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Looking at Pro-poor Growth from an Agricultural Perspective

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Looking at Pro-Poor Growth from an Agricultural Perspective

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Abstract

Pro-poor growth has been identified as one of the most promising pathways to reduce poverty worldwide. Related research has developed a multitude of instruments to measure pro-poor growth using absolute and relative approaches and income and non-income data. This article contributes to the literature by expanding the toolbox with several new measures based on the concept of the growth incidence curve by Ravallion and Chen (2003) and the opportunity curve by Ali and Son (2007) that take into account the extraordinary importance of agriculture for poverty reduction in developing countries. The toolbox is then applied to three comparable household surveys from Rwanda (EICV data for the years 1999-2001, 2005-2006, and 2010-2011), a country that has experienced impressive economic growth since the genocide in the mid-1990s and that has undertaken considerable efforts to increase the population's access to social services over the last decade. Results indicate that Rwanda achieved in this time period enormous progress in the income, but also in the education and health dimension of poverty, which was in various cases even pro-poor in the relative and strong-absolute sense. The new tools further reveal that agricultural productivity of the labor productivity-poor increased relatively (but not absolutely) faster than for the labor productivity-rich. Lastly, we find indications that the labor productivity-poor dispose of less education than the labor productivity-rich which may imply further potential to increase the poor's productivity levels if their education levels increased.

Keywords: Agricultural Productivity, Inequality, Multidimensional Poverty, Pro-Poor Growth, Rwanda, Sub-Saharan Africa

JEL classification: E6, I3, O1

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1. Introduction

Given that the eradication of poverty worldwide continues to be one of the most important challenges for humanity, much research effort has over the last decades been dedicated to the question how this ambitious goal may be achieved. As a result, the idea of growth that is particularly poverty-reducing, or "pro-poor" growth (PPG), emerged in the late 1990s/early 2000s as a way to accelerate poverty reduction (e.g. Klasen 2004, 2008; Grimm et al. 2007). Since then, this concept has received a great deal of attention and its focus on how the poor are benefitting from growth is seen as central to poverty reduction efforts (e.g. United Nations 2000; World Bank 2000a, b; Ravallion 2001; Klasen 2004; Besley and Cord 2007). The literature on pro-poor growth has developed various instruments providing researchers with the possibility to evaluate from an ex-post perspective the extent to which the poor benefited from recent developments in a country (these instruments are regularly referred to as the "pro-poor growth toolbox"). Most notably, Ravallion and Chen (2003) introduced the growth incidence curve (GIC) as a central tool to measure pro-poor growth which provides income growth rates by quantiles (e.g. vintiles or percentiles) ranked by income. Grosse et al. (2008) and Klasen (2008) showed with the so-called non-income growth incidence curve (NIGIC) that the concept of the GIC is also applicable to non-income dimensions of poverty such as education or health. Using the GIC/NIGIC one can then assess whether, according to the definitions proposed in Grosse et al. (2008) and Klasen (2008) and conditioning on income or the non-income dimension in question, growth was pro-poor in the weak absolute sense (it increased absolute outcomes for the (income or non-income) poor, GIC/NIGIC above 0 for the poor), relative sense (rates of progress were faster for the poor than the non-poor, GIC/NIGIC downward sloping), or strong absolute sense (absolute improvements for the poor greater than the non-poor, absolute GIC/NIGIC downward sloping). A related approach was also pursued by Ali and Son (2007) who developed the so-called opportunity curves which are likewise focused on non-income dimensions of poverty and plot the level of access to certain social services against the cumulative share of the population ranked by income.

However, all of the above-mentioned tools focus too far on income and non-income dimensions of well-being. One reasonable way to further extend the concept is to examine how pro-poor productivity improvements have been. Given the extraordinary importance of agricultural productivity improvements for poverty reduction worldwide (e.g. World Bank 2007; de Janvry and Sadoulet 2010; Valdés and Foster 2010; Christiaensen et al. 2011), we suggest here to define the "poor" not only in terms of income, education or health, but also in terms of agricultural productivity. Such an approach can be readily implemented in the PPG-toolbox by slightly modifying some of the existing tools. The resulting new instruments can be called "productivity growth incidence curve" (PGIC) and "productivity opportunity curve" (POC) and allow us to look at pro-poor growth from a complementary, agricultural productivity-based perspective. When doing so, it is important to recognize that the land and the labor productivity-poor are not automatically the same households. Instead, these two subgroups can regularly exhibit quite different characteristics and distinguishing between both groups in the analysis can hence provide us with interesting new insights in its own right.

To illustrate the potential of this extended toolbox, we then apply it to three waves of the nationally-representative EICV[1] household survey from Rwanda (years 1999-2001, 2005-2006, and 2010-2011). Rwanda was chosen for our empirical application for four reasons. First, the Rwandan economy has since the genocide in 1994 gone through an impressive development and Rwanda belongs currently to the most rapidly growing countries in Sub-Saharan Africa (with average annual growth rate of *per capita* income between 2000 and 2010 of 4.67% compared to an SSA average of 2.65% (WDI 2012)). Second, the Rwandan government has over the last decade undertaken considerable efforts to increase the population's access to social services (e.g. Saksena et al. 2011) which is one of the reasons why the United Nations consider Rwanda – despite the very challenging situation after the genocide – as one of the countries largely on track to achieve many of the Millennium Development Goals by the year 2015 (UNDP 2003, 2007). Third, Rwanda has the highest population density in Sub-Saharan Africa (approx. 431 inhabitants per square kilometer compared to an average of SSA countries of approx. 36 inhabitants per sq. km.) and its population keeps on growing rapidly at a rate of nearly 3% annually. Fourth, Rwanda remains a heavily rural and agriculturally based economy with more than 80% of the population living in rural areas and more than 75% of employed persons working in the agricultural sector (all numbers from WDI 2012). The combination of high population density, high population growth, and a largely agrarian economy requires the Rwandan government to find ways to increase the productivity of the agricultural sector to ensure food security as land is an increasingly scarce factor which cannot be expanded much anymore.

The results of our analysis indicate that Rwanda has in recent years achieved impressive progress in both, income and non-income dimensions of poverty. The observed progress was in many cases not only pro-poor according to the weak-absolute, but also according to the relative and, in various cases, even according to the strong-absolute definition (e.g. for adult literacy, access to improved sanitation and incidence of illness/injuries in the last 14 days). The new agricultural productivity-based tools, namely the monetary and crop-specific PGICs, revealed that the labor productivity-poor were able to increase their productivity levels relatively (but not absolutely) faster than the productivity-rich. Using the POCs (Type 1) it was further found that the labor productivity-poor

[1] The French acronym EICV stands for Enquête Intégrale sur les Conditions de Vie des Ménages au Rwanda.

exhibit in all three surveys lower education levels than the labor productivity-rich. Yet, as part of the recent expansion of education in Rwanda the absolute gap in education between these two groups has decreased slightly over the last years. Lastly, the POCs (Type 2) revealed considerably lower labor and land productivity levels for human capital-poor households in Rwanda.

The article proceeds as follows. Section 2 gives a brief overview on different concepts of pro-poor growth and the measurement tools so-far suggested in the PPG-literature. Section 3 discusses the policy relevance and limitations of the existing toolbox. In addition, it introduces the new instruments which enable us to look at pro-poor growth from an agricultural perspective. In section 4 it is explained why – at least in the Rwandan context – it is important to look at the land and labor productivity-poor separately. Section 5 describes the EICV household data which are used for the empirical application. The results of our pro-poor analysis are then discussed separately for the existing PPG-toolbox (section 6) and the new agricultural productivity-based tools (section 7). Lastly, section 8 summarizes the main results of our analysis and discusses potential limitations and policy implications.

2. Definition and measurement of pro-poor growth

Starting from the empirical finding that both lower initial inequality as well reductions in inequality are key drivers of poverty reduction (e.g. Ravallion 2001; Bourguignon 2004), the idea of pro-poor growth has emerged in the late 1990s/early 2000s as one of the key instruments to achieve sustainable poverty reduction (United Nations 2000; World Bank 2000a, b; Ravallion 2001; Klasen 2004). Despite numerous attempts, there is until today no consensus definition of what is meant by pro-poor growth (for attempts see e.g. McCulloch and Baulch 1999; Kakwani and Pernia 2000; Hanmer and Booth 2001; White and Anderson 2001; Ravallion and Datt 2002; Ravallion and Chen 2003; Duclos and Wodon 2004; Klasen 2004; Son 2004), with different groups of researchers/policy makers emphasizing different aspects (Duclos and Wodon 2004; OECD 2006).

As discussed above, we follow Grosse et al. (2008) and Klasen (2008), and distinguish between a weak-absolute, a relative, and a strong-absolute definition. According to the weak-absolute definition, every growth spell where the poor benefited to any extent (i.e. their aggregated growth rate was larger than zero) must be called pro-poor. The idea behind this notion is that to achieve poverty reduction (at least when applying an absolute concept of poverty) it is not important how the income growth of the poor compared to the one of the non-poor, but only that their incomes increased at all. However, one obvious downside of the weak-absolute definition is that it calls, somewhat counterintuitively, a growth spell pro-poor even when the poor benefited significantly less from it than the non-poor. The relative definition addresses this shortcoming and argues that growth episodes are only pro-poor if the poor's income grew relatively faster than the one of the non-poor (i.e. the growth rate of the poor was larger). Hence, growth rates must be biased in favor of the poor implying that relative inequality between the poor and the non-poor will fall. The strong-absolute definition goes even a step further since it requires the *absolute* income gains of the poor to be larger than those of the non-poor. Some researchers describe such growth as "biased in a dramatic fashion in favor of the poor" (Klasen 2008, p. 421) or even "super pro-poor" (Kakwani et al. 2004, p. 4). As shown empirically by White and Anderson (2001) the criteria of the strong-absolute definition of pro-poor growth are only rarely satisfied in reality. However, this is particularly true if the analysis is focused on the monetary dimension. When analyzing progress in non-monetary dimensions of poverty, it is not completely unusual to observe pro-poor growth according to all three definitions since many of the indicators are bounded above, i.e. they have by definition a predefined maximum value (e.g. number of vaccinations, share of the population having access to certain services, years of schooling) which particularly facilitates the occurrence of pro-poor growth according to the relative and the strong-absolute definition. Also, as argued by Klasen (2008), in non-income dimensions the strong absolute definition is intuitively more plausible as absolute increments in health and education are usually seen as the relevant metric (rather than percentage changes which is more often used in the income sphere).

Based on the above concepts of pro-poor growth, various researchers have suggested tools and instruments aiming to measure *if* and also *how* pro-poor recent developments in a country were. Most notably, Ravallion and Chen (2003) introduced their growth incidence curve which graphically illustrates how the gains from economic growth were distributed. In order to construct the GIC, the individuals are first ranked for each period by their p.c. income and are then subdivided into p quantiles (e.g. vintiles or percentiles). For each of those quantiles the mean growth rate in p.c. income between $t-1$ and t is calculated separately being defined as

(1) $$g_t(p) = \frac{y_t\,(p)}{y_{t-1}\,(p)} - 1 = \frac{L'_t\,(p)}{L'_{t-1}\,(p)}(\gamma_t + 1) - 1$$

where $\gamma_t = \frac{\mu_t}{\mu_{t-1}} - 1$ is the growth rate in mean income μ and $L'_t\,(p)$ denotes the slope of the Lorenz curve at time t for quantile p. The GIC is then obtained by simply plotting the quantiles of the population ranked by their p.c. income on the horizontal axis against quantile-specific growth rates in p.c. income on the vertical axis. The concept of the GIC allows distinguishing between the above-mentioned three definitions of pro-poor growth. If $g_t(p)$ > 0 (i.e. the quantile-specific growth rates in p.c. income are larger than zero) for all poor quantiles, developments have been pro-poor according to the weak-absolute definition. If the (relative) GIC is sloped downwards (i.e. growth rates of p.c. income were larger for poor than for non-poor households), this indicates pro-poor growth in the relative sense. To test whether developments have even been pro-poor according to the strong-absolute definition, the mean change in p.c. income in *absolute* terms has to be calculated for each quantile. If the corresponding absolute GIC is sloped downwards, this implies pro-poor growth according to the strong-absolute definition.

To further assess the *degree* of pro-poorness of a growth spell, Ravallion and Chen (2003) introduced a measure called pro-poor growth rate (PPGR) which can be formally defined as (notion in line with Grosse et al. 2008)

(2) $$PPGR = g_t^p = \frac{1}{H_t} \int_0^{H_t} g_t\,(\mathrm{p})\mathrm{d}p$$

The $PPGR$ is equivalent to the area under the GIC up to the headcount ratio H_t and thus measures the average growth rate of the poor quantiles. Conveniently, it can be derived from the Watts poverty index and a pro-poor growth rate above 0 will reduce the poverty as measured by the Watts index. Moreover, if the PPGR exceeds the growth rate in mean income (GRIM), growth has been pro-poor according to the relative definition. To test for pro-poor growth in the strong-absolute sense, it is necessary to calculate analogously to (2) the mean *absolute* change of the poor

(3) $$PPCH = c_t^p = \frac{1}{H_{t-1}} \sum_1^{H_t} c_t(p)$$

This measure can be called "pro-poor change" (PPCH) and reflects the area lying under the absolute GIC up to the headcount (Grosse et al. 2008). If the PPCH exceeds the absolute change in mean income, then growth was pro-poor according to the strong-absolute definition.

One drawback of the growth incidence curves as introduced by Ravallion and Chen (2003) is that they are exclusively focused on the income dimension and therefore do not account for the multidimensionality of poverty (e.g. Sen 1983, 1998; World Bank 2000a) which is, for instance, reflected in the MDGs. Yet, Grosse et al. (2008) and Klasen (2008) showed that the general concept of the GIC and the related measures is equally applicable to non-income dimensions of poverty (using outcome based welfare indicators) yielding the so-called non-income growth incidence curves (NIGIC). These NIGICs are often presented in a "conditional" and an "unconditional" version. The former resembles very much the income GIC since on the horizontal axis the individuals are likewise ranked by their p.c. income. However, on the vertical axis, there is no longer the growth rate in monetary terms but in an appropriate non-income dimension (e.g. years of education, number of vaccinations etc.). Hence, conditional NIGICs answer the question to what extent different parts of the *income* distribution were able to increase their level in the contemplated *non-income* indicator. The unconditional NIGIC additionally differs from the GIC in the sense that on the horizontal axis, the individuals are now ranked by their attainment in terms of the respective non-income indicator in time period $t-1$. Thus, the question answered by the unconditional NIGIC is whether growth in, for instance, years of schooling was relatively or absolutely faster for the education-poor than for the education-rich. Even though there is obviously some correlation between the poor in monetary and non-monetary terms, this relationship is far from perfect (e.g. Anand and Ravallion 1993; Sen 1998). As a consequence, the above two versions of the NIGICs regularly yield different results whereat the information provided by both types can be of considerable relevance for policy-makers (see section 3).

A third approach to measure pro-poor growth[2] was introduced by Ali and Son (2007) with the so-called "opportunity curves" which are closely related to the idea of a social welfare function. The general idea of these curves is relatively similar to the one of a conditional NIGIC with the exception of two things. First, as in the case of conditional NIGICs, there are quantiles of the population ranked by p.c. income on the horizontal axis; however these quantiles are in the case of the opportunity curves *cumulated*. With this procedure, Ali and Son (2007) want – in line with the inherent idea of pro-poor growth – to implicitly weigh the opportunities enjoyed by the poor higher than those enjoyed by the rich. As a second difference, the opportunity curve plots the *level* and not the *growth* in the access to certain services on the vertical axis against the cumulative share of the population.[3]

3. Policy relevance and limitations of the existing pro-poor growth toolbox

As the above explanations have shown, the literature so far has come up with a wide range of tools to measure pro-poor growth. The combination of all these tools provides researchers and policy makers with the possibility to ex-post evaluate who has benefited from recent developments in a country from quite different angles.

First, the "classical" growth incidence curve as introduced by Ravallion and Chen (2003) gives insights from the purely monetary perspective, thus indicating which parts of the income distribution experienced the highest growth rates/absolute increases in p.c. income whereas it cannot be distinguished whether such gains stem from direct participation in economic growth or from any kind of (governmental) transfers received. Nonetheless, the information provided by GICs is of considerable relevance for policy makers since it must be their goal to assure that no parts of the population are excluded from the benefits of economic growth. Such exclusion is not only

[2] We use the term pro-poor growth even though Ali and Son (2007) speak of "inclusive growth". Indeed, there are minor differences between the two concepts; however, for the purpose of this article, we consider these discrepancies as negligible. See Klasen (2010) for a further discussion of inclusive growth.

[3] It is noteworthy that if the quantiles on the horizontal axis were *not* cumulated in the case of the opportunity curve, the conditional NIGIC would simply be the first derivative of the opportunity curve.

problematic from a welfare point of view, but might also undermine opportunities for further economic growth (e.g. Galor and Zeira 1993; Persson and Tabellini 1994; Alesina and Rodrik 1994; Bourguignon 2004).

The insights provided by conditional NIGICs and opportunity curves can be seen as a complementary perspective which is closely related to the first. In particular, such tools allow policy makers to evaluate whether the poor in monetary terms were able to improve their level of well-being in non-income dimensions. As pointed out by Grosse et al. (2008) and Klasen (2008), such an analysis can be seen as an outcome-based incidence analysis (e.g. Van de Walle and Nead 1995; Van de Walle 1998; Lanjouw and Ravallion 1999) which differs from the traditional expenditure incidence analysis in the sense that not the distribution of spending is measured, but the distribution of improvements in outcomes. In doing so, this variant circumvents the commonly criticized assumption of the expenditure incidence analysis that the consumer's benefit from the service can be approximated by the government's provision cost (Van de Walle 1998). From a policy point of view, the information provided by conditional NIGICs and opportunity curves may facilitate the maximization of the income poverty reducing effect of public expenditures for social services since it allows policy makers to evaluate whether the income-poorest have been reached by recent interventions. This can be seen as desirable in order to reduce the vulnerability of income-poor households and hence to enable them to break out of existing poverty traps.

The unconditional NIGIC approaches the issue of poverty from an additional third perspective because it no longer conceives of the poor in monetary but in non-monetary dimensions. Consequently, it provides policy-makers with information whether increased social services provision has really reached those being most deficient in the dimension of interest (e.g. health or education). Against the background of the not income-related MDGs 2-6, such information is crucial for many Sub-Saharan African governments since they must try to allocate their scarce resources as efficiently as possible to achieve progress towards the ambitious non-income targets.

All of these measures share the feature that they are concerned with the distributional pattern of *development outcomes*. But we may also be interested in the distributional pattern of key drivers of development outcomes. For example, it is commonly held that improvements in agricultural productivity are critical for poverty reduction in low income countries (e.g. World Bank 2007; de Janvry and Sadoulet 2010; Valdés and Foster 2010; Christiaensen et al. 2011). The importance of agriculture is, of course, related to the fact that in most low-income countries a large share of the economically active population is still employed in agriculture (e.g. the average of Sub-Saharan African countries in 2010: 59.1% (FAO 2011)). Furthermore, land of good quality becomes increasingly scarce in numerous SSA countries due to limits to rising population density and poor soils. Against the backdrop of consistently high population growth rates (average of Sub-Saharan African countries in 2010: 2.50% (WDI 2012)), growth, poverty reduction and food security will heavily depend on success in raising agricultural productivity.

The extraordinary role of agriculture for poverty reduction has also been highlighted directly and indirectly by several authors from the pro-poor growth literature. Most fundamentally, the poor are regularly characterized as typically living in rural areas, depending directly or indirectly on agriculture for their subsistence and to mainly possess the production factor of (unskilled) labor and to some extent land while human capital is usually rather scarce (e.g. Alderman et al. 2000; Ames et al. 2000; Eastwood and Lipton 2000; Ravallion and Datt 2002; World Bank 2000a). Taking these features together, Klasen (2004) claimed that it is crucial for pro-poor growth to be concentrated on rural areas, to use intensively (unskilled) labor and to enhance agricultural incomes. Eastwood and Lipton (2000) even went a step further and directly related pro-poor growth to the issue of productivity when calling for greater attention that should be given to increasing agricultural productivity in order to attain a significant reduction of poverty. Against the background of such claims, it appears important to assess the distributional pattern of agricultural productivity growth to find out who has benefited from recent improvements (see also World Bank 2007).

We therefore propose and apply several new instruments which should be understood as complements to the existing PPG-toolbox and allow researchers and policy-makers to ex-post evaluate distributional developments in a country from a fourth, agricultural productivity-based perspective. The first tool, which we call the "productivity growth incidence curve" (PGIC) is closely related to the "classical" GIC of Ravallion and Chen (2003) and plots quantiles of the population ranked now by their initial agricultural productivity on the horizontal axis against quantile-specific growth rates (or absolute increases) of agricultural productivity on the vertical axis. The resulting curves give researchers and policy-makers the opportunity to evaluate to what extent the productivity-poor (e.g. in terms of agricultural land productivity) were able to increase their agricultural production per hectare, and thus allow an assessment of how improvements of agricultural productivity are distributed.

The second new tool relies on the idea of the opportunity curve of Ali and Son (2007) and we therefore call it "productivity opportunity curve" (POC) of which two different versions can be constructed. The POC (Type 1[4]) differs from the "classical" opportunity curve in the sense that we no

[4] It should be noted that it would likewise be possible to construct a productivity-based form of a conditional NIGIC where one would then have vintiles of the population sorted by agricultural productivity on the horizontal axis and growth rates/absolute increases in terms of an appropriate non-income indicator (e.g. years of schooling) on the y-axis.

longer have the cumulated share of the population sorted by income on the horizontal axis, but that quantiles are now sorted by agricultural productivity. Hence, such a POC (Type 1) investigates to what extent the productivity-poor are able to increase their education/health levels. In contrast to this, the second version of the productivity opportunity curve plots the cumulated share of the population sorted by education/health/human capital on the horizontal axis against the absolute levels of agricultural productivity on the vertical axis. Thus, it is the goal of the POC (Type 2) to answer the somewhat converse question, namely how the levels of agricultural productivity relate to deprivations in health or education.

Both of these questions are relevant for policy makers for several reasons. First, there is a broad literature indicating considerable productivity-increasing effects of improved farmer's education and health at the micro (e.g. Ali and Flinn 1989; Young and Deng 1999; Alene and Manyong 2006; Asadullah and Rahman 2009 for education and Antle et al. 1998; Croppenstedt and Muller 2000; Loureiro 2009; Ulimwengu 2009; Asenso-Okyere et al. 2011 for health) and the macro level (e.g. Reimers and Klasen 2013). Second, various studies analyzing the effects of different types of government expenditures on agricultural growth and poverty reduction in developing countries showed that investments in social services provision yield considerable returns in terms of agricultural productivity[5] (see e.g. Fan et al. 2000 and Fan et al. 2008 for India; Fan and Zhang 2008 for Uganda). Third, policy-makers are also interested in the question of whether those who suffer from particularly low agricultural productivity were benefiting from expanding opportunities in health and education. This is important from a multidimensional welfare perspective as one is interested to know whether those who are disadvantaged from an agricultural productivity perspective are benefiting from improvements in other dimensions of well-being. It is also important as improvements in health and education of the productivity poor could, over time, set in motion improvements in agricultural productivity, thus facilitating an escape from income poverty.

4. The importance of distinguishing between the land and the labor productivity-poor

Before coming to a concrete application of the expanded PPG-toolbox, we would like to point to the importance of the regularly observed inverse relationship between farm-size and agricultural land productivity (often referred to as the IFSP relationship) for our newly introduced tools. As is well known, over the last decades there have been debates in the academic literature about the reasons for the IFSP given its apparent contradiction to the presumed scale advantage of larger farms due to the lumpiness of various expensive inputs such as farm machinery etc. (Binswanger et al. 1995; Kimhi

[5] To be more precise, these studies found particularly high returns for investments in education whereas the returns to government spending on health turned out to be rather limited.

2006). According to Barrett (2010), it is possible to distinguish between three major explanations for this phenomenon. The first claims that for the existence of the inverse farm-size productivity relationship to exist, there must be failures on (multiple) factor markets which cause unobservable inter-household variation in the shadow prices of the production factors. This variation implies in turn differentials in the input intensity levels which are correlated with farm size and therefore could explain the IFSP (Barrett et al. 2010).[6] The second class of explanations states that an omitted variable bias (e.g. due to differentials in soil quality) is actually driving the IFSP[7] (e.g. Bhalla 1988; Bhalla and Roy 1988; Benjamin 1995). In contrast, the more recent third class of arguments (e.g. Lamb 2003) claims that measurement error/reporting bias in the farm/plot size data may be responsible for the IFSP relationship if smallholders misreport the size of their farms systematically differently from large landowners (Barrett et al. 2010).[8]

Turning to the Rwandan case, we observe in our data a clear inverse farm-size *land* productivity relationship, but a positive association between farm-size and *labor* productivity. This finding is in line with the relatively recent results of Ansoms et al. (2008) and Byiringiro and Reardon (1996) who empirically tested some of the above-described explanations of the IFSP for the Rwandan case. More specifically, Byiringiro and Reardon (1996) recognize that Rwandan households who dispose only of relatively small farms crop their land more intensively, make more ample use of the production factor of labor, let the land more rarely lie idle and invest much more in soil conservation activities. They further find that the marginal value product of land is considerably higher for the smallest farms than the common land rental rate while the marginal value product of labor amounts to as little as one third of the market wage. This kind of "bottling-up of labor on the smallest farms" (Byiringiro and Reardon 1996, p. 132) hence points in the direction that prevailing imperfections on the land and labor markets are the main drivers for the detection of the IFSP relationship in the Rwandan case.[9]

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[6] With regard to the question how such imperfections could actually look like, numerous suggestions have been made in the literature (e.g. Sen 1966; Bardhan 1973; Barrett 1996). A particularly well-known argument suggests that family and hired labor are actually only imperfect substitutes and that labor productivity of hired workers on large farms is positively associated with the level of supervision by the landowner (Feder 1985; Frisvold 1994). Hence, large landowners will regularly exhibit a higher optimal land-to-labor ratio than smallholders and – given imperfections on the land market – the IFSP relationship will emerge (Assunção and Braido 2007).

[7] The underlying assumptions are that if better soil quality actually leads to higher output and if soil quality has a negative correlation with farm size, then the IFSP may be detected if the analysis does not adequately account for differentials in soil quality (Barrett et al. 2010).

[8] It should be pointed out that various relatively recent articles have tried to empirically test the validity of the above-mentioned arguments, but have come to rather conflicting results (see e.g. Kimhi 2006; Assunção and Braido 2007; Barrett et al. 2010).

[9] Yet, it should be emphasized that Byiringiro and Reardon (1996) cannot entirely rule out the possibility that measurement error/reporting bias is also contributing to the detection of the IFSP relationship.

As a result, two things become evident that will be important for the following analysis. First, the fact that some households exhibit relatively high levels of land productivity does not necessarily imply that the production process on these farms is more efficient than on others since the higher land productivity could just have been "bought" at the expense of particularly high levels of labor input. Second, it therefore appears advisable not just to contemplate the land-productivity-poor and assume that these households are automatically also the labor productivity-poor. Instead, one should deliberately contemplate both groups separately, given that this may provide new insights in its own right about who the labor and land productivity-poor actually are and to what extent they benefited from recent developments in the country.

Lastly, it can be argued that for policy-makers both types of productivity-poor are actually different, but important target groups. First, the land productivity-poor could be in the focus of governmental efforts to increase agricultural productivity since – from an endowment perspective – the maximization of crop yields on *all* agricultural land has to have top priority in order to ensure food security in the future. Second, policy makers could also pursue the goal of increasing the agricultural productivity of the labor productivity-poor given that these households regularly exhibit relatively low consumption levels and small farm sizes (see section 7) and given that they are probably those most trapped by the above-described imperfections on the labor and land markets.

Given that the new instruments should be seen as *complements* to the classical devices from the PPG-literature, we will in the following empirical application first apply the existing toolbox (section 6). After this we will use in section 7 the newly introduced instruments (differentiating between land- and labor productivity-poor households wherever possible) to show that they can provide us with additional important insights about recent developments in Rwanda.

5. Data and methodology

For the empirical part of this article, we use data from three waves of the Rwandan Integrated Household Living Conditions Survey (EICV) which were collected in the years 1999-2001, 2005-2006, and 2010-2011. These three surveys are nationally representative and cover 6,420, 6,900, and 14,308 households, respectively (equivalent to 32,153, 34,785, and 68,398 individuals, respectively). The questionnaires of the surveys consist of a wide array of modules that include detailed questions e.g. about agricultural production, education, health, and household consumption. One particularity of the EICV consumption module is that each household was not just visited once, but numerous times (urban households eleven times at 3-day intervals and rural households eight times with 2-day intervals). Such an approach was chosen to ensure that payday-effects are adequately included for urban wage earners[10] and it can hence be expected that the consumption data from the EICV surveys will probably be more reliable than the ones obtained from other surveys where each household was just visited once. As a complement to the EICV2 household data, a community survey was conducted that includes a detailed price module for agricultural and non-agricultural goods on 28 local markets throughout Rwanda. The data from this price module will be used for the calculation of the agricultural production aggregate (see below).

As a first step of data preparation, we calculated a deflated[11] annual consumption aggregate for each household. In doing so, we mainly followed the approach used by the Rwandan National Institute for Statistics (NISR) in collaboration with the Oxford Policy Management Team (OPM) under the lead of Andy McKay and Emilie Perge (see NISR (2012) and Appendix A for a description of the approach).

Secondly, we computed two measures of agricultural productivity (namely labor and land productivity) for each household involved in agriculture whereat both measures were calculated in a four step-procedure as follows. Given that Rwandan farmers regularly report their harvests in non-standard units (i.e. not in kilogram, liters etc.), we had – as a first step – to calculate the average weight for each crop-container combination to be able to convert the harvest reported in non-standard units to kilograms. As a second step, we used the above-described price data from the EICV2 community survey to calculate regional average prices per kg for each crop. The resulting prices are – as a third step – used to convert the total harvest in kg for each crop in each of the in Rwanda typically two harvest periods into monetary values. The fourth step is then to simply aggregate the monetary values of those harvests on a household-level and to divide this sum either by the total size of *active* agricultural plots in hectares (i.e. excluding all plots lying idle in the time period under consideration) or by the total number of adults in a household who consider agriculture as their primary occupation[12]. The resulting measures of agricultural land/labor productivity reflect the theoretical[13] monetary value (in constant 2005 regional market prices) of the household's gross agricultural production per hectare of agricultural land/per adult worker in the 12 months preceding the survey.

[10] The issue of payday-effects can be expected to be rather less severe for rural areas of Rwanda where only small shares of the population are actually wage earners. Consequently, it was considered less important to maintain the 30-day reference period for rural households and a reference period of 14 days was applied instead (MINECOFIN 2002).

[11] When adjusting for price differences, we used January 2001 as a basis for our consumption aggregate.

[12] Unfortunately, the information on agricultural labor contained in the EICV datasets are relatively crude and we therefore consider our measure for agricultural land productivity as more reliable.

[13] We are using the term *theoretical* since this number relies on the total amount harvested and not the total amount actually sold by the household, i.e. this number includes the monetary value of the harvest used e.g. for self-consumption, seeds, etc..

As a last step of data preparation, we computed various health and education indicators for both surveys. Given that those measures are standard in the literature, we do not explain their calculation in further detail. Before starting to discuss the findings of our empirical application, we would like to emphasize that the results of the following PPG-analysis could generally have been presented in two alternative ways. First, we could have focused the analysis on the entire Rwandan population for the existing PPG toolbox and have then restricted the analysis to the agrarian population for our newly developed tools where we require detailed agricultural production data. However, this approach would prevent comparability of the results of the two sections since they were actually based on different samples. We therefore decided to restrict the sample throughout the entire PPG-analysis to the agrarian population which comprises in our case all households where at least one adult household member (aged 15 and above) reported working on the farm as his/her primary occupation. In this context, it should be noted that in Rwanda, as in many developing countries, the share of agricultural households declined in recent years. More specifically, while according to the EICV1 survey still approx. 89.20% of the population fulfilled our above definition of an agricultural household, this share reduced to 84.25% in the EICV2 and 76.82% in the EICV3 survey, respectively. To give the reader a first idea of our sample, Table 1 provides an overview of the means of some key indicators for all three EICV surveys.

Table 1: Sample means for EICV1, EICV2 and EICV3 (agrarian population only)

	EICV1	s.e.	EICV2	s.e	EICV3	s.e
No. of households	5,376		5,399		10,843	
No. of individuals	26,705		27,668		52,978	
Household size	4.94	(0.034)	5.11	(0.032)	4.88	(0.023)
Age of household head	44.39	(0.223)	45.23	(0.219)	46.82	(0.173)
Share of male headed households (%)	67.44	(0.706)	71.86	(0.635)	72.30	(0.469)
Literacy rate (% - aged 15+)	51.73	(0.459)	63.15	(0.401)	67.45	(0.299)
Years of schooling (aged 15+)	2.38	(0.026)	3.42	(0.024)	3.84	(0.019)
Years of schooling of household head (aged 15+)	1.30	(0.036)	2.91	(0.041)	3.10	(0.031)
Share of households having access to impr. drinking water (%)	67.86	(0.707)	68.16	(0.654)	72.11	(0.447)
Share of households having access to impr. sanitation (%)	47.94	(0.751)	56.70	(0.699)	74.49	(0.448)
Illnesses/injuries in the last 14 days (%)	26.48	(0.298)	19.75	(0.248)	17.47	(0.182)
Annual consumption expenditures per a.e. (in 1000 RWF)	71.43	(0.734)	78.59	(0.749)	88.97	(0.621)
Farm size (hectare)	0.80	(0.014)	0.76	(0.015)	0.61	(0.008)
Number of persons having agriculture as their prim. Occupation	2.17	(0.016)	1.98	(0.014)	1.76	(0.009)
Value of ann. gross production per ha (in 1000 RWF)	455.70	(8.022)	509.87	(6.505)	517.01	(3.829)
Value of ann. gross production per worker (in 1000 RWF)	100.26	(1.667)	128.51	(1.831)	140.31	(1.296)

One issue worth mentioning is the relatively low share of male headed households in Rwanda (compared to other Central African states) which has increased by almost five percentage points between EICV1 and EICV3. These low values are still a consequence of the Rwandan genocide in 1994 where mortality was much larger for men than for women. Besides that, considerable progress can be observed for all three education indicators and also for the three health indicators (perhaps with the exception of access to improved drinking water sources where progress was rather limited). Furthermore, it can be seen that Rwanda's rapid economic growth over the last years is also reflected in our micro data where the average annual consumption expenditures per adult equivalent (in constant January 2001 prices) grew from approx. 71,435 RWF in EICV1 to 88,973 RWF in EICV3[14]. Turning to the agricultural data, the increasingly important problem of land scarcity becomes obvious in the numbers for the avg. land size per farm household where levels were substantially below one hectare in all three surveys and, due to population growth, decreased even further between the EICV1 and EICV3 surveys from 0.80 to 0.61 hectare. These values are particularly alarming given that consequently a large share of Rwandan households cultivates less than 0.7 hectares which is – according to the Rwandan Ministry of Agriculture – the minimum land size required to provide a typical Rwandan family with sufficient food for their living (Howe and McKay 2007). The calculated relatively high values of annual gross production per hectare of approx. 517,012 RWF (EICV3) in combination with the relatively low values of annual gross production per worker of approx. 140,310 RWF (EICV3) are therefore not entirely surprising given that farming is until today the main source of income for a considerable share of Rwandan households and that these households have – with limited access to agricultural land and scarce employment opportunities outside of agriculture – virtually no other alternative than trying to increase the productivity of their scarce land by the excessive use of (manual) labor.

6. Results for the existing PPG toolbox

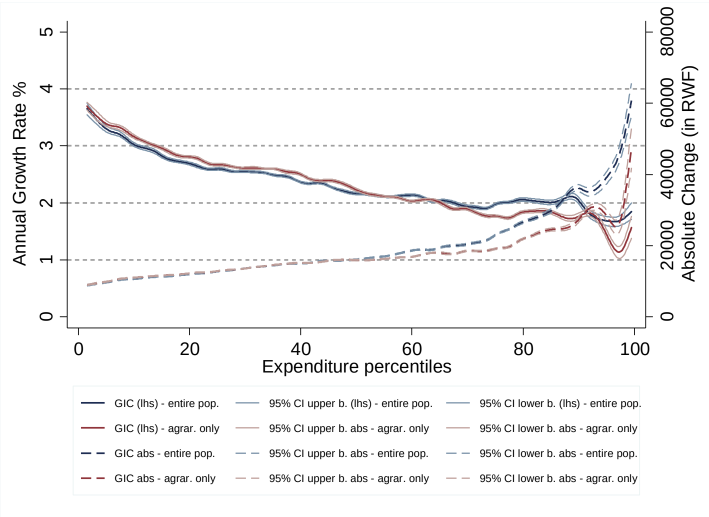
Figure 1 approaches the question of who has benefitted from recent developments in Rwanda from the income[15] perspective. To illustrate how closely related the above-mentioned samples from the agrarian and the entire population actually are, we computed, for the case of the "standard" GICs

[14] It should be noted that these numbers differ from the ones reported in NISR (2012) due to two reasons. First, as described in Appendix A, we decided to exclude the use value of durable goods and the (imputed) rents for the household's dwelling from our consumption aggregate which leads to a lower consumption per adult equivalent. Second, other than NISR (2012) we used an exponent of 0.9 to explicitly account for economies of scale in the household which reduces our denominator when calculating the consumption expenditures per adult equivalent, thus leading to higher values for this indicator. It turns out that the first effect over-compensates the second and we therefore obtain lower values for the annual consumption expenditures per adult equivalent compared to NISR (2012).

[15] We speak here (and henceforth) of *income-poor* households even though it would be more precise to use the term *expenditure-poor* given that we based our rankings on the consumption expenditures per adult equivalent. However, we think that it is straightforward to still speak of the income-poor since the consumption expenditures were only used as a proxy for income due to the typically high volatility of household incomes in developing countries.

(based on Ravallion and Chen 2003), the curves separately for the entire and the agrarian population.[16]

Figure 1: Income growth incidence curves: EICV1-EICV3



As can be seen, the resulting relative and absolute GICs[17] lie above zero for all percentiles of the respective populations (i.e. consumption expenditures of all percentiles increased between EICV1 and EICV3) which implies that growth has been pro-poor according to the weak-absolute definition. Comparing the annual growth rate in the mean which was 2.02 % for the agrarian population (see Appendix D) with the mean growth rate of the income-poorest 20%[18] of the same agrarian population (3.18%) further reveals that growth has also been pro-poor in the relative sense.[19] However, as indicated by the upward sloped absolute GICs (bold dashed lines), the absolute increases of the poor were for both samples smaller than those of the non-poor indicating that growth has not been pro-poor according to the strong-absolute definition (abs. increase in the mean of 17,538 RWF compared to an avg. increase for the poorest 20% of 10,793 RWF).

[16] It would have been possible to do this analogously for all other tools from the existing PPG-toolbox. However, we recognized that this would actually overload some of the graphs and would therefore make their interpretation quite complex.

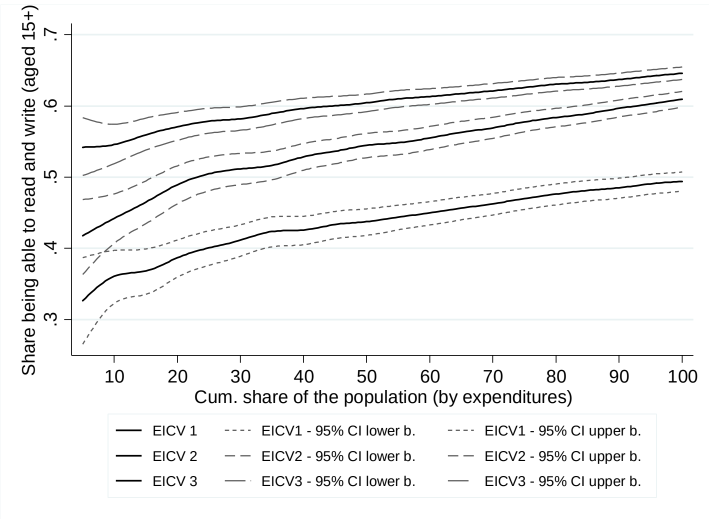
[17] In line with Grosse et al. (2008) and Klasen (2008), we included in all figures shown below the bootstrapped 95% confidence intervals which are constructed by first drawing 200 random samples (with replacement) for each of the two periods and separately calculating the percentiles, growth rates and absolute increases for each of these drawings. In a second step, we then calculate the mean and the standard deviation over the 200 observations and use the resulting values to calculate the 95% confidence intervals.

[18] In the following analysis, we will always define the poor to be the poorest 20% of the population in terms of the dimension of interest. However, given that this threshold is obviously debatable, we included in Appendix D also the growth rates/absolute increases of other shares of the population.

[19] For the entire population, the finding would be very similar, yet with PPG in the relative sense being slightly less pronounced.

In order to account for the multidimensional nature of poverty, we use the literacy rate[20] for the population aged 15 and above as a first education indicator and construct opportunity curves following the approach of Ali and Son (2007)[21]. As can be seen in Figure 2, the literacy levels for income-poor households are substantially below those of richer households. However, throughout the income distribution considerable progress between the three survey rounds can be observed which is reflected in an upward shift of the curves. This can e.g. be exemplified for the poor (again defined as the poorest 20%) of which in the EICV3 survey as much as 57.07% of all adults were literate (see Appendix C) while the corresponding share only amounted to 38.68% in the EICV1 survey which was collected approximately eleven years earlier.

Figure 2: Opportunity curves for adult literacy (aged 15+)



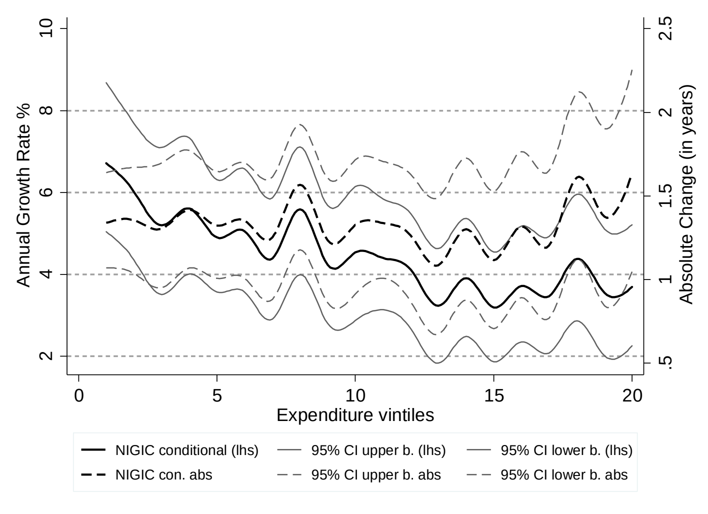
This progress has to be judged as pro-poor in the weak-absolute (given that all poor vintiles of the population were able to increase their avg. literacy levels) and the relative sense (annual growth rate of the poor of 3.65% compared to a GRIM of 2.47%). In addition, progress was even pro-poor according to the ambitious strong-absolute definition with the increases for the poor being 18.39%-points (compared to an abs. increase in the mean of 15.18%-points).

Given that the adult literacy rate is for various reasons a rather imperfect education indicator (Barro and Lee 1993; for recent evidence see Reimers and Klasen 2013), we also use the average years of schooling for individuals aged 15 and above as a second measure for education.

[20] In line with the related literature, we define literacy here as the ability to read *and* write.

[21] It should be noted that we calculated the 95% bootstrapped confidence intervals also for the opportunity curves in this article (Ali and Son (2007) did not show any confidence intervals in their original article). However, we think it is important to show the confidence intervals to give the reader a feeling for the precision of the estimates.

Figure 3: Conditional NIGICs for avg. years of schooling (aged 15+): EICV1-EICV3

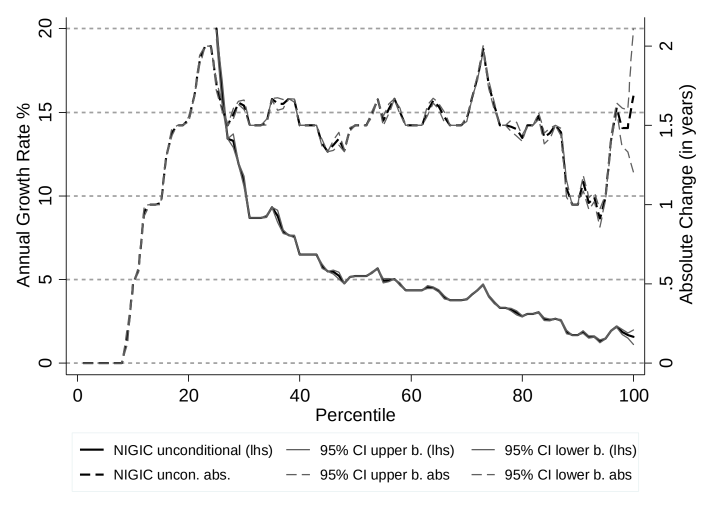


The conditional NIGICs for the avg. years of education (Figure 3) generally confirm the above-described results for the adult literacy rate. In particular, we find that all vintiles[22] of the population were able to increase their average level of schooling in the time period under consideration (i.e. growth has been pro-poor in the weak-absolute sense) and that the annual growth rate of the poor (5.89%) exceeded the growth rate in the mean (4.35%) which implies that growth has been pro-poor according to the relative definition. Yet, for this indicator, progress was not clearly pro-poor in the strong-absolute sense since the absolute increase for the poor (1.35 years of schooling) was almost identical to the absolute increase in the mean (1.34 years of schooling). Nevertheless, it should be pointed out that for both indicators the magnitude of the achieved progress is impressive given that the adult literacy of the income-poor increased in only about eleven years by as much as 18.39%-points or put differently, an income poor Rwandan adult observed in the EICV3 survey had received approx. 1.35 years of schooling more than an income-poor adult observed in the EICV1 survey. This is particularly remarkable since most of the older individuals no longer attend any form of education and act therefore as a kind of inbuilt-inertia for the indicator; thus the improvements derive mostly from poorly educated cohorts dying and being replaced by better educated younger cohorts.

As a last step of the analysis in the field of education, we calculated the unconditional NIGIC for the avg. years of schooling where we no longer rank households by income per adult equivalent on the horizontal axis but by the endowment in terms of education (i.e. years of schooling). As can be seen from Figure 4, the shape of the unconditional NIGIC greatly differs from the conditional NIGIC which is to some extent a consequence of the fact that there is a considerable share of households where no adult has received any education.

[22] In line with the recent literature (e.g. Grosse et al. 2008 and Klasen 2008), we used vintiles instead of percentiles of the population for the conditional NIGICs (and likewise for the opportunity curves) given the relatively high heterogeneity of non-income achievements (and related growth rates) within income quantiles.

Figure 4: Unconditional NIGICs for avg. years of schooling (aged 15+): EICV1-EICV3



However, this share decreased extraordinarily between EICV1 and EICV3 from approx. 24% to 8% which is reflected in the graph by the increase of the *absolute* NIGIC[23] from 0 to almost 2 years between the percentiles 9 and 24. From a pro-poor growth perspective, this means that considerable progress has been made in providing the education-poor with schooling. Furthermore, also for those quantiles where household members had already in the EICV1 survey received some education (to the right from percentile 24), the absolute increases in terms of schooling were – with an average increase of almost 1.5 years – very impressive. When comparing these findings to the results presented by Grosse et al. (2008) for Bolivia (1989-1998) and Burkina Faso (1994-2003), it can be recognized that Rwanda in fact was much more successful than Burkina Faso and even slightly more successful than Bolivia in increasing the education-levels of the education-poor.

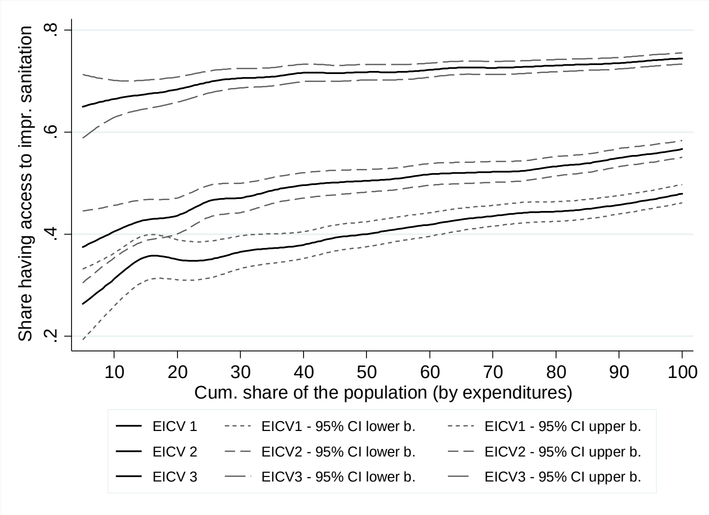
Turning to the health dimension of poverty, we analyzed – as a first step – how the agrarian population's access to improved sanitation[24] developed in the time period under consideration. As shown by the opportunity curves in Figure 5, the level of access to improved sanitation of poor households was considerably below the one of non-poor households at the time of EICV1. However, we see a considerable upward shift of the opportunity curves between EICV1 and EICV3 which is particularly large between EICV2 and EICV3. For example, the access to improved sanitation for the poorest 20% of the population increased from 35.1% (EICV1) to 68.4% (EICV3). Not surprisingly, this progress has to be judged as pro-poor according to all three definitions given that the access to improved sanitation has increased for all vintiles of the population and that both, the annual avg. growth rate (6.43% compared to a GRIM of 4.09%) as well as the avg. absolute increase (33.33%-

[23] It should be noted that a relative unconditional NIGIC is up to percentile 24 not defined given that the denominator for the growth rate is in these cases equal to zero. For this reason, we also refrain from categorizing the progress into the three pro-poor growth classifications.

[24] The categorization of sanitation facilities into improved and unimproved systems was done based on the definition provided by the Joint Monitoring Programme of UNICEF and WHO (JMP 2012).

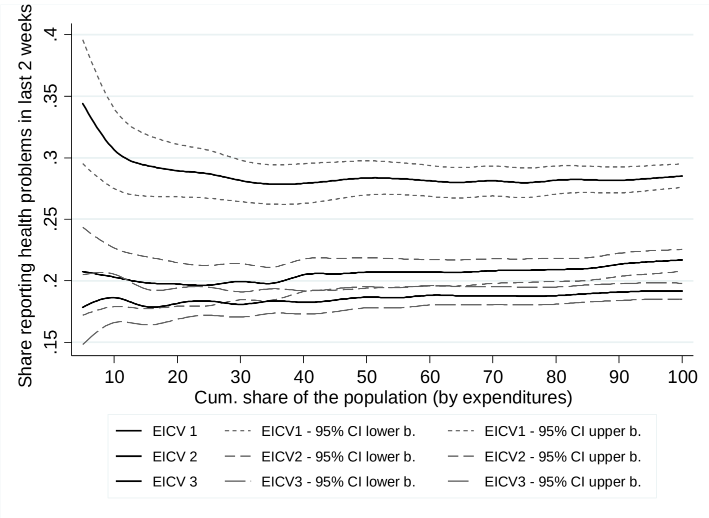
points compared to an avg. absolute increase in the mean of 26.54%-points) have been higher for the poor than for the non-poor.

Figure 5: Opportunity curves for access to improved sanitation



As a second health indicator, we then looked at the access to improved drinking water sources[25] (Appendix E) where the picture is much less positive and the data suggest that the access of the income-poor to improved drinking water sources only improved marginally between the surveys (68.8% in EICV1 to 69.3% in EICV3). Despite the admittedly relatively broad confidence intervals of these curves, this is certainly a point which requires particular attention of the Rwandan authorities and where considerable progress can potentially be made in the future.

Figure 6: Opportunity curves for health problems in the last two weeks



Lastly, we analyzed data for self-reported illnesses/injuries in the two weeks preceding the interview (Figure 6). Against the background that the perception of being ill or injured may differ greatly

[25] The categorization of drinking water facilities into improved and unimproved systems was likewise done on the basis of the definition from JMP (2012).

between individuals, such numbers have always to be treated with caution. However, one would expect that – on average over the whole population – this subjective assessment will remain relatively stable over time (at least for relatively short time periods) and it may therefore be worthwhile to look at time trends for this indicator.

The resulting opportunity curves in Figure 6 reveal an extraordinarily rapid reduction of levels for this indicator especially between EICV1 and EICV2. While in the EICV1 survey still 28.94% of the poor were reportedly injured or ill in the two weeks preceding the interview, this share amounted just to 19.73% in EICV2 and decreased further to 18.15% in EICV3. This enormous progress implies pro-poor growth according to all three definitions since the incidence of illness declined for all poor quantiles of the population and decreased more rapidly in relative and absolute terms for the poor than for the non-poor (-4.11% for the poor compared to a GRIM of -3.55% and -10.79%-points reduction for the poor compared to an abs. decrease in the mean of -9.36%-points).

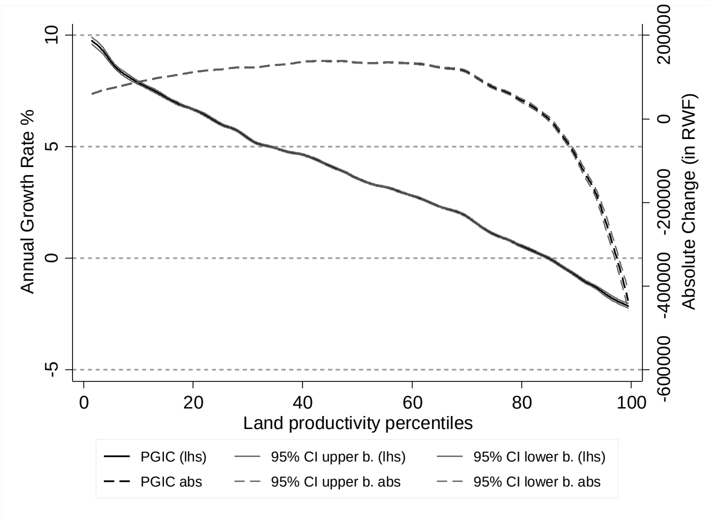
7. Results for the agricultural perspective

Until now, we applied the existing pro-poor growth toolbox and concluded that household per adult equivalent incomes have not only increased in the mean, but also for the poor significantly between the three surveys. Furthermore, the analysis revealed that the education and health levels of the income-poor (and the education-poor for the case of the years of schooling) improved considerably and that this progress has on various occasions been pro-poor not only according to the weak-absolute and relative, but also according to the strong-absolute definition of pro-poor growth.

We now want to look at pro-poor growth from the agricultural perspective and ask to what extent the poor in terms of agricultural productivity were able to increase their productivity levels between the three survey rounds. As emphasized in section 4, it would be misleading to simply assume that the land and the labor productivity-poor are in the Rwandan case the same households. This can be illustrated with the tables in Appendices F and G which nicely show that both groups actually exhibit quite different characteristics with the labor productivity-poor being considerably poorer (particularly in terms of land holdings, but also in terms of consumption per adult equivalent). As a consequence, we will in the following analysis distinguish between the land and the labor productivity-poor whenever our data allows.

As a first step of our analysis for the agricultural perspective, we therefore calculate a *monetary* productivity growth incidence curve where we use as our indicator for agricultural productivity the monetary measure for the household's gross agricultural production per hectare of agricultural land in the 12 months preceding the survey (see section 5).

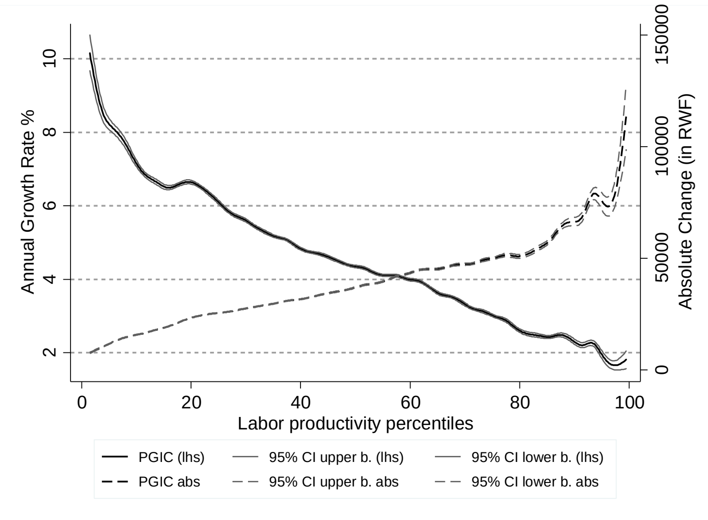
Figure 7: Monetary land productivity growth incidence curves: EICV1-EICV3



As shown in Figure 7, the resulting relative monetary PGIC has quite narrow confidence bands and is clearly sloped downwards indicating that agricultural productivity increased relatively faster for land productivity-poor households whereas productivity growth was even slightly negative for the land productivity-richest households. In absolute terms, the curve exhibits a somewhat different pattern with a maximum absolute increase in agricultural productivity for percentile 47. Still, the achieved progress has to be judged as pro-poor according to the weak-absolute, the relative and the strong-absolute definition (abs. increase in the mean of 61,313 RWF compared to an avg. increase for the poorest 20% of 87,971 RWF).

In line with our above explanations, we calculated – as a second step – the corresponding monetary PGICs for agricultural *labor* productivity (Figure 8). Again, the absolute PGIC lies above zero for all productivity-poor percentiles and the relative PGIC exhibits a clearly downward sloped pattern which indicates pro-poor growth in the weak-absolute and the relative sense. Yet, given the upward sloped absolute PGIC, one has to acknowledge that labor productivity growth has not been pro-poor according to the strong-absolute definition. From a poverty perspective these results are nevertheless quite encouraging given that they imply that the labor productivity-poor were able to increase the yield per worker considerably and even relatively faster than the labor productivity-rich.

Figure 8: Monetary labor productivity growth incidence curves: EICV1-EICV3



The monetary PGICs in Figure 7 and 8 are generally a relatively straightforward way to evaluate to what extent the productivity-poor (either land or labor productivity) were able to increase their productivity levels. However, there are at least two reasons why the results of these monetary PGICs should be interpreted with some caution. First, in contrast to many of the non-income indicators, increases in agricultural productivity may not be the result of a (more or less) steady process but are of a relatively volatile nature e.g. they could be due to adverse/good weather conditions. Therefore, one should be rather careful when interpreting the *levels* shown in Figure 7 and 8 since it could theoretically be that the EICV1 data were simply collected in a very bad and/or the EICV3 data in a very good year in terms of agricultural harvest. Second, there may be differentials in the crops planted by the productivity-poor and -rich. For instance, it could be that we observe declining relative PGICs due to the fact that harvests of the most prevalent crops planted by the productivity-rich were rather bad while harvests for the most prevalent crops of the productivity-poor were rather good.[26] Despite these downsides, we interpret the results in Figure 7 and 8 as first indications that the increases in agricultural land/labor productivity were rather distributed in a pro-poor manner.

Against the background of the above-described drawbacks, we calculated as a third step of our productivity analysis *crop-specific* PGICs for land productivity[27] for the three most important single crops in Rwanda (according to the land use numbers reported in the EICV3 survey) which are in

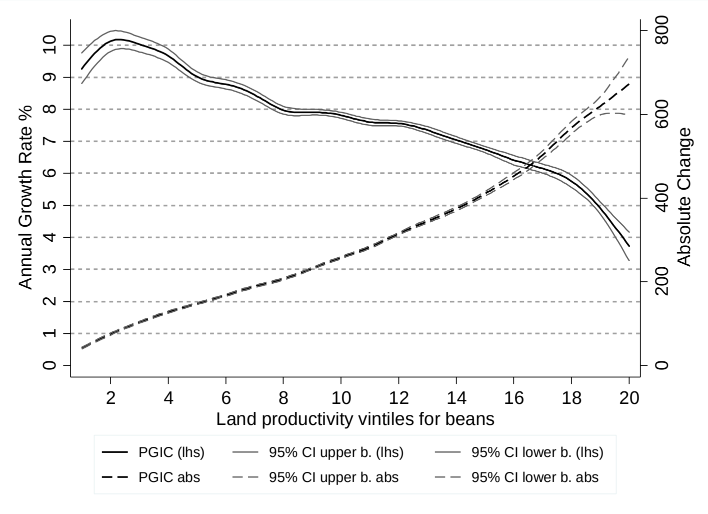
[26] One could also argue that our results may be driven by systematic measurement error in the harvests of the poor in one of the two contemplated surveys. However, we are quite confident that this is not the case given that we observe quite similar patterns also for sub-periods (EICV1-EICV2 and EICV2-EICV3, respectively) as well as independently for various crops.

[27] Given that the EICV data do not contain detailed information on labor input by crop, we were unfortunately not able to calculate crop-specific PGICs for agricultural labor productivity.

decreasing order of importance: beans, manioc and maize (see Appendix H for the exact share of each crop in the three surveys). Taken together these three crops account for almost half of all agricultural land reported which underlines the crucial importance of the crops for Rwanda's agricultural sector.

In comparison to the monetary PGICs, these crop-specific PGICs have the advantage that the underlying productivity measure is no longer a combination of the (theoretical) revenues generated by various crops per one hectare of agricultural land, but that it is now simply the total amount harvested (in kilograms) of the crop of interest per hectare. This basically solves the second of the two above-described problems since it is no longer possible that a certain shape of the PGIC is simply a consequence of different crops planted by the productivity-poor and -rich.[28]

Figure 9: Land productivity growth incidence curves for bean production: EICV1-EICV3



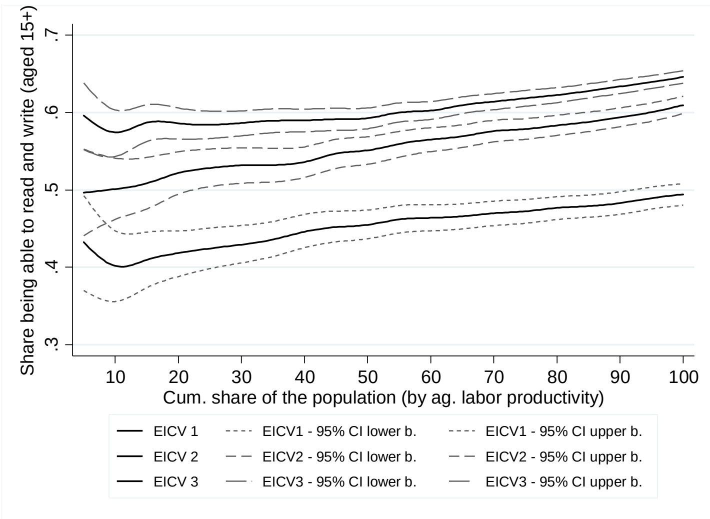
As can be seen from the crop-specific PGICs for bean production in Figure 9, all vintiles of the bean-producing population were able to increase their agricultural land productivity considerably in the time-period under consideration (even though one should – as noted above – interpret the levels with some caution). What is even more interesting is, however, the shape of the relative PGIC which has a negative slope indicating that the productivity-poor (in terms of bean production per hectare) were able to increase their land productivity relatively faster than the average (annual avg. growth rate for the poor of 9.77% compared to a GRIM of 6.24%), i.e. growth has been pro-poor in the relative sense. A similar picture (even though with slightly different shapes of the crop-specific PGICs) is obtained when looking at manioc and maize production likewise indicating pro-poor growth

[28] It should be noted that the above-described analysis still assumes both homogeneity in the crops and in the quality of the harvest. However, given that these are common assumptions in the analysis of household-level production data and that there is no real way to solve these issues, we accept it as one possible source of measurement error in our analysis.

according to the weak-absolute and the relative definition (see Appendices I and J).[29] In this sense, the results of the crop-specific PGICs are in line with the findings from the monetary PGICs and are quite encouraging that recent efforts of the Rwandan government to increase agricultural land productivity of the productivity-poor were successful. Nevertheless, it should be noted that the absolute harvest increases of the productivity-rich were – for all three crops considered – substantially larger than those of the productivity-poor which implies that the absolute gap between the two groups has risen considerably.

Until now, we studied recent developments in Rwanda from a purely productivity-based perspective trying to answer the question to what extent the land/labor productivity-poor were able to increase their yields per hectare/worker. Given the above-described evidence from the micro and macro level of productivity-enhancing effects from increased education and health, we ask as a next step how well the labor productivity-poor are equipped in these two dimensions. This is done by constructing labor productivity opportunity curves (Type 1) for the adult literacy rate (Figure 10) as well as the incidence of illness/injuries in the two weeks preceding the survey (Figure 11 - the corresponding curves for agricultural land productivity are provided in Appendices L and M).

Figure 10: Labor productivity opportunity curves (Type 1) for adult literacy (aged 15+)

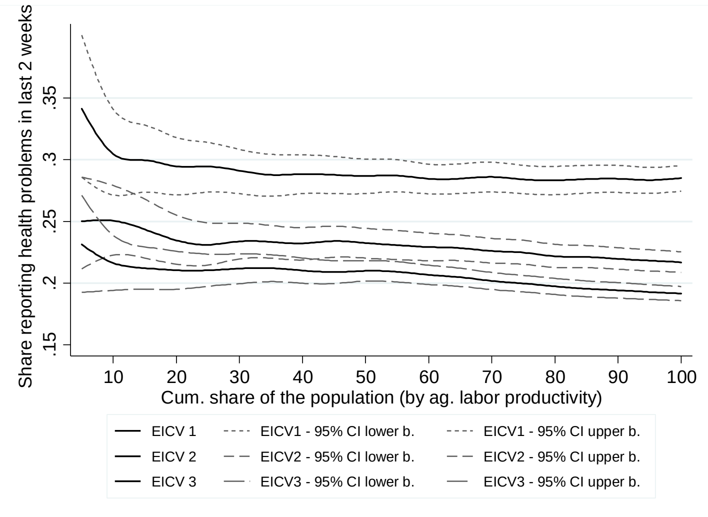


As shown in Figure 10, all three labor productivity opportunity curves are sloped upwards implying that literacy levels of the productivity-poor were in all surveys below those of the productivity-rich. Yet, the POCs further show that the productivity-poor were not excluded from the expansion of education in Rwanda and were in fact able to increase their average literacy levels in the time period under consideration from approx. 41.83% (EICV1) to 58.62% (EICV3). This has to be judged as a quite

[29] To illustrate that this favorable result is by no means warranted, we also show in Appendix K the Land PGIC for maize production between EICV1 and EICV2 which exhibits a clearly negative slope (i.e. an anti-poor development in the relative sense).

impressive development which was not only pro-poor in the weak-absolute, but also in the relative and strong-absolute sense (abs. increase in the mean of 15.18%-points compared to an avg. increase for the poorest 20% of 16.79%-points). Hence, the absolute education gap between the labor productivity-poor and -rich has decreased slightly during the time period under consideration. Turning to self-reported health problems in the last two weeks, Figure 11 reveals slightly higher incidence levels and a smaller decrease in the indicator of interest for the labor productivity-poor compared to the labor productivity-rich (yet with relatively wide confidence intervals) which implies that developments have been pro-poor in the weak-absolute, but not in the relative and strong-absolute sense. When comparing these findings to those for the land productivity-poor (Appendices L and M), we find indications that the education-levels of the land productivity-poor are likewise smaller than those of the land productivity-rich (particularly in the EICV2 and EICV3 survey), but we do not find any evidence for differentials in the incidence of health problems between the land productivity-poor and -rich.

Figure 11: Labor productivity opportunity curves (Type 1) for health problems in the last two weeks

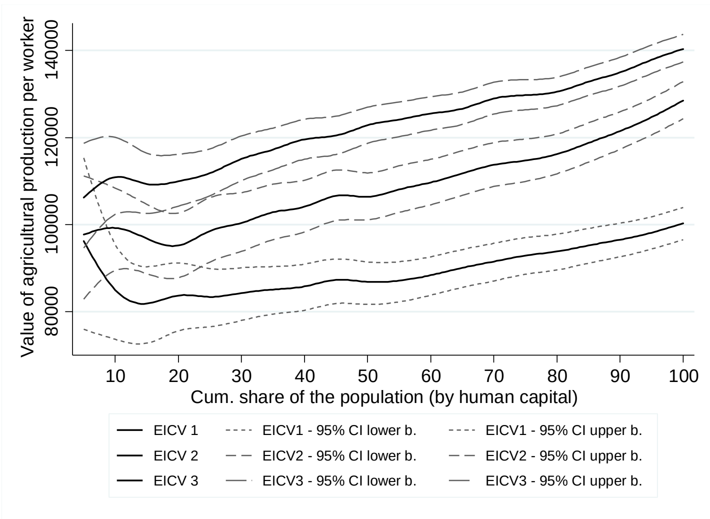


As a last step of our analysis, we pursue the converse question, namely whether the productivity levels of the human capital-poor are lower or higher than those of the human capital-rich. To be able to answer this question, we calculate productivity opportunity curves (Type 2) separately for land and labor productivity which are constructed in a two-step-procedure as follows. First, we use principal component analysis to calculate a human capital index which reflects each household's endowment with human capital.[30] Based on this index we then rank households (cumulated) on the

[30] More specifically, we use three education indicators (adult literacy, adult participation in school, adult years of schooling) and three health indicators (self-reported health problems in the last 14 days, access to improved drinking water sources, access to improved sanitation) to construct our human capital index.

horizontal axis and plot this against the land/labor productivity levels on the vertical axis. The resulting POCs (Type 2) for the case of agricultural labor productivity can be seen in Figure 12 and reveal a positive slope indicating that the labor productivity levels of the human capital-poor are in fact in all three surveys below those of the human capital-rich. Moreover, it seems that indeed both groups were able to increase their labor productivity levels, but that the increase for the human capital-poor was less rapid (annual avg. growth rate for the human capital-poor of 2.57% compared to a GRIM of 3.10%) which hence implies a widening of the absolute gap in labor productivity levels between the human capital-poor and -rich. A similar finding is obtained when looking at the corresponding POCs (Type 2) for land productivity (Appendix N) where developments likewise failed to be pro-poor in the relative sense.[31]

Figure 12: Labor productivity opportunity curves (Type 2) for human capital



8. Conclusion

In the pursuit of sustainable poverty reduction worldwide, pro-poor growth has been identified by many researchers and organizations as probably the most promising pathway to achieve this ambitious goal (e.g. United Nations 2000; World Bank 2000a, b; Ravallion 2001; Klasen 2004; Besley and Cord 2007). Against this background, multiple authors have made suggestions for how pro-poor growth can be measured which has led to the creation of the so-called "pro-poor growth toolbox". The instruments contained in the existing toolbox look at pro-poor growth mainly from the income or the education/health dimension answering the question to what extent the poor in terms of income or education/health were able to benefit from recent developments. However, we argue in this article that the toolbox could be further extended to take account of the crucial importance of

[31] Instead of taking human capital as a whole, we also differentiated between the education-poor and -rich and the health-poor and -rich. It turned out that results for human capital are mainly driven by our education indicators and to a smaller extent by the health measures.

the agricultural sector for poverty reduction worldwide (e.g. World Bank 2007; de Janvry and Sadoulet 2010; Valdés and Foster 2010; Christiaensen et al. 2011). We therefore suggest that one can define the poor not only in terms of income or education/health, but also in terms of agricultural productivity and that it is possible by slightly modifying some of the existing tools to account for this agricultural productivity perspective on poverty. We further emphasized that it is important to recognize that the land and the labor productivity-poor can be different households exhibiting quite different characteristics, so it may be warranted to conduct such an analysis separately for both subgroups. The resulting labor/land productivity growth incidence curves (in two versions: monetary and crop-specific) and the labor/land productivity opportunity curves (likewise in two versions) should be seen as complements to the existing toolbox and allow researchers as well as policy makers to gain further insights about who has benefited from recent developments in the country of interest from quite different angles.

This was illustrated for the case of Rwanda using three waves of the nationally representative EICV household surveys. The results for the existing PPG-toolbox indicate that income growth of the poor was relatively faster than for the average, implying that Rwanda successfully achieved pro-poor growth in the weak-absolute and the relative sense. Furthermore, the access of the income-poor to education and health increased impressively in the time period under consideration and this progress was on various occasions even pro-poor according to all three definitions (examples of adult literacy, access to improved sanitation and incidence of illness/injuries). However, room for improvement was identified for the access to improved drinking water sources where the access levels of the (income-) poor only improved marginally.

Turning to the agricultural perspective, the two types of monetary PGICs provided us with first indications that productivity growth of the labor/land productivity-poor was relatively faster than for the labor/land productivity-rich. This finding was confirmed by the three crop-specific land productivity growth incidence curves (for beans, manioc, and maize) which uniformly suggested that productivity growth was not only pro-poor according to the weak-absolute, but also according to the relative definition.[32] Moreover, the productivity opportunity curves (Type 1) revealed lower literacy levels (and slightly higher incidence levels of self-reported illness/injuries) for the labor productivity-poor, thus pointing in the direction that the labor productivity-poor are constrained in their access to social services. However, we observe that both, labor productivity-poor and -rich, were able to improve their education levels considerably between the three surveys and that the gap in literacy

[32] Yet, it is important to emphasize that the rapid increases in agricultural land productivity have to be seen in the Rwandan context with some caution since they may on the one hand indeed be due to efficiency gains by Rwandan farmers, but may on the other hand also be a consequence of a further “bottling-up of labor on the smallest farms” (Byiringiro and Reardon 1996, p. 132).

levels between the two groups actually decreased slightly. Lastly, the POCs (Type 2) showed that the human capital-poor in fact exhibit conspicuously lower levels of labor and land productivity compared to the human capital-rich and that their productivity increases were smaller in both, relative and absolute terms. This result appears not entirely surprising given the above-discussed broad evidence in the literature of positive effects of improved education/health on agricultural productivity on the micro and the macro level.

Taken together the above results are encouraging in the sense that the Rwandan agricultural sector experienced in the first decade of the 2000s a period with rapid increases in agricultural productivity levels. It appears likely that these successes are to some extent a consequence of the wide array of programs to modernize the agricultural sector that were set up by the Rwandan government as part of the *Rwanda Vision 2020*[33]. While future research may shed further light onto which single interventions worked best in reaching the (productivity-)poor, this analysis has shown that the overall mix of programs led to a situation where productivity-poor households in Rwanda were able to benefit disproportionately (at least in relative terms) from productivity growth.

We conclude with some caveats and further suggestions. First, we are aware of the fact that all data obtained from household interviews (and particularly information on agricultural production) may be prone to considerable measurement and/or recall error which could bias our results. However, we did our best to reduce such measurement error by systematically cleaning the data from outliers at the most disaggregated level possible (i.e. the crop- and item-region-level for the production and the consumption aggregate, respectively) and included various types of plausibility checks. With regard to the existence of a recall bias, it should be noted that a recent article by Beegle et al. (2012) tested this issue empirically coming to the conclusion that the quality of recalled agricultural production data is actually better than expected. Second, we would like to point out that – by definition – the previous analysis cannot prove any kind of causality and it should further be emphasized that many factors have an impact on agricultural productivity for which we did not control in our analysis (e.g. differentials in climate, infrastructure, input use etc.[34]). Nevertheless, we consider the information provided by such a pro-poor analysis as an interesting first step for policy-makers and practitioners in the development field to pursue the question *who* has actually benefited from recent developments in a country. The results may then contribute to improve the targeting of governmental and non-governmental efforts in the field of education, health or agricultural policy. Against the background

[33] To highlight only a few, one could mention the various crop intensification programmes, the commercialization of crops initiative as well as the erosion protection programmes.

[34] A relatively easy way to account for differentials in location-specific factors such as climate would either be to re-conduct the above analysis on the region/province level or to first run a regression of agricultural productivity on climate indicators and then construct the PGICs/POCs using the residual of this regression. Yet, in an attempt not to overload this article, we decided to leave this exercise for future research.

that Rwanda is in many dimensions in a pioneering role for other SSA countries – being it the introduction of a national health insurance or the increasing scarcity of agricultural land – the case study provided in this article should further be seen as an opportunity for other SSA countries to learn from the quite successful Rwandan experience over the last years.

Appendix A: Construction of the Consumption Aggregate

We included in our consumption aggregate all food purchases, consumption of own produced food, non-food consumption (in line with Deaton and Zaidi (2002) excluding rather "lumpy" expenditures), regular health and education expenses, cost of utilities (such as electricity or drinking water), and wages/transfers/other benefits received in kind (as a counterpart to consumption).[35] For outlier correction, we calculated – in line with NISR (2012) – the natural logarithm of all non-zero consumption values (on a per adult equivalent basis) and identified all those observations as outliers where the observed value was more than 3.5 standard deviations away from the mean value. The identified outliers were then replaced with the mean value for the respective consumption category multiplied with the number of adult equivalents in the household. Given that there may be regional differences in consumption patterns, the above-described outlier correction was not simply done at the item level for food- and non-food consumption but at the item-region level.[36] To take into account differentials in household size and composition, we calculated the number of adult equivalents in each household using equivalence scales that were implemented by FAO already in the 1980s (NISR 2005) and are since then used as the national standard in Rwanda (see Appendix B for the exact scales). To further adjust for potentially existing economies of scale, we decided to use an exponent of 0.9 for the calculation of the number of adult equivalents.[37]

Appendix B: Adult Equivalence Scales

Age groups	Sex	
	Male	Female
Less than 1 year	0.41	0.41
1 to 3 years	0.56	0.56
4 to 6 years	0.76	0.76
7 to 9 years	0.91	0.91
10 to 12 years	0.97	1.08
13 to 15 years	0.97	1.13
16 to 19 years	1.02	1.05
20 to 39 years	1.00	1.00
40 to 49 years	0.95	0.95
50 to 59 years	0.90	0.90
60 to 69 years	0.80	0.80
More than 70 years	0.70	0.70

[35] We deviate from the approach described in NISR (2012) in excluding the use value of durable goods and the (imputed) rents for the household's dwelling since these are probably the two categories where measurement error is highest (particularly against the background that less than 10% of Rwandan households actually pay rent). Given that such measurement error could severely bias the ranking of households needed for the following pro-poor analysis, we decided to favor reliability of our consumption aggregate over its completeness and hence excluded the two expenditure categories.

[36] Please refer to NISR (2012) for a very good and more detailed description of the outlier correction procedure used.

[37] This represents another difference to the methodology used by NISR (2012) who do not directly account for economies of scale in a household.

Appendix C: Levels of the contemplated income and non-income indicators for Rwanda (based on EICV1, EICV2 and EICV3 – agrarian population only)

Indicator	Survey	Tool	Unit	Mean of decile... (cumulated in case of opportunity curves)										10:1 Ratio	Gini
				1	2	3	4	5	6	7	8	9	10		
Avg. household expenditures per a.e.	EICV1	GIC	RWF	22,459	31,022	38,322	45,123	53,551	63,238	74,342	90,601	113,051	182,838	8.14	0.34
Avg. household expenditures per a.e.	EICV2	GIC	RWF	25,647	35,306	43,403	50,852	58,955	68,656	80,557	97,165	123,857	201,642	7.86	0.33
Avg. household expenditures per a.e.	EICV3	GIC	RWF	32,433	42,635	51,223	59,673	69,183	79,520	92,156	110,068	137,547	215,365	6.64	0.31
Avg. literacy rate (aged 15+)	EICV1	OC	%	36.08	38.68	41.15	42.58	43.76	44.97	46.26	47.62	48.52	49.42		
Avg. literacy rate (aged 15+)	EICV2	OC	%	44.22	48.94	51.18	52.86	54.47	55.51	56.93	58.37	59.66	60.97		
Avg. literacy rate (aged 15+)	EICV3	OC	%	54.59	57.07	58.20	59.65	60.44	61.32	62.13	63.05	63.71	64.60		
Avg. years of schooling (aged 15+)	EICV1	Cond. NIGIC	years	1.39	1.73	1.89	1.99	2.12	2.23	2.53	2.68	2.66	3.13	2.25	0.49
Avg. years of schooling (aged 15+)	EICV2	Cond. NIGIC	years	2.10	2.55	2.81	3.03	3.13	3.24	3.56	3.73	3.80	4.49	2.14	0.37
Avg. years of schooling (aged 15+)	EICV3	Cond. NIGIC	years	2.74	3.09	3.23	3.40	3.40	3.53	3.73	3.90	4.06	4.64	1.69	0.34
Avg. years of schooling (aged 15+)	EICV1	Uncond. NIGIC	years	0.00	0.00	0.31	1.15	1.74	2.22	2.79	3.41	4.47	6.29	n.d.	0.49
Avg. years of schooling (aged 15+)	EICV2	Uncond. NIGIC	years	0.01	0.88	1.68	2.23	2.83	3.27	3.99	4.75	5.60	7.23	866.54	0.37
Avg. years of schooling (aged 15+)	EICV3	Cond. NIGIC	years	0.07	1.19	2.04	2.73	3.17	3.78	4.33	5.03	5.82	7.58	112.43	0.34
Access to improved sanitation	EICV1	OC	%	31.25	35.08	36.53	37.94	40.05	41.91	43.57	44.46	45.79	47.95		
Access to improved sanitation	EICV2	OC	%	40.51	43.66	47.15	49.61	50.48	51.75	52.23	53.32	54.97	56.70		
Access to improved sanitation	EICV3	OC	%	66.54	68.41	70.59	71.65	71.80	72.23	72.64	73.09	73.55	74.49		
Access to improved drinking water	EICV1	OC	%	68.60	68.82	69.43	68.83	69.30	68.62	68.35	67.51	67.67	67.86		
Access to improved drinking water	EICV2	OC	%	67.07	66.70	66.26	66.50	67.01	67.16	67.46	66.82	67.30	68.16		
Access to improved drinking water	EICV3	OC	%	70.77	69.31	70.11	70.34	70.49	70.88	71.14	71.04	71.29	72.12		
Health problems in the last 14 days	EICV1	OC	%	30.64	28.94	28.15	27.91	28.35	28.12	28.13	28.17	28.16	28.51		
Health problems in the last 14 days	EICV2	OC	%	20.29	19.73	19.94	20.48	20.69	20.70	20.81	20.92	21.33	21.68		
Health problems in the last 14 days	EICV3	OC	%	18.62	18.15	18.08	18.24	18.66	18.82	18.77	18.78	19.07	19.15		
Avg. production per ha (all crops)	EICV1	PGIC	RWF	49,772	89,697	133,640	186,809	249,922	331,858	436,067	611,754	898,863	1,571,304	31.57	0.50
Avg. production per ha (all crops)	EICV2	PGIC	RWF	78,627	134,449	190,784	254,092	329,866	421,585	538,568	694,717	954,293	1,504,059	19.13	0.44
Avg. production per ha (all crops)	EICV3	PGIC	RWF	123,861	191,524	252,814	316,001	387,544	466,052	559,423	685,373	883,049	1,305,331	10.54	0.36
Avg. production per worker (all crops)	EICV1	PGIC	RWF	8,860	19,070	28,536	40,600	54,643	71,954	95,460	132,472	193,640	357,951	40.40	0.51
Avg. production per worker (all crops)	EICV2	PGIC	RWF	14,203	28,830	43,729	58,909	77,253	98,570	127,278	167,351	236,694	432,834	30.47	0.48
Avg. production per worker (all crops)	EICV3	PGIC	RWF	20,842	38,652	54,315	70,574	89,215	112,344	141,360	182,408	252,612	441,029	21.16	0.45
Avg. production per ha (beans only)	EICV1	PGIC	kg	32.43	63.93	100.33	143.81	189.11	242.12	313.67	427.20	607.91	1,122.74	34.62	0.50
Avg. production per ha (beans only)	EICV2	PGIC	kg	46.09	92.97	138.45	188.85	249.48	326.19	426.19	562.43	806.19	1,360.88	29.53	0.48
Avg. production per ha (beans only)	EICV3	PGIC	kg	90.81	179.33	259.51	341.19	433.29	541.34	673.05	856.79	1,140.02	1,769.10	19.48	0.42
Avg. production per ha (manioc only)	EICV1	PGIC	kg	89.34	182.33	285.63	414.56	602.08	874.52	1,252.60	2,057.09	3,357.94	7,174.36	80.31	0.61
Avg. production per ha (manioc only)	EICV2	PGIC	kg	136.44	304.92	524.57	793.89	1,099.11	1,567.76	2,297.46	3,347.99	5,052.95	10,268.72	75.26	0.58
Avg. production per ha (manioc only)	EICV3	PGIC	kg	188.27	370.75	570.10	785.38	1,039.95	1,364.93	1,830.16	2,460.35	3,569.74	6,711.50	35.65	0.51

Note: The abbreviation "n.d." stands for not defined and is used in cases where one would have to divide by zero to obtain the 10:1 ratio.

Appendix C (ctd.): Levels of the contemplated income and non-income indicators for Rwanda (based on EICV1, EICV2 and EICV3 – agrarian population only)

Indicator	Survey	Tool	Unit	Mean of decile... (cumulated in case of opportunity curves)										10:1 Ratio	Gini
				1	2	3	4	5	6	7	8	9	10		
Avg. production per ha (maize only)	EICV1	PGIC	kg	30.97	62.86	93.41	130.40	178.18	236.23	312.10	427.50	674.93	1,382.95	44.65	0.54
Avg. production per ha (maize only)	EICV2	PGIC	kg	39.06	74.84	118.84	165.65	223.15	304.85	408.40	566.81	879.23	1,686.15	43.17	0.54
Avg. production per ha (maize only)	EICV3	PGIC	kg	80.15	156.14	234.55	322.76	435.14	562.58	736.75	978.19	1,343.29	2,298.70	28.68	0.47
Avg. literacy rate (aged 15+)	EICV1	Land POC - Type 1	%	48.19	49.51	48.62	49.16	49.65	49.88	49.91	49.79	49.91	50.36		
Avg. literacy rate (aged 15+)	EICV2	Land POC - Type 1	%	56.27	56.75	57.73	58.19	58.96	59.85	60.11	60.22	60.51	61.15		
Avg. literacy rate (aged 15+)	EICV3	Land POC - Type 1	%	62.02	61.79	61.62	62.72	63.06	63.58	63.90	64.30	64.41	64.88		
Health problems in the last 14 days	EICV1	Land POC - Type 1	%	28.14	28.29	28.02	27.67	28.38	28.12	27.79	27.95	28.12	28.10		
Health problems in the last 14 days	EICV2	Land POC - Type 1	%	22.60	21.94	21.62	21.50	21.51	21.08	20.97	21.10	21.36	21.23		
Health problems in the last 14 days	EICV3	Land POC - Type 1	%	19.00	19.78	19.79	19.58	19.54	19.43	19.23	19.21	19.26	19.02		
Avg. literacy rate (aged 15+)	EICV1	Labor POC - Type 1	%	40.17	41.83	42.94	44.59	45.50	46.40	46.98	47.68	48.30	49.42		
Avg. literacy rate (aged 15+)	EICV2	Labor POC - Type 1	%	50.12	52.19	53.18	53.61	55.12	56.51	57.60	58.35	59.39	60.97		
Avg. literacy rate (aged 15+)	EICV3	Labor POC - Type 1	%	57.44	58.62	58.66	58.99	59.27	60.26	61.42	62.27	63.37	64.60		
Health problems in the last 14 days	EICV1	Labor POC - Type 1	%	30.46	29.46	29.11	28.84	28.68	28.45	28.60	28.33	28.45	28.51		
Health problems in the last 14 days	EICV2	Labor POC - Type 1	%	25.05	23.46	23.37	23.22	23.25	22.92	22.60	22.17	21.96	21.68		
Health problems in the last 14 days	EICV3	Labor POC - Type 1	%	21.62	21.04	21.18	21.02	20.99	20.67	20.17	19.73	19.42	19.15		
Avg. production per ha (all crops)	EICV1	Land POC - Type 2 (human cap.)	RWF	442,904	434,959	440,163	447,372	440,360	437,734	444,318	445,286	450,072	455,675		
Avg. production per ha (all crops)	EICV2	Land POC - Type 2 (human cap.)	RWF	436,720	445,410	464,638	472,891	481,437	484,589	494,017	494,835	503,306	509,828		
Avg. production per ha (all crops)	EICV3	Land POC - Type 2 (human cap.)	RWF	480,389	485,797	494,335	501,150	504,498	504,628	509,100	510,735	514,575	516,841		
Avg. production per worker (all crops)	EICV1	Labor POC - Type 2 (human cap.)	RWF	84,997	83,747	84,290	85,838	86,883	88,392	91,540	93,864	96,549	100,272		
Avg. production per worker (all crops)	EICV2	Labor POC - Type 2 (human cap.)	RWF	99,244	95,226	100,408	104,100	106,408	109,677	113,718	116,193	121,461	128,484		
Avg. production per worker (all crops)	EICV3	Labor POC - Type 2 (human cap.)	RWF	110,907	109,957	115,100	119,586	122,804	125,482	128,921	130,489	134,937	140,338		

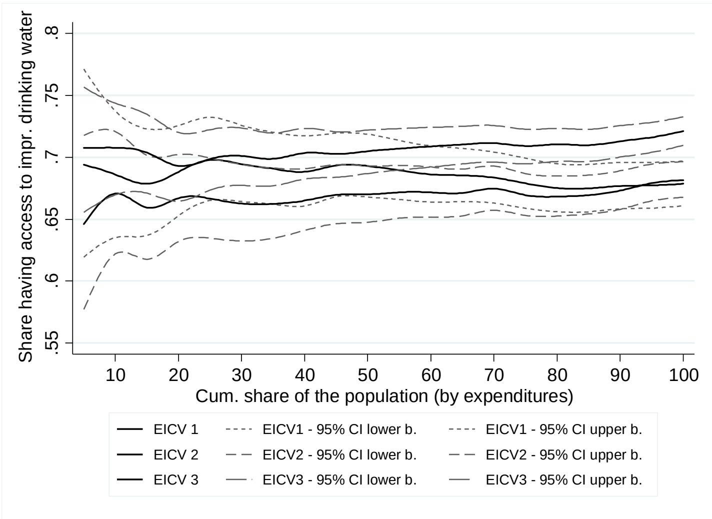
Note: The abbreviation "n.d." stands for not defined and is used in cases where one would have to divide by zero to obtain the 10:1 ratio.

Appendix D: Pro-poor growth rates and growth rates in the mean for Rwanda (based on EICV1, EICV2 and EICV3 – agrarian population only)

Indicator	Tool	Reference Period	Ann. growth rate in the mean (%)	Avg. annual growth rate for the poorest... (in %)						Abs. increase in the mean	Abs. increase for the poorest...					
				5%	10%	15%	20%	25%	100%		5%	10%	15%	20%	25%	100%
Avg. household expenditures per a.e.	GIC	EICV1-EICV3	2.02	3.56	3.42	3.29	3.18	3.09	2.32	17,538	9,295	9,968	10,431	10,793	11,143	17,527
Avg. literacy rate (aged 15+)	OC	EICV1-EICV3	2.47	4.71	3.88	3.90	3.65	3.45	2.54	15.18	21.54	18.51	19.11	18.39	17.79	15.18
Avg. years of schooling (aged 15+)	Cond. NIGIC	EICV1-EICV3	4.35	6.72	6.37	5.98	5.89	5.69	4.50	1.34	1.34	1.35	1.33	1.35	1.35	1.34
Avg. years of schooling (aged 15+)	Uncond. NIGIC	EICV1-EICV3	4.35	n.d.	n.d.	n.d.	n.d.	n.d.	5.18	1.34	0.00	0.07	0.35	0.63	0.88	1.34
Access to improved sanitation	OC	EICV1-EICV3	4.09	8.55	7.24	6.22	6.43	6.60	4.32	26.54	38.65	35.29	31.89	33.33	34.81	26.54
Access to improved drinking water	OC	EICV1-EICV3	0.55	0.17	0.28	0.33	0.07	0.01	0.56	4.25	1.34	2.17	2.52	0.49	0.07	4.25
Health problems in the last 14 days	OC	EICV1-EICV3	-3.55	-5.80	-4.36	-4.37	-4.11	-3.95	-3.54	-9.36	-16.57	-12.02	-11.50	-10.79	-10.33	-9.36
Avg. production per ha (all crops)	PGIC	EICV1-EICV3	1.15	9.37	8.78	8.35	7.98	7.65	3.58	61,313	65,764	74,112	81,485	87,971	93,631	61,138
Avg. production per worker (all crops)	PGIC	EICV1-EICV3	3.10	9.18	8.42	7.85	7.53	7.30	4.60	40,047	9,461	11,985	13,854	15,791	17,611	40,019
Avg. production per ha (beans only)	PGIC	EICV1-EICV3	6.24	9.26	9.70	9.81	9.77	9.62	7.61	305.46	41.33	58.31	73.21	86.82	98.98	304.43
Avg. production per ha (manioc only)	PGIC	EICV1-EICV3	1.47	7.22	7.06	7.01	6.88	6.81	4.09	279.70	73.55	98.92	122.79	143.88	166.72	259.58
Avg. production per ha (maize only)	PGIC	EICV1-EICV3	6.63	8.82	8.99	8.90	8.81	8.79	7.89	361.30	36.01	49.23	60.40	71.26	82.63	360.43
Avg. production per ha (maize only)	PGIC	EICV1-EICV2	4.02	4.66	4.10	3.66	3.52	3.58	4.08	93.88	7.39	8.15	8.70	10.11	12.36	92.91
Avg. literacy rate (aged 15+)	Land POC (Type 1)	EICV1-EICV3	2.33	1.96	2.33	2.12	2.04	2.26	2.34	14.52	12.04	13.83	12.71	12.28	13.38	14.52
Health problems in the last 14 days	Land POC (Type 1)	EICV1-EICV3	-3.49	-3.43	-3.50	-3.16	-3.21	-3.07	-3.48	-9.08	-8.66	-9.13	-8.38	-8.52	-8.15	-9.08
Avg. literacy rate (aged 15+)	Labor POC (Type 1)	EICV1-EICV3	2.47	2.96	3.33	3.34	3.13	2.97	2.48	15.18	16.38	17.27	17.73	16.79	16.00	15.18
Health problems in the last 14 days	Labor POC (Type 1)	EICV1-EICV3	-3.55	-3.48	-3.02	-3.06	-2.99	-2.99	-3.58	-9.36	-11.00	-8.84	-8.74	-8.42	-8.42	-9.36
Avg. production per ha (all crops)	Land POC (Type 2) (by human capital)	EICV1-EICV3	1.15	0.85	0.74	1.00	1.02	1.10	1.18	61,138	41,832	37,485	49,160	50,838	55,444	61,167
Avg. production per worker (all crops)	Labor POC (Type 2) (by human capital)	EICV1-EICV3	3.10	0.90	2.53	2.73	2.57	2.74	3.11	40,065	9,999	25,910	27,419	26,211	28,389	40,066

Note: The abbreviation “n.d.” stands for not defined and is used in cases where one would have to divide by zero to obtain the annual growth rate.

Appendix E: Opportunity curves for access to improved drinking water



Appendix F: Comparison of land and labor productivity poor households (based on EICV1)

Indicator	Land productivity poor households	s.e.	Labor productivity poor households	s.e.
Total consumption per ae	79,487	(6,969)	58,083	(1,816)
Ag. productivity per ha	67,230	(867.7)	175,088	(8,557)
Ag. productivity per worker	41,474	(1,507)	13,385	(201.8)
Total size of plots (in hectares)	1.27	(0.043)	0.45	(0.020)
Household Size	4.81	(0.086)	5.12	(0.099)
Number of farmers	2.17	(0.044)	2.65	(0.056)
Literacy Rate (aged 15+)	49.51	(1.422)	43.22	(1.511)
Years of schooling (aged 15+)	2.16	(0.071)	1.74	(0.068)
Access to impr. sanitation	45.82	(1.881)	44.25	(2.164)
Access to impr. drinking water	66.78	(1.778)	68.76	(2.010)
Health problems in the last 2 weeks	28.31	(1.080)	28.79	(1.203)

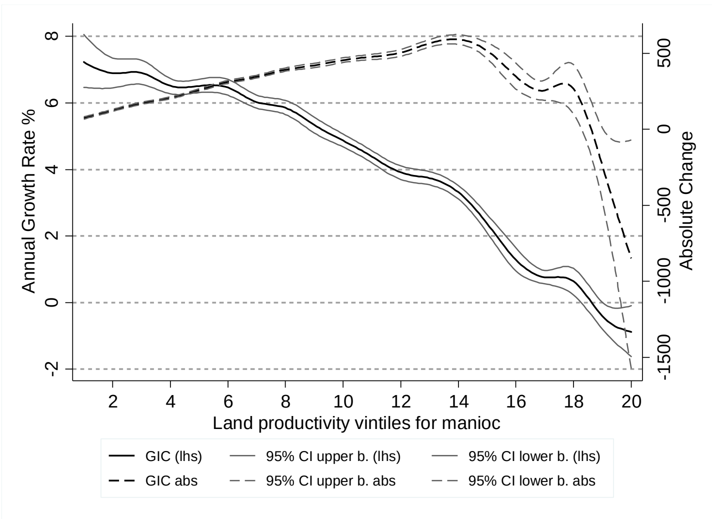
Appendix G: Comparison of land and labor productivity-poor households (based on EICV3)

Indicator	Land productivity poor households	s.e.	Labor productivity poor households	s.e.
Total consumption per ae	90,301	(2,586)	83,704	(2,368)
Ag. productivity per ha	153,601	(981.3)	314,848	(6,358)
Ag. productivity per worker	87,236	(2,281)	28,664	(251.6)
Total size of plots (in hectares)	0.97	(0.026)	0.28	(0.007)
Household Size	4.73	(0.055)	4.56	(0.060)
Number of farmers	1.72	(0.024)	2.01	(0.023)
Literacy Rate (aged 15+)	61.79	(0.882)	58.51	(0.934)
Years of schooling (aged 15+)	3.41	(0.053)	3.08	(0.049)
Access to impr. sanitation	76.67	(1.026)	70.72	(1.228)
Access to impr. drinking water	69.28	(1.066)	72.87	(1.095)
Health problems in the last 2 weeks	19.77	(0.678)	21.08	(0.772)

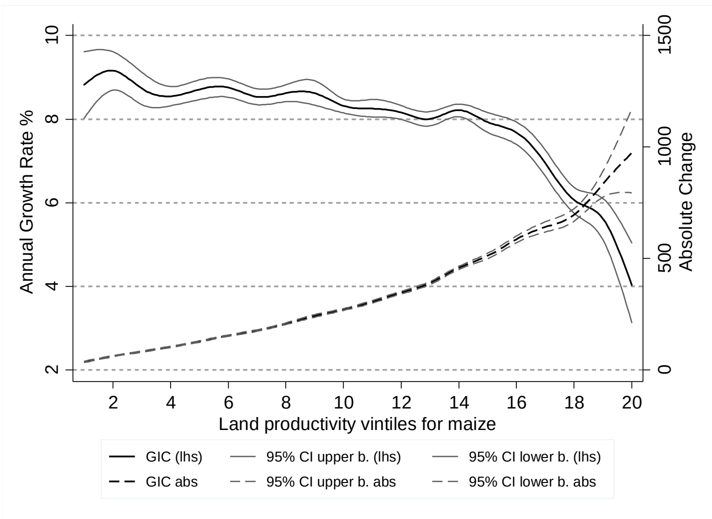
Appendix H: Share of land used in total active agricultural land by major crops

Crop	EICV1	EICV2	EICV3
Beans	27.18%	28.32%	21.70%
Corn	8.18%	10.76%	11.47%
Manioc	10.25%	9.89%	12.76%
Peas	1.45%	1.82%	1.32%
Potatoes	7.11%	6.25%	5.55%
Sorghum	11.37%	12.39%	7.64%
Soy	1.85%	2.29%	1.36%
Sweet potatoes	12.69%	12.30%	8.74%
Taro	1.77%	1.41%	2.08%
Various types of bananas	10.57%	6.96%	18.25%
Other	7.57%	7.61%	9.14%

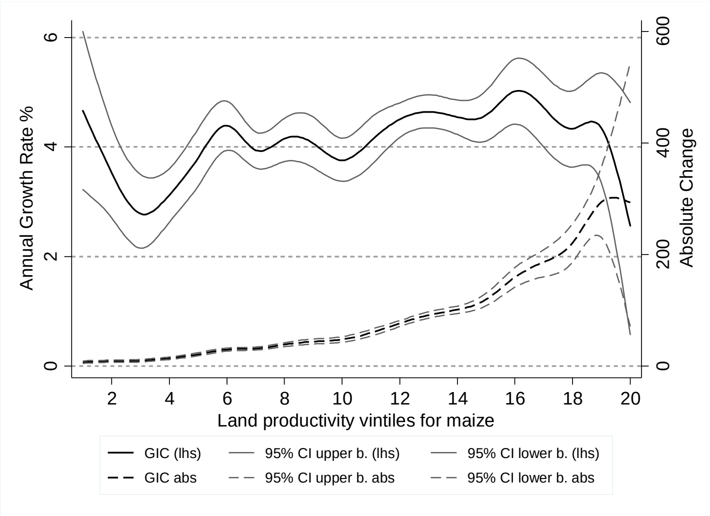
Appendix I: Land productivity growth incidence curves for manioc production: EICV1-EICV3



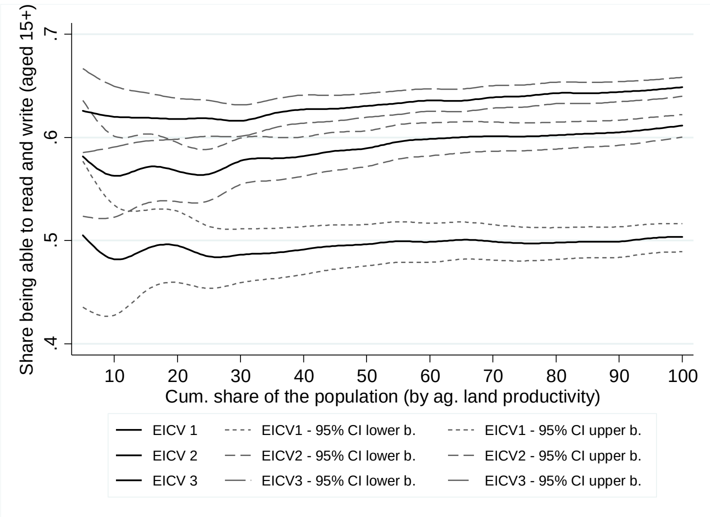
Appendix J: Land productivity growth incidence curves for maize production: EICV1-EICV3



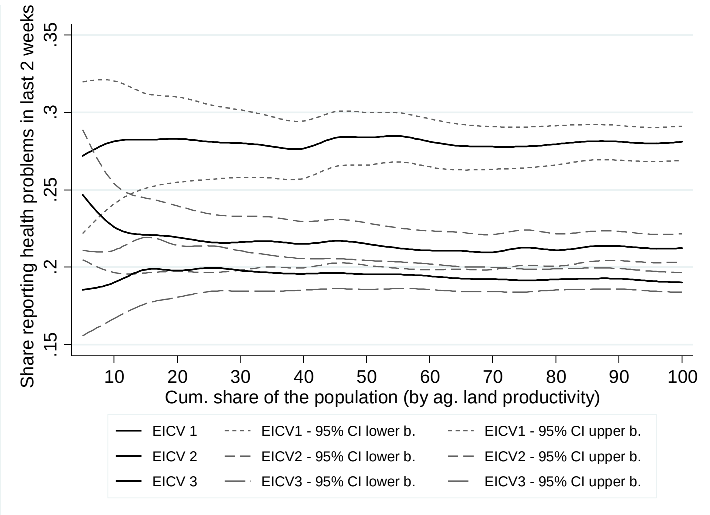
Appendix K: Land productivity growth incidence curves for maize production: EICV1-EICV2



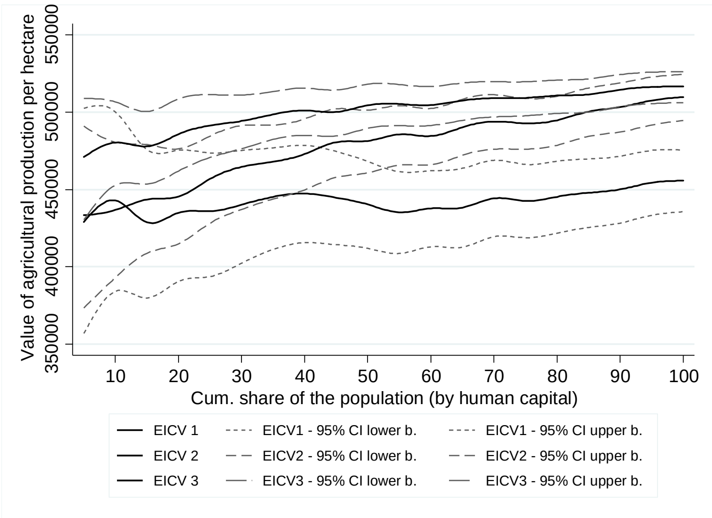
Appendix L: Land productivity opportunity curves (Type 1) for adult literacy (aged 15+)



Appendix M: Land productivity opportunity curves (Type 1) for health problems in the last two weeks



Appendix N: Land productivity opportunity curves (Type 2) for human capital



References

Alderman, H., L. Cord, N. Chaudhury, and C. Cornelius. 2000. "Rural Poverty." *World Bank: PRSP Sourcebook (version of August 29, 2000)*.

Alene, A. D., and V. M. Manyong. 2006. "Endogenous Technology Adoption and Household Food Security: The Case of Improved Cowpea Varieties in Northern Nigeria." *Quarterly Journal of International Agriculture*, *45*(3): 211-30.

Alesina, A., and D. Rodrik. 1994. "Distributive Politics and Economic Growth." *The Quarterly Journal of Economics*, 465-90.

Ali, I., and H. H. Son. 2007. "Measuring Inclusive Growth." *Asian Development Review*, *24*(1): 11-31.

Ali, M., and J. C. Flinn. 1989. "Profit Efficiency among Basmati Rice Producers in Pakistan Punjab." *American Journal of Agricultural Economics*, *71*(2): 303-10.

Ames, B., W. Brown, S. Devarajan, and A. Izquierdo. 2000. "Macroeconomic Issues." *World Bank: PRSP Sourcebook (version of September 21, 2000)*.

Anand, S., and M. Ravallion. 1993. "Human Development in Poor Countries: On the Role of Private Incomes and Public Services." *The Journal of Economic Perspectives*, *7*(1): 133-50.

Ansoms, A., A. Verdoodt, and E. Van Ranst. 2008. *The Inverse Relationship between Farm Size and Productivity in Rural Rwanda*. Antwerpen: University of Antwerp. Institute of development policy and management (IOB).

Antle, J. M., D. C. Cole, and C. C. Crissman. 1998. "Further Evidence on Pesticides, Productivity and Farmer Health: Potato Production in Ecuador." *Agricultural Economics*, *18*(2): 199-207.

Asadullah, M. N., and S. Rahman. 2009. "Farm Productivity and Efficiency in Rural Bangladesh: The Role of Education Revisited." *Applied Economics*, *41*(1): 17-33.

Asenso-Okyere, K., F. A. Asante, J. Tarekegn, and K. S. Andam. 2011. "A Review of the Economic Impact of Malaria in Agricultural Development." *Agricultural Economics*, *42*(3): 293-304.

Assunção, J. J., and L. H. B. Braido. 2007. "Testing Household-Specific Explanations for the Inverse Productivity Relationship." *American Journal of Agricultural Economics*, *89*(4): 980-90.

Bardhan, P. K. 1973. "Size, Productivity, and Returns to Scale: An Analysis of Farm-Level Data in Indian Agriculture." *The Journal of Political Economy*, 1370-86.

Barrett, C. B. 1996. "On Price Risk and the Inverse Farm Size-Productivity Relationship." *Journal of Development Economics*, *51*(2): 193-215.

Barrett, C. B., M. F. Bellemare, and J. Y. Hou. 2010. "Reconsidering Conventional Explanations of the Inverse Productivity Size Relationship." *World Development*, *38*(1): 88-97.

Barro, R. J., and J. W. Lee. 1993. "International Comparisons of Educational Attainment." *Journal of Monetary Economics, 32*(3): 363-94.

Beegle, K., C. Carletto, and K. Himelein. 2012. "Reliability of Recall in Agricultural Data." *Journal of Development Economics, 98*(1): 34-41.

Benjamin, D. 1995. "Can Unobserved Land Quality Explain the Inverse Productivity Relationship?" *Journal of Development Economics*, *46*(1): 51-84.

Besley, T., and L. Cord. 2007. *Delivering on the Promise of Pro-Poor Growth: Insights and Lessons from Country Experiences*. Washington DC: World Bank Publications.

Bhalla, S. S. 1988. "Does Land Quality Matter? Theory and Measurement." *Journal of Development Economics*, *29*(1): 45-62.

Bhalla, S. S., and P. Roy. 1988. "Mis-Specification in Farm Productivity Analysis: The Role of Land Quality." *Oxford Economic Papers*, 55-73.

Binswanger, H. P., K. Deininger, and G. Feder. 1995. "Power, Distortions, Revolt and Reform in Agricultural Land Relations," J. Behrman , and T. N. Srinivasan, *Handbook of Development Economics Vol. 3b.* Amsterdam: North-Holland, 2659-772.

Bourguignon, F. 2004. "The Poverty-Growth-Inequality Triangle." *Mimeo*, The World Bank.

Byiringiro, F., and T. Reardon. 1996. "Farm Productivity in Rwanda: Effects of Farm Size, Erosion, and Soil Conservation Investments." *Agricultural Economics*, *15*(2): 127-36.

Christiaensen, L., L. Demery, and J. Kuhl. 2011. "The (Evolving) Role of Agriculture in Poverty Reduction: An Empirical Perspective." *Journal of Development Economics*, *96*(2): 239-54.

Croppenstedt, A., and C. Muller. 2000. "The Impact of Farmers' Health and Nutritional Status on Their Productivity and Efficiency: Evidence from Ethiopia." *Economic Development and Cultural Change*, *48*(3): 475-502.

De Janvry, A., and E. Sadoulet. 2010. "Agricultural Growth and Poverty Reduction: Additional Evidence." *The World Bank Research Observer*, *25*(1): 1-20.

Deaton, A., and S. Zaidi. 2002. Guidelines for Constructing Consumption Aggregates for Welfare Analysis. Washington D.C.: World Bank Publications.

Duclos, J. Y., and Q. Wodon. 2004. "What Is Pro-Poor?" *Working Paper 04-25*, Laval: CIRPÉE.

Eastwood, R., and M. Lipton. 2000. "Pro-Poor Growth and Pro-Growth Poverty Reduction: Meaning, Evidence, and Policy Implications." *Asian Development Review*, *18*(2): 22-58.

Fan, S., A. Gulati, and S. Thorat. 2008. "Investment, Subsidies, and Pro-Poor Growth in Rural India." *Agricultural Economics*, *39*(2): 163-70.

Fan, S., and X. Zhang. 2008. "Public Expenditure, Growth and Poverty Reduction in Rural Uganda." *African Development Review*, *20*(3): 466-96.

Fan, S., P. Hazell, and S. Thorat. 2000. "Government Spending, Growth and Poverty in Rural India." *American Journal of Agricultural Economics*, *82*(4): 1038-51.

FAO. 2011. "Faostat." (February 03, 2012), *available at* faostat.fao.org

Feder, G. 1985. "The Relation between Farm Size and Farm Productivity: The Role of Family Labor, Supervision and Credit Constraints." *Journal of Development Economics*, *18*(2): 297-313.

Frisvold, G. B. 1994. "Does Supervision Matter? Some Hypothesis Tests Using Indian Farm-Level Data." *Journal of Development Economics*, *43*(2): 217-38.

Galor, O., and J. Zeira. 1993. "Income Distribution and Macroeconomics." *The Review of Economic Studies*, *60*(1): 35-52.

Grimm, M., S. Klasen, and A. McKay. 2007. *Determinants of Pro-Poor Growth: Analytical Issues and Findings from Country Cases*. Houndmills: Palgrave Macmillan.

Grosse, M., K. Harttgen, and S. Klasen. 2008. "Measuring Pro-Poor Growth in Non-Income Dimensions." *World Development*, *36*(6): 1021-47.

Hanmer, L., and D. Booth. 2001. "Pro-Poor Growth: Why Do We Need It?" *Overseas Development Institute, London: Processed*.

Howe, G., and A. McKay. 2007. "Combining Quantitative and Qualitative Methods in Assessing Chronic Poverty: The Case of Rwanda." *World Development, 35*(2): 197-211.

JMP. 2012. "Types of Drinking-Water Sources and Sanitation." available at http://www.wssinfo.org/definitions-methods/watsan-categories/, accessed on March 22, 2012.

Kakwani, N., and E. M. Pernia. 2000. "What Is Pro-Poor Growth?" *Asian Development Review*, *18*(1): 1-16.

Kakwani, N., S. Khandker, and H. H. Son. 2004. "Pro-Poor Growth: Concepts and Measurement with Country Case Studies." *International Poverty Centre*, Brasilia, Brazil: United Nations Development Programme.

Kimhi, A. 2006. "Plot Size and Maize Productivity in Zambia: Is There an Inverse Relationship?" *Agricultural Economics*, *35*(1): 1-9.

Klasen, S. 2004. "In Search of the Holy Grail: How to Achieve Pro-Poor Growth?," *Toward Pro Poor Policies-Aid, Institutions, and Globalization.* 63-94.

____. 2008. "Economic Growth and Poverty Reduction: Measurement Issues Using Income and Non-Income Indicators." *World Development*, *36*(3): 420-45.

____. 2010. "Measuring and Monitoring Inclusive Growth: Multiple Definitions, Open Questions, and Some Constructive Proposals." *Asian Development Bank: Sustainable Development Working Paper Series* (12): 1-23.

Lamb, R. L. 2003. "Inverse Productivity: Land Quality, Labor Markets, and Measurement Error." *Journal of Development Economics*, *71*(1): 71-95.

Lanjouw, P., and M. Ravallion. 1999. "Benefit Incidence, Public Spending Reforms, and the Timing of Program Capture." *The World Bank Economic Review*, *13*(2): 257-73.

Loureiro, M. L. 2009. "Farmers' Health and Agricultural Productivity." *Agricultural Economics*, *40*(4): 381-88.

McCulloch, N., and B. Baulch. 1999. "Tracking Pro-Poor Growth." *ID21 insights*, *31*.

MINECOFIN. 2002. "Final Report of the Integrated Household Living Conditions Survey in Rwanda (2000-2001)." Kigali: Rwandan Ministry of Finance and Economic Planning (MINECOFIN).

NISR. 2005. "Methods Used for Poverty Analysis in Rwanda." Kigali: National Institute of Statistics of Rwanda (NISR).

____. 2012. "The Evolution of Poverty in Rwanda from 2000 to 2011." Kigali: National Institute of Statistics of Rwanda (NISR).

OECD. 2006. "Promoting Pro-Poor Growth: Key Policy Messages." Paris: OECD.

Persson, T., and G. Tabellini. 1994. "Is Inequality Harmful for Growth?" *The American Economic Review*, 600-21.

Ravallion, M. 2001. "Growth, Inequality and Poverty: Looking Beyond Averages." *World Development*, *29*(11): 1803-15.

Ravallion, M., and S. Chen. 2003. "Measuring Pro-Poor Growth." *Economics Letters*, *78*(1): 93-99.

Ravallion, M., and G. Datt. 2002. "Why Has Economic Growth Been More Pro-Poor in Some States of India Than Others?" *Journal of Development Economics*, *68*(2): 381-400.

Reimers, M., and S. Klasen. 2013. "Revisiting the Role of Education for Agricultural Productivity." *American Journal of Agricultural Economics, 95*(1): 131-152.

Saksena, P., A. F. Antunes, K. Xu, L. Musango, and G. Carrin. 2011. "Mutual Health Insurance in Rwanda: Evidence on Access to Care and Financial Risk Protection." *Health Policy*, *99*(3): 203-09.

Sen, A. K. 1966. "Peasants and Dualism with or without Surplus Labor." *The Journal of Political Economy*, *74*(5): 425-50.

____. 1983. "Poor, Relatively Speaking." *Oxford Economic Papers*, *35*(2): 153-69.

____. 1998. *Development as Freedom*. New York: Knopf.

Son, H. H. 2004. "A Note on Pro-Poor Growth." *Economics Letters*, *82*(3): 307-14.

Ulimwengu, J. 2009. "Farmers' Health and Agricultural Productivity in Rural Ethiopia." *African Journal of Agricultural and Resource Economics*, *3*(2): 83-100.

United Nations. 2000. *A Better World for All*. New York: United Nations.

UNDP. 2003. *Millennium Development Goals: Status Report Rwanda 2003*. New York: United Nations Development Programme (UNDP).

____. 2007. *Millennium Development Goals: Status Report Rwanda 2007*. New York: United Nations Development Programme (UNDP).

Valdés, A., and W. Foster. 2010. "Reflections on the Role of Agriculture in Pro-Poor Growth." *World Development*, *38*(10): 1362-74.

Van de Walle, D. 1998. "Assessing the Welfare Impacts of Public Spending." *World Development*, *26*(3): 365-79.

Van de Walle, D., and K. Nead. 1995. *Public Spending and the Poor*. Baltimore: Johns Hopkins University Press.

WDI. 2012. "World Development Indicators." available at http://data.worldbank.org/data-catalog/world-development-indicators, accessed on March 22, 2012.

White, H., and E. Anderson. 2001. "Growth Versus Distribution: Does the Pattern of Growth Matter?" *Development Policy Review*, *19*(3): 267-89.

World Bank. 2000a. *World Development Report: Attacking Poverty*. New York: Oxford University Press

____. 2000b. *The Quality of Growth*. New York: Oxford University Press.

____. 2007. *World Development Report: Agriculture for Development*. New York: Oxford University Press

Young, D., and H. Deng. 1999. "The Effects of Education in Early-Stage Agriculture: Some Evidence from China." *Applied Economics*, *31*(11): 1315-23.