented an empirical snapshot of an apparently emergent rural economic transformation in the Senegal River Delta. For comparative purposes, variables representing components or consequences of rural economic transformation were collected both in the region hypothesized to be starting a transformation and in a neighboring region hypothesized not to be starting a transformation process. Because of the large number of variables covered in this document, it is useful to summarize findings by grouping variables.

Data were collected on ten categories that indicate whether or not a traditional agricultural transformation from subsistence agriculture to a modernizing, commercial agriculture with increasing farm sizes and higher rural incomes. Movement in nine of the ten categories is are consistent with agricultural transformation; one (farm specialization) shows little difference between the target and control areas but there does seem to be some movement towards specialization in cash crops in the target area. Variables representing stronger rural social institutions are consistent with institutionally-based descriptions of agricultural transformation. Variables representing gender empowerment are consistent with contemporary gendered descriptions of agricultural transformation. Three resilience measures are presented, two (resilience to input price shocks and resilience to output price shocks) are consistent with interpretations of agricultural transformation as growth via increased resilience out of rural poverty traps where risk and shocks chronically depress household assets, income and growth. The third (resilience to drought) is also consistent, but because of the multiple investments in irrigation in the area it is unclear whether this result is associated with transformation *per se*.

(Table 21)

Data were collected on seven variables related to sustainable rural communities. All seven indicate the emergence of sustainable rural towns or small cities that are chronologically and/or geographically associated with a rural economic transformation that includes development of financially viable rural communities. They are in general inconsistent with strict interpretations of the classical model that rely on rural-urban migration to large metropolises as the engine of growth, including modern interpretations promoting, e.g., “a vast reduction of the size of the population living in areas relatively far away from urban areas and the coast” (Collier & Dercon, 2014b).

Three variables related to societal goals were analyzed. Two are consistent with all models of transformation and with the first two Sustainable Development Goals (SDGs): poverty decreased and food security improved. The third variable, climate action, has not yet been incorporated into models of structural transformation but is nonetheless likely to become a societal concern as agricultures grow and climate change nears.

The first conclusion is that the Senegal River Delta shows evidence of agricultural transformation from subsistence to commercial farming, which is consistent with neo-classical structural transformation. The second conclusion is that the Senegal River Delta shows evidence of increasing business activity in rural towns and small cities that is consistent with a local structural transformation, but at least preliminarily differs in nature from classical structural transformation with widespread migration out of rural areas including small towns and into large urban metropolises. Finally, while the snapshot presented in this paper is very intriguing, further data collection and analysis over time is needed to draw firm conclusions about the sustainability and trajectory of this emergent transformation process.

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Tables

Table 1: Differences in Innovation and Intensification

	CONTROL	TARGET	P-values
INNOVATION (% of respondents)			
New seed/variety	54%	54%	0.873
New fertilizer	41%	43%	0.421
New methods or production standards	21%	41%	0.000
INTENSIFICATION (% of respondents)			
Acquired additional machinery	18%	22%	0.642
Increased fertilizer purchases	68%	83%	0.041
Leased or purchased new land	17%	17%	0.921

Table 2: Differences in Yield

CROP	CONTROL	TARGET	P-values
Rice	3870	4870	0.081
Maize	949	1384	0.354
Millet	668	803	0.213
Onion	9104	11509	0.351

Table 3: Differences in Diversity of Crops Planted

CROP	LAND ALLOCATION, 5-YEAR RECALL			CURRENT LAND ALLOCATION		
	CONTROL	TARGET	P-values	CONTROL	TARGET	P-values
Rice	34,0%	58,9%	0.001	10,5%	14,8%	0.543
Corn	13,4%	7,2%	0.002	28,9%	14,8%	0.411
Millet	16,7%	8,2%	0.000	10,5%	3,7%	0.868
Sorghum	2,2%	1,6%	0.641	7,9%	11,1%	0.901
Cowpea	11,0%	3,3%	0.000	7,9%	3,7%	0.321
Other grains	0,8%	0,3%	0.651	0,0%	0,0%	0.891
Sweet potatoes	0,8%	2,6%	0.082	2,6%	0,0%	0.122
Other tubers	0,5%	0,3%	0.842	2,6%	0,0%	0.123
Peanut	6,8%	0,0%	0.004	7,9%	0,0%	0.217
Onion	11,0%	14,1%	0.591	15,8%	29,6%	0.188
Citrus	0,3%	0,3%	0.832	0,0%	0,0%	0.890
Other fruit	2,5%	3,0%	0.769	5,3%	22,2%	0.061

Table 4: Differences in Markets

	CONTROL	TARGET	P-values
Output market participation	44%	54%	0.000
Good marketing conditions (e.g. access, bargaining power)	52%	68%	0.002
Better prices due to standards	36%	48%	0.003
Market improvement in past five years	29%	49%	0.008

Table 5: Access to and use of credit

	CONTROL	TARGET	P-values
% of households with access to credit	39%	52%	0.000
Amount of credit	285,390	449,426	0.453
% of household using credit for agricultural productions	36%	53%	0.074
% of households using credit for food purchases	38%	20%	0.028
% of households responding that credit has become easier since arrival of PCE	45%	60%	0.031

Table 6: Differences in Share of Income from Various Sources

Share of Income From	CONTROL	TARGET	P-values
Agriculture	42%	50%	0.055
Construction	5%	3%	0.431
Commerce	11%	20%	0.000
Services	4%	9%	0.000
Remittances	11%	12%	0.652

Table 7: Employment in value chains

	CONTROL	TARGET	P-values
Agriculturally Based Enterprises			
% of agricultural employees in relation to production	20%	36%	0.000
Number of production employees	3.4	3.7	0.631
Number of production employees five years ago	2.5	2.1	0.431
Non-Agricultural Enterprises			
Number of employees	1.4	1.618	0.318

Table 8: Comparison of job creation among the different groups

	CONTROL	TARGET	P-values
Job elimination	11.43%	3.28%	0.219
Neither creation nor elimination	62.86%	37.70%	0.125
Between 1 and 5 jobs created	20.00%	50.82%	0.308
More than 5 jobs created	5.71%	8.20%	0.624

Table 9: Representation of different producer groups

Group	CONTROL	TARGET	P-values
Sports Club	6.82%	2.78%	0.042
Family Support	0.38%	0.00%	0.851
Entraide Neighbors	2.27%	2.08%	0.921
Associative, Charitable Work,	8.71%	6.94%	0.541
Cooperatives	1.14%	2.08%	0.461
National NGOs	0.00%	0.35%	0.731
International NGOs	0.00%	1.04%	0.058
Tontine	18.18%	17.01%	0.641
Producer Organization	19.32%	13.19%	0.071
Promoting Female Group	29.92%	21.18%	0.045
Economic Interest Group	11.36%	31.94%	0.000
Political Parties	0.38%	0.69%	0.762
Other	1.52%	0.69%	0.751

Table 10: Leadership and benefits

	CONTROL	TARGET	P-values
% with leadership role in the group	22%	34%	0.000
% receiving services from the group	53%	41%	0.000

Table 11 : Type of network support (% of respondents receiving)

	CONTROL	TARGET	P-values
Financial support	55%	36%	0.000
Support during construction	2%	1%	0.682
Support due to illness	1%	0%	0.821
Support for product marketing	1%	3%	0.791
Production support	38%	57%	0.000

Table 12: Differences in Resilience

	CONTROL	TARGET	P-values
Lack of water	44%	23%	0.000
Scale of magnitude of event	6	5	0.709
Improved resistance to the shock in the past five years	13%	20%	0.087

Table 13: Time allocation for women and their participation in advocacy groups

	CONTROL	TARGET	P-Values
Women's time allocation by activity			
Household tasks	49%	43%	0.531
Own revenue generation	12%	13%	0.812
Household revenue generation	7%	10%	0.731
Rest	24%	24%	0.912
Leisure	9%	11%	0.031
% of women participating in advocacy group	61%	49%	0.000

Table 14: Resilience to price shocks

	CONTROL	TARGET	P-values
Fall in sale price	27%	34%	0.562
Scale of magnitude of event	5	5	0.931
Resistance to the shock since the arrival of the PCE	11%	16%	0.321
Increase in price of purchased products	35%	38%	0.451
Scale of magnitude of event	5	5	0.891
Resistance to the shock since the arrival of the PCE	14%	20%	0.431

Table 15: Level of satisfaction of consumption demand

	CONTROL	TARGET	p-values
Satisfaction of local demand in your region ?	45%	48%	0.421
Satisfaction of national demand ?	19%	29%	0.534
Level of integration in the market economy ?	20	49	0.000
Existence of a stocking system for your products ?	30%	45%	0.037
Certification to access international markets ?	1%	1%	0.891

Table 16: Differences in household food security

FOOD SECURITY INDICATOR	CONTROL	TARGET	P-values
Number of daily meals prepared in the household	2.887	2.955	0.061
Sufficiency of the meal			
More than sufficient	4.0%	5.6%	0.671
Sufficient	75.4%	82.4%	0.091
Less than sufficient	20.6%	12%	0.431
The pre-harvest 'hungry season'			
Duration (months)	3.784	3.185	0.073
Sold durable goods to combat the pre-harvest period (% households)	4.5%	5.1%	0.724
Sold livestock to combat the pre-harvest period (% households)	23.5%	10.8%	0.000
A member departed during the pre-harvest period (% households)	11.5%	4.6%	0.068
Started new crop activity during the preharvest period (% household)	43.0%	50.8%	0.821
Frequency of dietary problems			
Never	18.5%	21.5%	0.434
Rarely	35.9%	42.0%	0.481
Sometimes	19.5%	20.0%	0.895
Often	17.5%	21.0%	0.866
Always	2.5%	1.5%	0.729

Table 17: Non-farm revenue and income in control and target households, 2011-2013

	CONTROL	TARGET	p-values
Gross Revenue 2011	151,389 CFA	196,084 CFA	0.321
Gross Revenue 2012	278,389 CFA	332,085 CFA	0.214
Gross Revenue 2013	229,000 CFA	403,085 CFA	0.431
Net income 2011	126,611 CFA	108,750 CFA	0.451
Net income 2012	151,944 CFA	147,666 CFA	0.621
Net income 2013	137,000 CFA	155,583 CFA	0.583

Table 18: Subjective poverty of households

	CONTROL	TARGET	P-values
Very poor	11.1%	10.3%	0.792
Poor	66.2%	61.5%	0.454
Rich	22.7%	27.2%	0.521
Very rich	0.0%	1.0%	0.337

Table 19: Distribution of the sample according to quality of life and group

	1st quartile	2nd quartile	3rd quartile	4th quartile	Total
Control	29.70%	24.26%	26.24%	19.80%	100.00%
Target	20.10%	25.77%	23.71%	30.41%	100.00%
Total	25.00%	25.00%	25.00%	25.00%	

Table 20: Improvement of revenue according to quality of life and group

	1st quartile	2nd quartile	3rd quartile	4th quartile	Total
Control	11 440	26 260	33 810	28 360	24 440
Target	39 000	42 330	44 890	46 000	43 810
Ratio	3,41	1,61	-	1,62	1,79
Point difference	27 560	16 070	11 070	17 640	19 370
p-value	0.000	0.041	0.532	0.023	0.031

Table 21. Summary of variables related to rural economic transformation in the Senegal River Delta, direction of change, results summary, and interpretation

INDICATOR	RESULT STATEMENT (target # v. control #)	INTERPRETATION
AGRICULTURAL VARIABLES		
Farm technology, productivity and production	New/more intensive use of fertilizers (83% v. 68%), improved agronomic practices (41% v. 21%), higher crop yields (rice: 1.0 kg/ha increase; onion 2.4 kg/ha increase), higher production	Results are consistent with agricultural transformation
Market linkages and development	More farmers participating in markets (54% v. 44%)	Consistent with agricultural transformation
	Overall market improvement (49% v. 29%), better conditions for smallholders (68% v. 52%), higher prices due to standards (48% v. 36%),	Consistent with agricultural transformation
Access to and use of credit	More households (52% v. 39%) are accessing larger amounts of credit (449,000 v. 285,000 CFA, about $280 difference) with a greater likelihood of using it for agricultural production (53% v. 36%)	Consistent with agricultural transformation

INDICATOR	RESULT STATEMENT (target # v. control #)	INTERPRETATION
Farm size and specialization	Farm sizes are higher; greater specialization (86% v. 68% concentration) and emphasis on high-value crops (onion: 49% v. 20%; fruit 16% v. 5%).	Farm size temporal evidence is lacking and effects of opening irrigated perimeters are unclear. Greater specialization and emphasis on high-value crops is consistent with transformation.
Farm income	Higher prevalence of self-reported household farm income growth past five years (58.3% v. 46.1%).	Consistent with agricultural transformation
Household Income	Higher 5-year household revenue growth (43,810 CFA v. 24,440 CFA) including among the quartile with lowest quality of life (39,000 CFA v. 11,400 CFS).	Consistent with agricultural transformation. NB Income growth among lowest quartile target households exceeds growth in any segment of control population.
INSTITUTIONS		
Social institutions	More households benefit from services provided by a farmers' organization or similar organization (53% v. 40%), which provide a	consistent with institutionally-based descriptions of agricultural transformation

INDICATOR	RESULT STATEMENT (target # v. control #)	INTERPRETATION
	wider range of services (producer support services 57% v. 38%; financial services 5% v. 36%)	
GENDER		
Gender empowerment	Greater number of women's advocacy organizations	consistent with gendered descriptions of institutional progress with productivity implications
RESILIENCE		
Resilience to drought, price shocks	Lower likelihood of water shortage (23% v. 44%) and better resilience (20% v. 13%); slightly greater risk of input price shocks (38% v. 35%) but better resilience to them (20% v. 14%); greater risk of output price shocks (24% v. 27%) but better resilience to them (16% v. 11%).	On drought resistance: unable to delineate irrigation effects from transformation effects. Price results consistent with transformation and escape from rural poverty traps but not statistically significant.
SUSTAINABLE RURAL ECONOMIES		
Rural non-farm employment and entrepreneurship	More household members employed (1.09 v. 0.55); greater share of household income from commerce, services.	consistent with emerging literature on role of rural towns and small cities in structural transformation

INDICATOR	RESULT STATEMENT (target # v. control #)	INTERPRETATION
Rural employment creation	target-area firms more likely to have agricultural production employees (36% v. 20%) with higher 5-year increase in number of employees (1.6 v. 0.9).	consistent with emerging literature on role of rural towns and small cities in structural transformation
Rural business income	Higher rural business income	Consistent with emerging literature on role of rural towns and small cities in structural transformation
Rural Population Growth	Higher rural small town population growth rates from 2002-2013: population growth 2.82% and 4.95% in rural town and small city in target area v. 2.82% in St. Louis (nearest coastal city) and 2.66% in Dakar (capital city).	consistent with emerging literature on role of rural towns and small cities in structural transformation
Rural Town Commercialization	Higher likelihood of a dynamic commercial area (35% v. 5%)	consistent with emerging literature on role of rural towns and small cities in structural transformation
SOCIETAL GOALS		
Poverty	- Fewer households subjectively report being very poor (10.3%	results are consistent with all models of structural

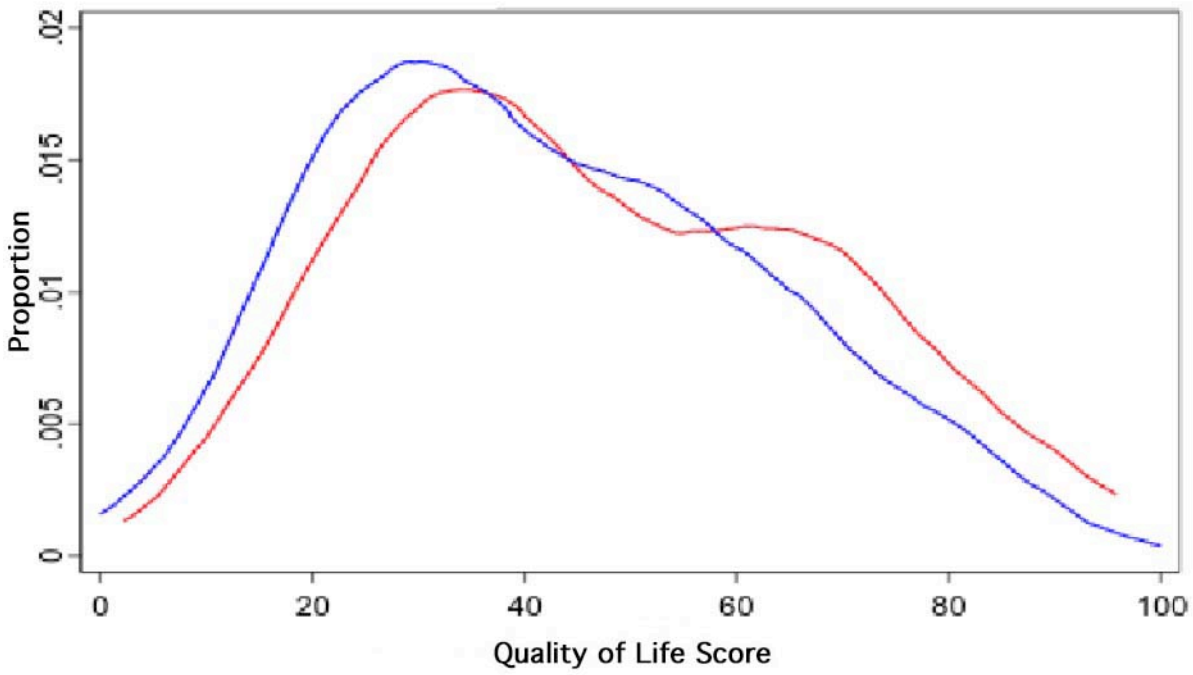
INDICATOR		RESULT STATEMENT (target # v. control #)	INTERPRETATION
		v 11.1%) or poor (61.5% v 66.2%).	transformation but not statistically significant
Climate Action	+/0	GHG footprint in target area may be smaller (indirect evidence)	If true, it is due to switching from rice to onions; the switch from a staple crop to a high-value crop does not necessarily cause GHG to decline and the opposite may be likely, especially as production commercializes.
Food security	+	Shorter hungry season (3.2 v 3.8 months), more likely to experience hunger never (21.5% v 18.5%) or rarely (42.0% v. 35.9%).	consistent with all models of structural transformation

Figure Legends

Figure 1 Legend:

Figures

Figure 1: Distribution of quality of life by Target v. Control group



ANNEX: Calculation of sample size

Whether θ a proportion that one evaluates by $\hat{\theta}$ that is the same proportion measured by a sample size n_{sas} obtained by a simple random sampling (sas)

$$\text{With } f = \frac{n_{sas}}{N} \; ; \; V_{sas}\left(\hat{\theta}\right) = (1-f)\frac{S_\theta^2}{n_{sas}} \qquad (1)$$

θ being a proportion, $S_\theta^2 = \theta(1-\theta)$

$$\text{therefore } V_{sas}\left(\hat{\theta}\right) = (1-f)\frac{\theta(1-\theta)}{n_{sas}} \qquad (2)$$

For a threshold β the difference between the value that will produce the estimator and the true value θ, we want to find n_{sas} so that $\forall\ \theta \in [0;1]$; the event $\left|\hat{\theta}-\theta\right| > \beta$ is very rare.

The notion of scarcity can be quantified from the following method : the event $\left|\hat{\theta}-\theta\right| > \beta$ is tolerated in as many as $\alpha\%$ of cases

Thus,

$$\Pr\left(\left|\hat{\theta}-\theta\right| > \beta\right) \le \alpha \Leftrightarrow \Pr\left(\frac{\left|\hat{\theta}-\theta\right|}{\sqrt{V_{sas}\left(\hat{\theta}\right)}} \le \frac{\beta}{\sqrt{V_{sas}\left(\hat{\theta}\right)}}\right) \ge 1-\alpha \Leftrightarrow \frac{\beta}{\sqrt{V_{sas}\left(\hat{\theta}\right)}} \ge \mu_{(1-\alpha/2)}$$

Where $\mu_{(1-\alpha/2)}$ is the fractal of the order $\left(1-\alpha/2\right)$ of the standard normal distribution.

$$\frac{\beta}{\sqrt{V_{sas}\left(\hat{\theta}\right)}} \ge \mu_{(1-\alpha/2)} \Leftrightarrow \left(\frac{1}{n_{sas}} - \frac{1}{N}\right)\theta(1-\theta) \le \left(\frac{\beta}{\mu_{(1-\alpha/2)}}\right)^2 \qquad (3)$$

But $\forall\ \theta \in [0;1]\ g(\theta) = \theta(1-\theta)$ takes its maximum value for $\theta = 0.5$

$$\text{Thus, } \forall\ \theta \in [0;1], \left(\frac{1}{n_{sas}} - \frac{1}{N}\right)\theta(1-\theta) \leq \left(\frac{1}{n_{sas}} - \frac{1}{N}\right)0.5(1-0.5) \qquad (4)$$

given that the equation (3) should be proven $\forall\ \theta \in [0;1]$; it should also be proven for $\theta = 0.5$

In combining (3) et (4), we obtain

$$\forall\ \theta \in [0;1], \left(\frac{1}{n_{sas}} - \frac{1}{N}\right)0.5(1-0.5) \leq \left(\frac{\beta}{\mu_{(1-\alpha/2)}}\right)^2 \qquad (5)$$

$\Rightarrow \forall\ \theta \in [0;1], n_{sas} \geq \left(0.5\frac{\mu_{(1-\alpha/2)}}{\beta}\right)^2$ making the estimation $\frac{1}{N} \approx 0$ because

to have precision β of $\hat{\theta}$ around the real value of θ with a Type 1 error α , it takes at least a size n_{sas} sampling so that

$$n_{sas} = \left(0.5\frac{\mu_{(1-\alpha/2)}}{\beta}\right)^2 \qquad (6)$$

If we take $\beta = 5\%$ and $\alpha = 5\%$ $Min(n_{sas}) = 384{,}16$

We therefore round $n_{sas} = 400$