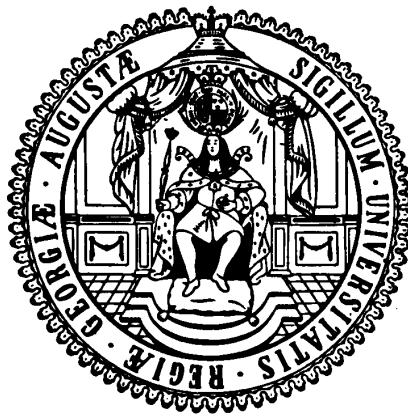# Courant Research Centre
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Looking at Pro-Poor Growth from an Agricultural Perspective

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Abstract

Pro-poor growth has been identified as one of the most promising pathways to accelerate poverty reduction in developing countries. The diagnostic pro-poor growth toolbox has so far focused on the income dimension as well as key non-income achievements in education and health. This article contributes to the literature by expanding the toolbox with several new measures that take into account the extraordinary importance of agricultural productivity for poverty reduction in developing countries. We distinguish between land productivity and labor productivity and find that the poor identified by low incomes, poor education outcomes, poor health outcomes, low land productivity and low labor productivity overlap only to a small degree, suggesting that analyses of pro-poor growth from these different perspectives are complementary. 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 agricultural productivity and improve the population's access to social services over the first decade of the 2000s. Our application shows that the enormous progress made in the income, education and health dimension of well-being has been pro-poor according to most definitions of the concept. The new tools reveal that the land productivity-poor experienced pro-poor growth in the relative (and absolute) sense while the labor productivity-poor increased their labor productivity relatively (but not absolutely) faster than the labor productivity-rich even though the former dispose of considerably lower education levels.

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

JEL classification: E6, I3, O1

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. Grimm et al. 2007; Klasen 2004, 2008). 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 where percentiles of households are lined up by income on the x-axis and then the growth rate of each percentile is mapped on the y-axis. Grosse et al. (2008) and Klasen (2008) introduced the concept of the non-income growth incidence curve (NIGIC) and showed that the pro-poor growth toolbox can be extended 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 or not. A related approach was also pursued by Ali and Son (2007) who developed the opportunity curve (OC) which is likewise focused on non-income dimensions of poverty and plots 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 agricultural 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 referring to the same households. Instead, these two subgroups can exhibit quite different characteristics and distinguishing between both groups in the analysis may 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 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 (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 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 the workforce being employed in the agricultural sector (all numbers from WDI 2012). The combination of high population density, high population growth, and a largely agrarian economy forces 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. Rwanda has in fact engaged in a variety of policies to improve agricultural productivity; therefore it is interesting to study which households actually experienced such productivity growth and what were its correlates.

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 even pro-poor according to the most demanding definitions of this term (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, first show that the overlap between income-poor, education-poor and agricultural land/labor productivity-poor is relatively small so that studying pro-poor growth from these perspectives is indeed complementary. They also reveal 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 is further

found that the labor productivity-poor 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) reveal 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 suggested so far. 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 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

Based on the empirical finding that both lower initial inequality as well as 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). Yet despite numerous contributions to the debate, there is until today no consensus definition of what precisely is meant by pro-poor growth (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).

In this article, we follow Grosse et al. (2008) and Klasen (2008), and distinguish between a weak-absolute, a relative, and a strong-absolute definition of pro-poor growth. 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 PPG according to all three definitions since many of the indicators are bounded above, i.e. they have a predefined maximum value (e.g. number of vaccinations, share of the population having access to certain services, years of schooling) which makes the occurrence of pro-poor growth according to the relative and the strong-absolute definition more feasible, particularly when better-off groups are already close to the upper bound.

Based on the above concepts, 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. The concept of the GIC allows distinguishing between the above-mentioned three definitions of pro-poor growth. If the GIC is located above zero for all poor quantiles (i.e. the quantile-specific growth rates in p.c. income are larger than zero), 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 PPG in the relative sense. To test whether developments have even fulfilled 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 PPG 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 and the recently agreed SDGs. 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 non-income

growth incidence curves. 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 also ranked by their p.c. income. However, on the vertical axis, there is no longer the growth rate in monetary terms but the growth rate in the 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 *non-income* achievements. 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. Thus, the question answered by the unconditional NIGIC is whether growth, for instance, increases in years of schooling were 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 (Grosse et al. 2008).

A third approach to measure pro-poor growth[1] was introduced by Ali and Son (2007) with the opportunity curve. 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 *cumulated* in the case of the opportunity curves. 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.[2] The opportunity curves are thus quite an intuitive complement to the growth incidence curves, with their focus on levels of access to opportunities for different population groups.

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

The combination of the above-described tools provides researchers and policy makers with the possibility to *ex-post* evaluate who has benefited from recent developments in a country from quite

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[1] 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.

[2] 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.

different angles. First, the "classical" growth incidence curve 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. This information 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.

The insights provided by conditional NIGICs and opportunity curves can be seen as a complementary second perspective. In particular, such tools allow evaluating 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 in terms of access to opportunities or non-income outcomes. 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. education or health). 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 not income-related MDGs 2-6 (or the corresponding new non-income SDGs).

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 has been shown 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 (the average of SSA countries in 2010: 59.1% (FAO 2011)); among the poor, the shares are substantially higher in all countries (World Bank, 2007). 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 SSA 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 PPG 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. This existing gap in the conceptual literature on the pro-poor growth toolbox is also illustrated in Table 1 which provides a categorization of recent contributions (including this article) to the concepts of growth incidence curves (and associated quantitative measures of pro-poor growth) and opportunity curves.

Table 1: Categorization of recent contributions to the PPG-literature

	Incidence Curve	*Opportunity Curve*
Income dimension	Ravallion and Chen (2003) Grosse et al. (2008) Klasen (2008)	Ali and Son (2007)
Non-income dimension	Grosse et al. (2008) Klasen (2008)	-
Ag. productivity dimension	Klasen and Reimers (2016)	Klasen and Reimers (2016)

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 agricultural productivity on the horizontal axis against quantile-specific growth rates (or absolute increases) of agricultural productivity on the vertical axis. The resulting curves enable us 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[3]) differs from the "classical" opportunity curve in the sense that we no 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, the POC (Type 1) investigates to what extent the productivity-poor are able to increase their education/health levels. In contrast, 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 (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

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[3] 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.

education/health. This is important from a multidimensional welfare perspective as one is interested in knowing 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.

Finally, as recognized e.g. by World Bank (2007) the agricultural sector has in developing countries traditionally been a sector without a strong political lobby. This is due to the fact that – in contrast to many industrialized countries – the agricultural sector in developing countries is often composed of many smallholders each owning very few hectares of agricultural land (even less in the Rwandan case) who are typically not well-organized and very dispersed. Against this background, the newly introduced tools can be seen as an opportunity to bolster the often marginalized smallholder agricultural sector in these countries since it allows stakeholders to transparently reflect recent developments in agricultural productivity improvements as well as existing bottlenecks to higher agricultural production.

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

Before turning to the 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 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 2006). According to Barrett (2010), it is possible to distinguish three major explanations for this phenomenon. The first claims that for the IFSP relationship to exist, there must be failures on (multiple) factor markets which cause unobservable inter-household variation in the shadow prices of production factors. This variation implies differentials in the input intensity levels which are correlated with farm size and therefore could explain the IFSP (Barrett et al. 2010).[4] The second potential explanation states that an omitted variable bias (e.g. due to differentials in soil quality) is

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[4] 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).

actually driving the IFSP[5] (e.g. Bhalla 1988; Bhalla and Roy 1988; Benjamin 1995). In contrast, the recent third class of arguments (e.g. Lamb 2003) claims that measurement error/reporting bias in the farm/plot size data may cause the IFSP relationship if smallholders misreport the size of their farms systematically differently from large landowners (Barrett et al. 2010).[6]

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 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 towards prevailing imperfections on the land and labor markets being the main drivers for the IFSP relationship in the Rwandan case.

As a result, two things 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 since the higher land productivity could just have been "bought" at the expense of particularly high levels of labor input. Second, it 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, since this may provide new insights about who the labor and land productivity-poor actually are and to what extent they benefited from recent developments.

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

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[5] 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).

[6] 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).

food security in the future.[7] Second, policy makers could also pursue the goal of increasing 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.

Since the new instruments should be seen as complements to the classical devices from the PPG-literature, we will in the empirical application first use the existing toolbox (section 6) and then extend it to the newly introduced instruments (section 7).

5. Data and methodology

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. As a complement to the second survey (EICV2), 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[8] 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 Oxford Policy Management (see NISR (2012) and appendix A for a description).

Secondly, we computed two measures of agricultural productivity (namely labor and land productivity) for each household involved in agriculture where both measures were calculated in a four step-procedure as follows. Given that Rwandan farmers frequently 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

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[7] Of course, one could worry here about the issue of sustainability of such increases in agricultural land productivity. While the risk of over-fertilization seems – for the particular case of Rwanda – at the moment rather small due to the still very low levels of fertilizer use (see Table 2), there appears to be a concrete danger of leaching out the relatively poor tropical soils by farming plots too intensively.
[8] When adjusting for price differences, we used January 2001 as a basis for our consumption aggregate.

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 typically two harvest periods into monetary values.[9] The fourth step is then to simply aggregate the monetary values of those harvests on the 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) or by the total number of adults in a household who consider agriculture as their primary occupation[10]. The resulting measures of agricultural land/labor productivity reflect the theoretical[11] 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.

Lastly, we computed various health and education indicators for both surveys. Given that those measures are rather standard, we do not explain their calculation in detail. 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 it to the agrarian population for our newly developed tools where we require 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 comprising all households where at least one adult household member (aged 15 and above) reported working on the farm as 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 89.20% of the population fulfilled our above definition of an agricultural household, this share fell to 84.25% in the EICV2 and 76.82% in the EICV3 survey, respectively.

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[9] When doing so, we are unfortunately constrained by the fact that community-level price data were only collected as part of the EICV2 survey, but not with the other two survey waves. As a consequence, we always have to use EICV2 prices to convert harvests in kg into monetary values. Yet, this appears less of a problem since we just use crop prices as a kind of conversion factor to aggregate different crops. The price level itself is, however, not important for our analysis, just that relative prices between major crops did not change significantly. That this is the case, can be backed up using price data from the Rwandan National Institute for Statistics.

[10] 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.

[11] 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..

Table 2: 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)
Share of farm size irrigated (%)	9.33	(0.467)	n.a.	n.a.	2.59	(0.118)
Expenditures for organic/chemical fertilizer (in 1000 RWF)	0.27	(0.038)	1.10	(0.080)	4.52	(0.263)
Expenditures for insecticides (in 1000 RWF)	0.19	(0.021)	0.68	(0.066)	1.52	(0.070)
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)

Table 2 provides an overview of the means of some key indicators. Considerable progress can be observed for all three education indicators and also for the three health indicators. Most notably, this progress has – despite the predominantly rural sample that we use – mostly been faster than in neighboring countries such as Burundi, Tanzania or Uganda (based on comparisons using the World Development Indicators database). 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 to 88,973 RWF. Turning to the agricultural data, the increasingly important problem of land scarcity becomes obvious in 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 EICV1 and EICV3 from 0.80 to 0.61 hectare. These values are particularly alarming given that a large share of Rwandan households therefore 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). With regard to input use, we see a clear upward trend in expenditures for organic/chemical fertilizer and insecticides; however, these values still remain at a quite low level in all three survey waves (EICV3 mean annual values corresponding to less than eight USD per household for fertilizer and less than three USD per household for insecticides). The calculated relatively high value of annual

gross production per hectare of approx. 517,012 RWF (EICV3) in combination with the relatively low value 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. 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.[12]

## 6. Results for the existing PPG-toolbox

Figure 1 approaches the question of who has benefitted from recent developments in Rwanda from the income[13] 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 GICs, the curves separately for the entire and the agrarian population.[14] In addition, please note that all graphs for GICs/NIGICs/PGICs below have two vertical axes: while the left axis together with the solid curve(s) maps the *relative* change in the indicator of interest, the right axis together with the dashed curve(s) always focuses on *absolute* change, thus allowing an assessment of relative and strong absolute pro-poor growth, respectively. This makes the interpretation of the graphs admittedly more complex, but allows to provide a more complete picture with just one graph per indicator.

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[12] Please refer to Ellis (1998) for a very thorough review of determinants of and potential constraints to rural livelihood diversification in Sub-Saharan Africa.

[13] We speak always of *income-poor* rather than *expenditure-poor* households since the consumption expenditures were only used as a proxy for income due to the typically high volatility of household incomes in developing countries.

[14] 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.

Figure 1: Income growth incidence curves: EICV1-EICV3
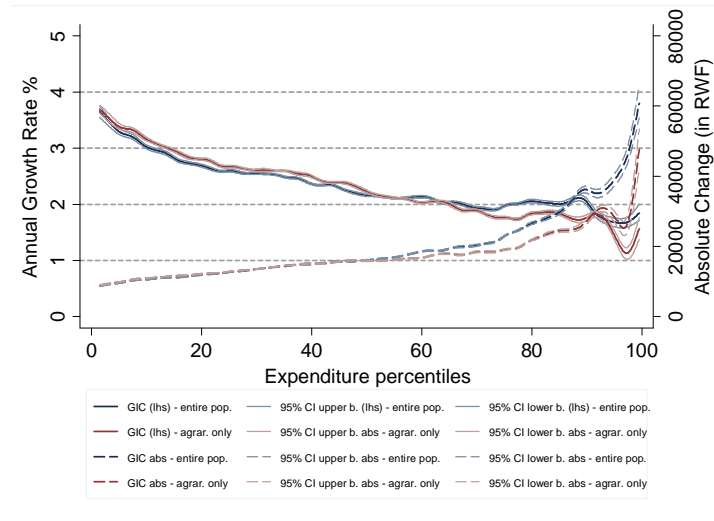
First note that the curves for the agrarian and total population is quite similar, particularly for the poorest 60% where the vast majority of people are famers. As can be seen, the resulting relative and absolute GICs[15] lie above zero for all percentiles of the respective populations (i.e. consumption 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 (GRIM) which was 2.02 % for the agrarian population (see appendix D) with the mean growth rate of the income-poorest 20%[16] of the same agrarian population (3.18%) further reveals that growth has also been pro-poor in the relative sense.[17][18] However, as indicated by the upward sloped absolute GICs (bold dashed lines), the absolute increases of the poor were smaller for both samples 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).

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[15] 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.

[16] 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.

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

[18] The comparison of the mean growth rate of the poor and the overall growth rate is only a somewhat crude summary statistic on the pro-poorness of growth and might hide variations in performance among the poor or the non-poor. Therefore it is always useful to study the entire shape of the incidence curve to fully assess the pro-poorness of growth.

In order to account for the multidimensional nature of poverty, we use the literacy rate[19] for the population aged 15 and above as a first education indicator and construct opportunity curves following the approach of Ali and Son (2007). 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.

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).

Figure 2: Opportunity curves for adult literacy (aged 15+)
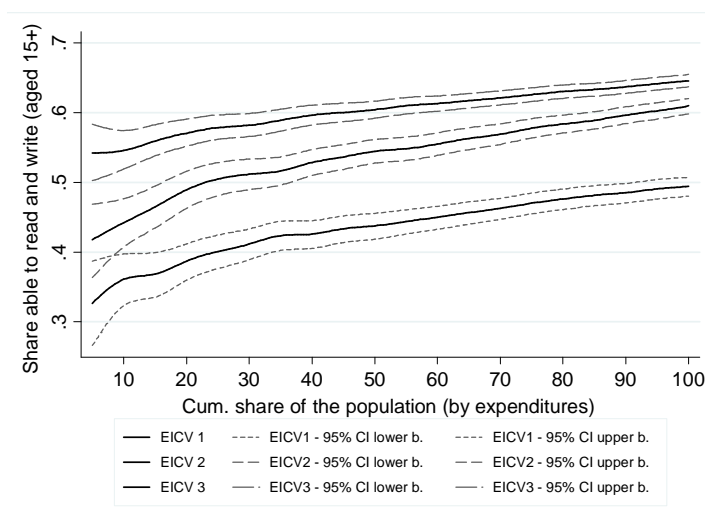
Given that the adult literacy rate is for various reasons a rather imperfect education indicator (Barro and Lee 1993; for recent evidence see Reimers and Klasen 2013), we also use the average years of schooling for individuals aged 15 and above as a second measure for education.

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

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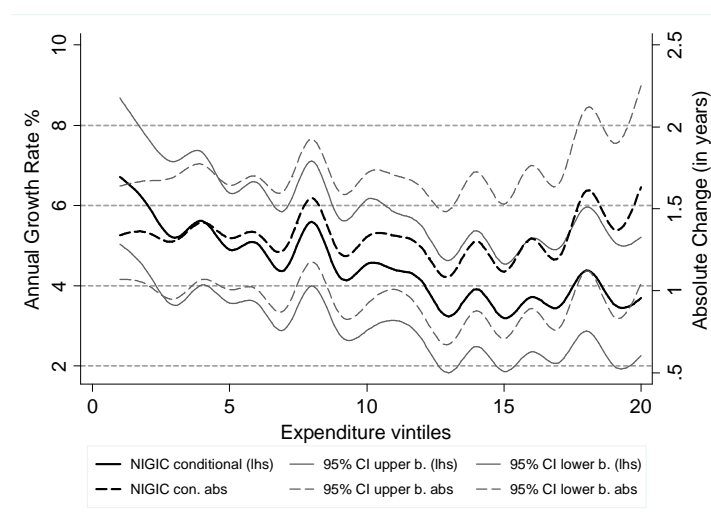

The conditional NIGICs for the avg. years of education (figure 3) generally confirm the above-described results for the adult literacy rate. In particular, we find that all vintiles[20] of the population were able to increase their average level of schooling in the time period under consideration (i.e. 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 therefore lead to inbuilt inertia in this 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

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[20] 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.

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.

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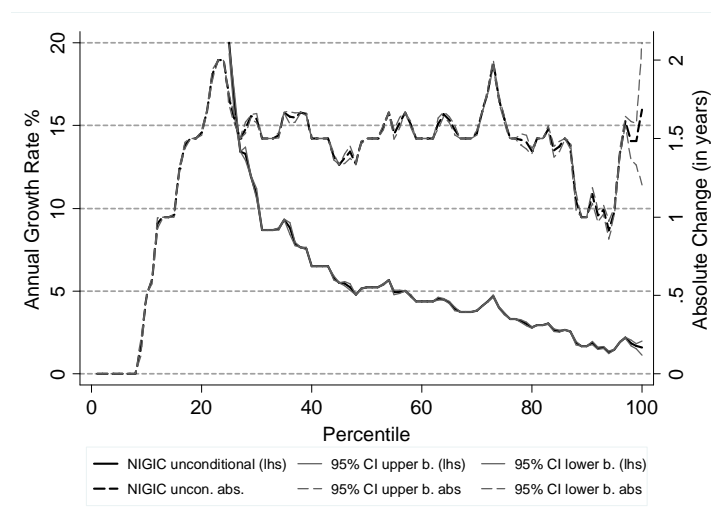

However, this share decreased extraordinarily between EICV1 and EICV3 from approx. 24% to 8% which is reflected in the graph by the increase of the *absolute* NIGIC[21] from 0 to almost 2 years between the percentiles 9 and 24. From a pro-poor growth perspective, this means that considerable progress 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.

To be sure, these are all quantitative measures of education that do not directly measure educational quality (beyond the crude indicator of literacy). But given the relatively close link between education and income poverty (see appendix F), and the close link between education and labor productivity (see Figure 12 below), these improvements in education are not only likely to be valuable as an end in itself as suggested by Sen's capability approach (Sen 1999) but also will help farmers escape income poverty via improved agricultural productivity (see also Reimers and Klasen 2013).

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[21] 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.

Turning to the health dimension of poverty, we analyzed – as a first step – how the agrarian population's access to improved sanitation[22] 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%-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
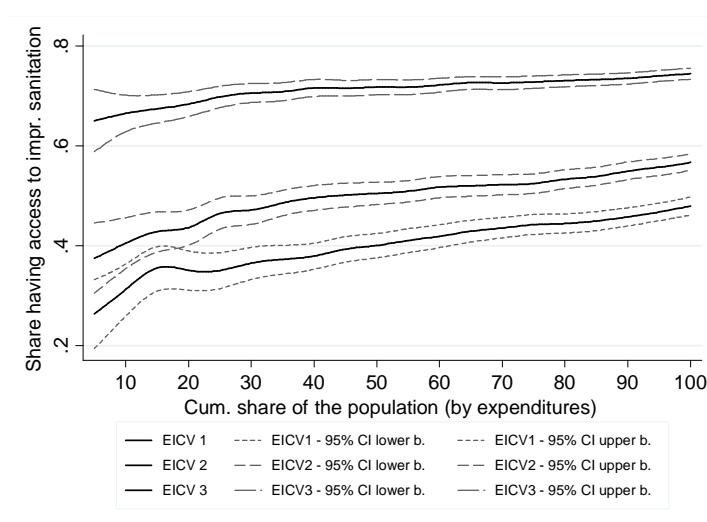
As a second health indicator, we then looked at the access to improved drinking water sources (appendix E) where the picture is much less positive and the data suggest that the access of the income-poor to improved drinking water sources only improved marginally between the surveys (68.8% in EICV1 to 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.

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

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 between individuals, such numbers have always to be treated with caution. However, one would expect that – on average over the 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.

Figure 6: Opportunity curves for health problems in the last two weeks
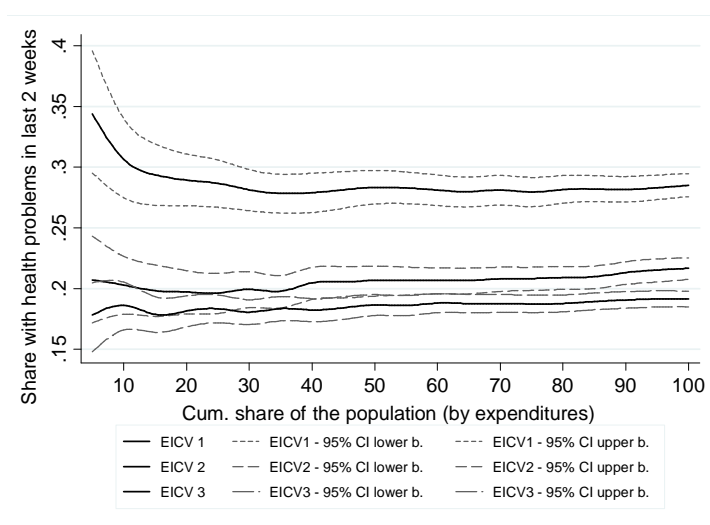
The resulting opportunity curves in figure 6 reveal an extraordinarily rapid reduction of levels for this indicator especially between EICV1 and EICV2. While in the EICV1 survey still 28.94% of the poor were reportedly injured or ill in the two weeks preceding the interview, this share amounted just 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 PPG-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 PPG-definition.

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. However, before we start to present the corresponding results, we would like to emphasize two things. First, one could raise the concern that the households identified by our new tools as land/labor productivity-poor are essentially the same households that were already identified as poor in the income/non-income dimension. This comes down to the question: Are the households identified by our new tools really different ones? To answer this question, we created a Venn-diagram and calculated the overlap between the various "types" of the poor. As a complete description of this exercise would distract from our main story, we summarize the results and refer to appendix F for details: While there is obviously some overlap between the different types of the poor (education poor, income poor, land productivity-poor, labor productivity poor), the overlaps between the different groups are in fact relatively small so that studying pro-poor growth from all of the above-described perspectives is indeed complementary. Second, 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 G and H 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 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).

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, relative and 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).

Figure 7: Monetary land productivity growth incidence curves: EICV1-EICV3
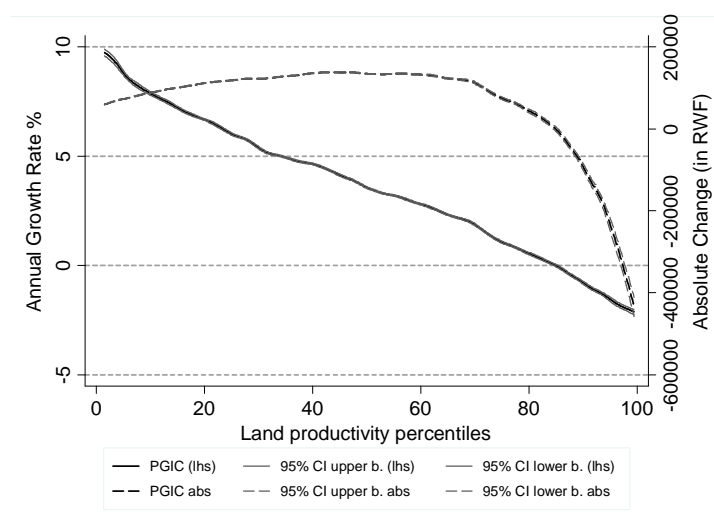
In line with our above explanations, we calculated – as a second step – the corresponding monetary PGICs for agricultural *labor* productivity (figure 8), with the latter being defined as the monetary measure for the household's gross agricultural production per adult worker in the 12 months preceding the survey. 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 encouraging since they imply that the labor productivity-poor were able to increase the output per worker considerably and even relatively faster than the labor productivity-rich.

Figure 8: Monetary labor productivity growth incidence curves: EICV1-EICV3
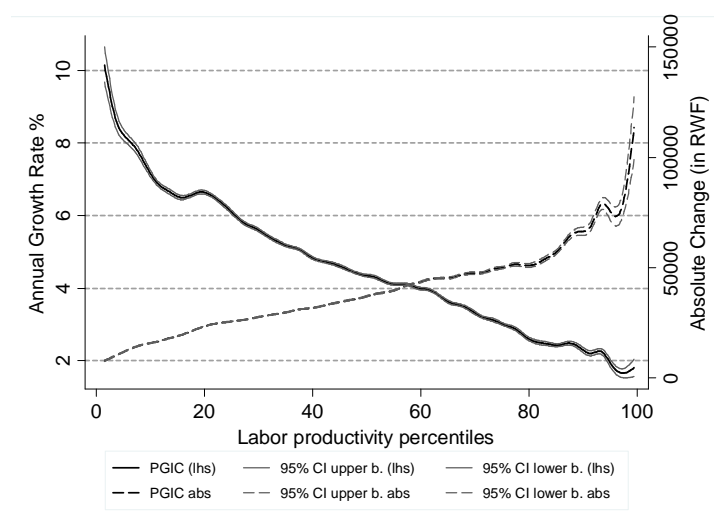
The monetary PGICs in figures 7 and 8 are generally a relatively straightforward way to evaluate to what extent the productivity-poor (either land or labor productivity) were able to increase their productivity levels. However, there are at least two reasons why the results of these monetary PGICs should 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 relatively volatile nature e.g. they could be due to adverse/good weather conditions. Therefore, one should be rather careful when interpreting the *average changes* 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.[23] Despite these downsides, we interpret the above results as first indications that the increases in agricultural land/labor productivity were rather distributed in a pro-poor manner.[24]

Against the background of the above-described drawbacks, we calculated as a third step of our productivity analysis *crop-specific* PGICs for land productivity[25] for the three most important single crops in Rwanda (according to the land use numbers reported in the EICV3 survey) which are in decreasing order of importance: beans, manioc and maize (see appendix I). 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

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[23] One could 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 similar patterns also for sub-periods (EICV1-EICV2 and EICV2-EICV3, respectively) as well as independently for various crops.
[24] In an attempt to account for potentially differing levels of capital intensity, we re-calculated figures 7 and 8 for net instead of gross agricultural land/labor productivity (results not shown). We noted that the overall input levels are very low in all three surveys. In addition, the overall pattern of the curves remains virtually unchanged with only minor shifts in the location of the curves, but not in the shapes. Unfortunately, input data are in our dataset of highly aggregated nature (no plot-level input data available) and we therefore decided to always show graphs for gross productivity for comparability reasons.
[25] Given that the EICV data do not contain detailed information on labor input by crop, we were not able to calculate crop-specific PGICs for agricultural labor productivity.

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.

Figure 9: Land productivity growth incidence curves for bean production: EICV1-EICV3
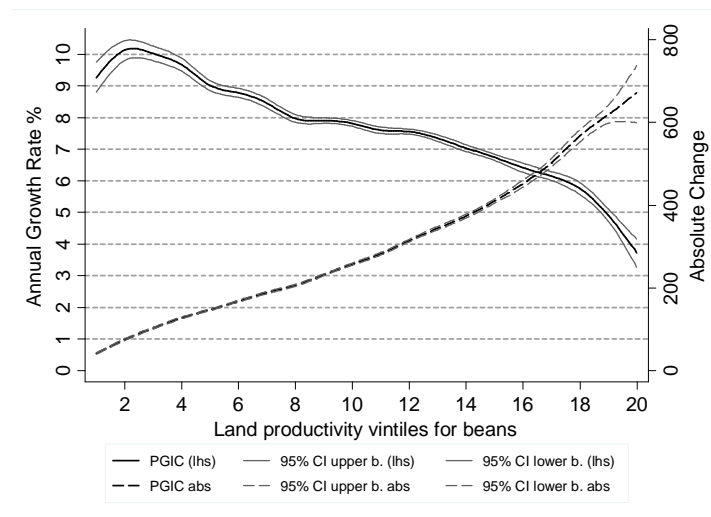
As can be seen from the crop-specific PGICs for bean production in figure 9, all vintiles of the bean-producing population were able to increase their agricultural land productivity considerably in the time-period under consideration (even though one should – as noted above – interpret the overall levels of changes 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 according to the weak-absolute and the relative definition[26] (see appendices J and K).[27] 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-non-poor

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[26] To illustrate that this favorable result is by no means guaranteed, we show in appendix L the land PGIC for maize production between EICV1 and EICV2 which exhibits clearly upwards sloped curves (i.e. an anti-poor development in the relative and the strong-absolute sense).

[27] At first look, the results in figure 7 may seem incompatible with those shown in figure 9 given that we detect in the former decreases in absolute productivity-levels for the land productivity-rich while we cannot confirm these results in figure 9. However, this is likely due to composition effects, i.e. the land productivity-rich plant different crops than the land productivity-poor (e.g. more cash crops) and suffered from a bad harvest in these crops.

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 M and N).

Figure 10: Labor productivity opportunity curves (Type 1) for adult literacy (aged 15+)
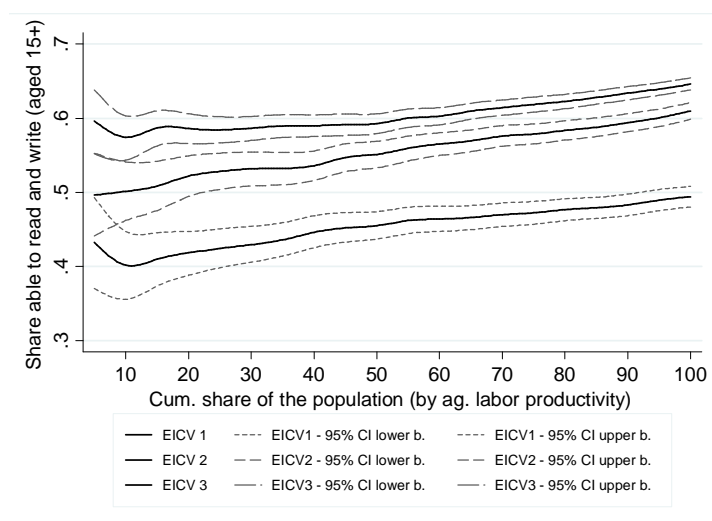
As shown in figure 10, all three labor productivity opportunity curves are sloped upwards implying that literacy levels of the labor productivity-poor were in all surveys below those of the productivity-rich. Yet, the POCs further show that the productivity-poor were not excluded from the expansion of 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 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

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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 M and N), 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
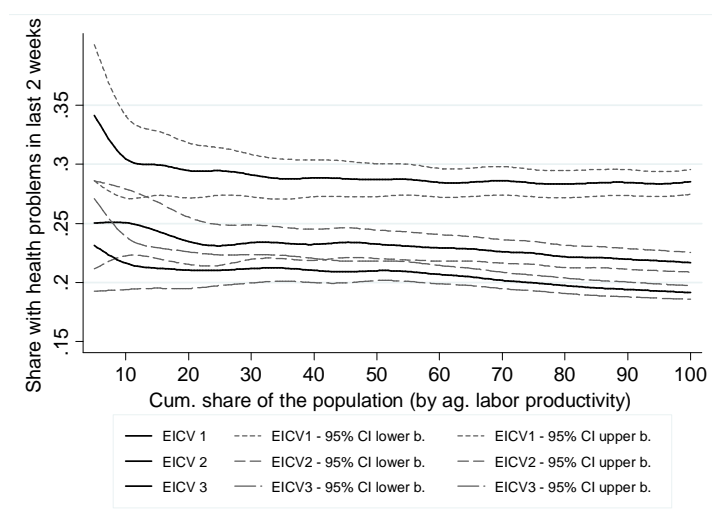
As a last step of our analysis, we pursue the converse question, namely whether the productivity levels of the human capital-poor are lower or higher than those of the human capital-rich. To be able to answer this question, we calculate productivity opportunity curves (Type 2) separately for land and 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.[28] Based on this index we then rank households on the horizontal axis (cumulated) 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

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[28] 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.

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 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 O) where developments likewise failed to be pro-poor in the relative sense.[29]

Figure 12: Labor productivity opportunity curves (Type 2) for human capital
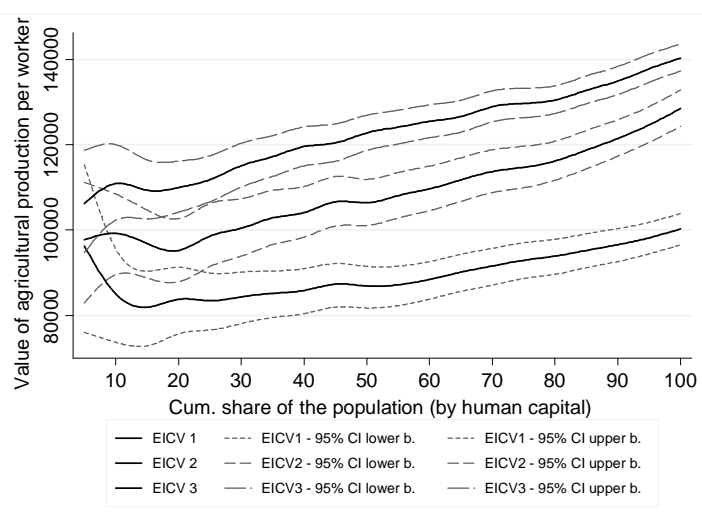
8. Conclusion and policy implications

Pro-poor growth has been identified by many researchers and organizations as probably the most promising pathway to achieve the ambitious goal of sustainable poverty reduction worldwide. Against this background, multiple authors made suggestions how pro-poor growth can be measured which has led to the creation of the PPG-toolbox. The existing instruments 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 the agricultural sector for poverty reduction worldwide. More specifically, we 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

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[29] 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.

poverty. We further emphasized that it is important to distinguish in the analysis between the land and the labor productivity-poor since they regularly exhibit quite different characteristics. 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 us to gain further insights about who has benefited from recent developments in a country.

The potential of this extended toolbox was illustrated for the case of Rwanda using three waves of the nationally representative EICV household surveys. Taken together our 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 commitment of the Rwandan government in the year 1998 to the ambitious Vision 2020 which pursues as one of the key pillars the transformation of Rwanda's agriculture into a productive and market-oriented sector (MINECOFIN 2000; 2012). In the following years, the Rwandan Ministry of Agriculture and Animal Resources (MINAGRI) developed a Strategic Plan for Agricultural Transformation (SPAT) whose first two phases affected the time period covered by the EICV 1-3 household surveys (MINAGRI 2004; 2009). As part of this plan, MINAGRI implemented – supported by various donors – a wide array of programs reaching from crop intensification (e.g. land consolidation, promotion of fertilizer/improved seeds, regionalization of crops) over post-harvest handling to mechanization and irrigation strategies. In addition, substantial investments were made in improving rural infrastructure (especially roads) which was aimed to improve the functioning of input and output markets and reduce transportation costs for farmers. While future research may shed further light onto which single interventions worked best in reaching the (productivity-)poor, the newly introduced tools have shown that the overall mix of programs led to a situation where productivity-poor households in Rwanda were able to benefit disproportionately from productivity growth.

We conclude with some caveats and further suggestions. First, we are aware that all data obtained from household interviews (and particularly information on agricultural production) are prone to measurement and/or recall error which could bias our results. However, we did our best to reduce such measurement error by systematically cleaning 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 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 stress 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.[30]). Nevertheless, we consider the information provided by such a pro-poor analysis as an interesting first step 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 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.

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[30] 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-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.

Appendix

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).[31] 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.[32] 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.[33]

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[31] 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.

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

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

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

Appendix C: Levels of contemplated income and non-income indicators for Rwanda (based on EICV1-EICV3 – ag. 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	Uncond. 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 contemplated income and non-income indicators for Rwanda (based on EICV1-EICV3 – ag. 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-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
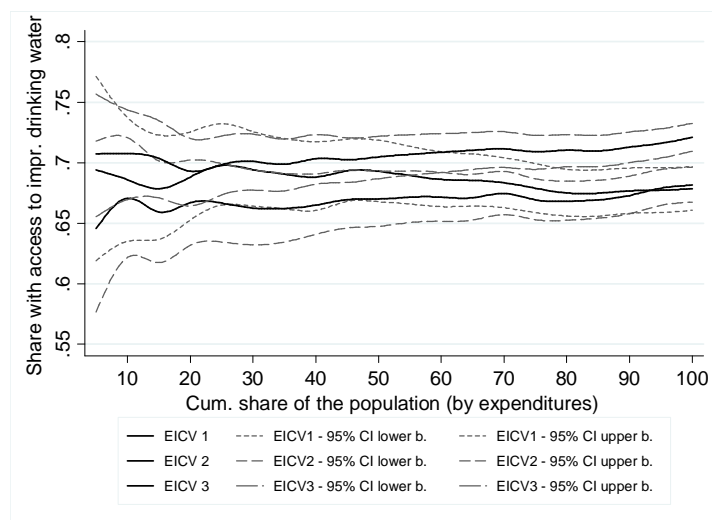
Appendix F: Overlap between the different types of the poor

A relatively straight-forward way to empirically illustrate the added value of the newly-introduced tools is to create a Venn-diagram illustrating the overlap between the potential target groups identified by the various tools. To do this, we created a simple dataset where we tag each time the poorest 20% in the dimension of interest (income, education, ag. labor productivity, ag. land productivity).[34] Then we used the user-written STATA command *venndiag* for the calculation of the Venn-diagram.

The result can be seen below for EICV3 while it should be noted that the above STATA command does not adjust the position of ellipses to correctly reflect the extent of overlap between the groups. This is to say that the graph itself is only for illustrative purposes, but the important information lies in the numbers provided in the different areas.

Based on these numbers, we calculated as a next step for each type of the poor the extent of overlap with other types of the poor (shown in the table below) and – in addition – the share of households that is only in this dimension considered as poor.

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[34] We also would have liked to include an ellipse for the health-poor, but the binary nature of the health indicators available in the dataset did not allow us to come up with a reliable ranking of households according to the health dimension. This was also the reason why we did from the beginning not include any unconditional NIGICs for health indicators in our article.

Venn Diagram
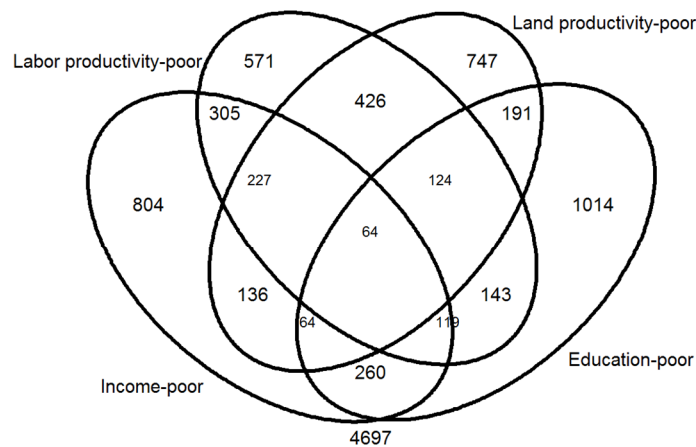
Type of Poor	Uniquely identified	Overlap with… (in percent)			
		Income-Poor	Education-Poor	Labor Productivity-Poor	Land Productivity-Poor
Income-Poor	41%	n.a.	26%	36%	25%
Education-Poor	51%	26%	n.a.	23%	22%
Labor Productivity-Poor	29%	36%	23%	n.a.	42%
Land Productivity-Poor	38%	25%	22%	42%	n.a.

Based on EICV3 data. Overlaps with more than one type of poor are possible and common, hence the shown percentages do not add up to 100% due to double-counting of these observations. Observed patterns are very similar for EICV1 and EICV2, respectively.

The above table reads as follows. Of the poorest 20% according to the income dimension as many as 41% were considered non-poor according to the education and the two ag. productivity dimensions. However, there is also a considerable overlap with other poverty dimensions: 36% of all income-poor households do e.g. at the same time fall into the category of labor productivity-poor households and around one fourth are identified as education-poor and land productivity-poor, respectively. Lastly, there is according to the Venn-diagramm also a (quite) small group of 64 households that is considered poor according to all four considered dimensions of poverty.

We conclude from this graph that the new tools in fact have their justification and should be seen as complements to the PPG-toolbox. This is because – despite various kinds of overlaps with other dimensions of poverty – they *uniquely* identify approx. 29% and 38%, respectively, of the households as poor which is a quite sizeable share.

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

| 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%

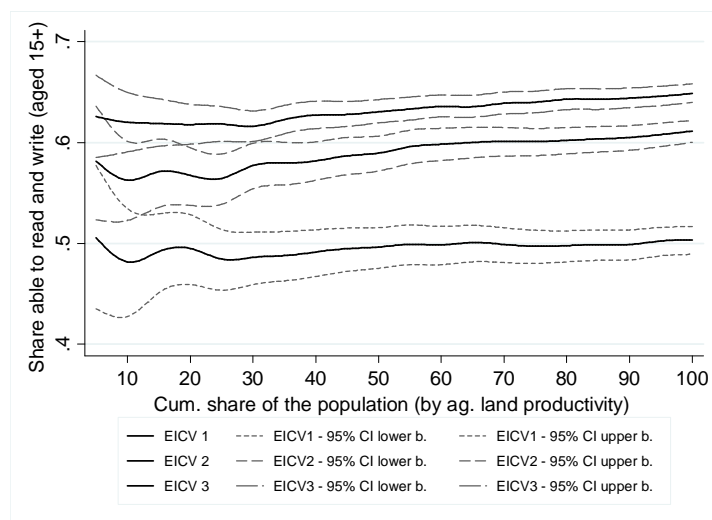**Appendix J: Land productivity growth incidence curves for manioc: EICV1-EICV3**
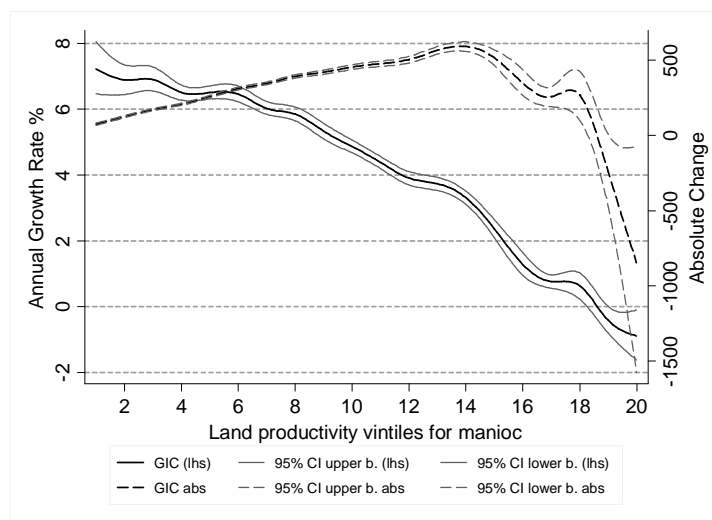
Appendix K: Land productivity growth incidence curves for maize: EICV1-EICV3
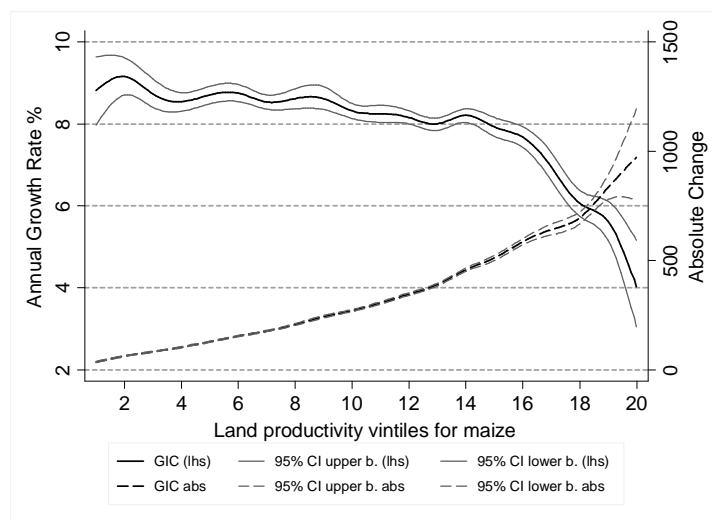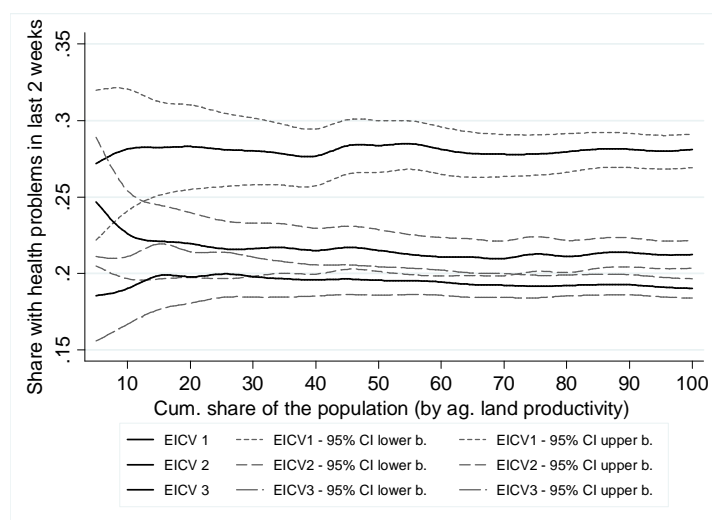

Appendix L: Land productivity growth incidence curves for maize: EICV1-EICV2
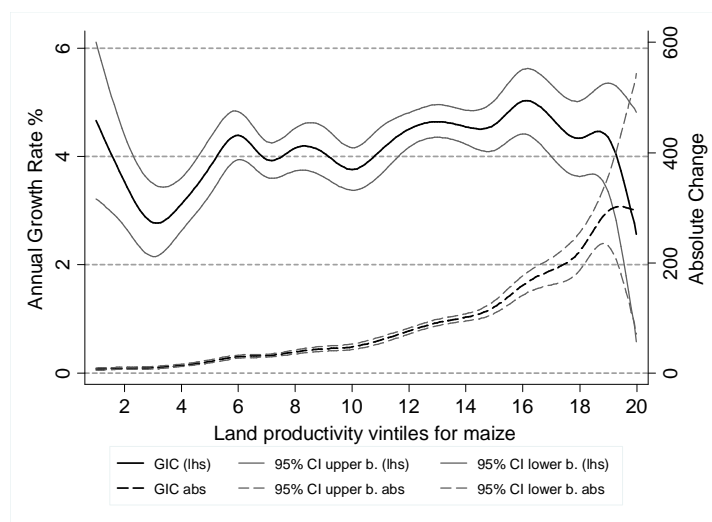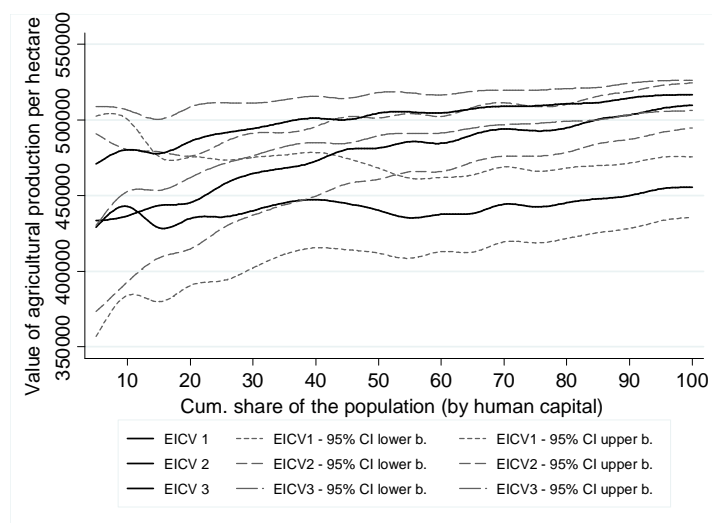
Appendix M: Land productivity opportunity curves (Type 1) for adult literacy (aged 15+)

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

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

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