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Analysis

Adoption of modern varieties, farmers' welfare and crop biodiversity: Evidence from Uganda

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ABSTRACT

This paper assesses the impact of modern varieties adoption on farmers' welfare and crop biodiversity conserved in-situ. Using nationally representative data collected in 2009/2010 in Uganda, an endogenous switching regression model estimates the net economic and environmental effects of switching from local landraces to modern species. Results show that, after controlling for market and agro-ecological factors, the local varieties perform better than modern ones in marginalized and climatic vulnerable areas. Crop biodiversity shows to play a fundamental role in farmers' risk minimizing strategies when the available modern varieties are not adaptable to the local context and not supported by the required level of agro-intensification. Rural development policies should consider the heterogeneity in the adoption returns and support diversity conservation as a national strategic asset for a suitable bioprospecting and a best-fitting agricultural system implementation.

1. Introduction

Evidence from the agricultural and development economics literature has proven that the adoption of modern varieties (MVs) has had a positive impact on productivity growth and food security in Asia and Latin America (Evenson and Gollin, 2003; Pingali, 2012). However, the increasing availability of modern hybrid species has been recognized as one of the main causes of a narrowing cultivation of local landraces (LLs), also called traditional varieties, causing in turn, a rapid declination of inter and intra agricultural genetic diversity conserved *on-farm* (Harlan, 1972; Altieri, 1999; Pascual and Perrings, 2007). As a matter of fact, the second report on the State of the World's Plant and Genetic Resources for Food and Agriculture finds that, since the beginning of the Green Revolution, the number of the worldwide consumed crop varieties have gradually decreased and, currently, only four crops provide 60% of human food energy (FAO, 2010).

The trade-off between agricultural productivity and the conservation of crop genetic diversity has historically been resolved in favour of the former. Especially in sub-Saharan Africa, where 26.8% of the population is afflicted by chronic undernourishment (FAO, 2012), prioritizing food security through the diffusion of new technologies seemed to be the only rational strategy. To this end, sub-Saharan African countries followed the example of other developing countries and fostered a shift from a traditional agriculture to an intensive one. National programmes and international organizations have concentrated their efforts on providing marginalized smallholders with high-yielding varieties of cash crops by assisting them in capacity building in new agro-technology use (Tripp and Rohrbach, 2001). In these cases, the results have been uneven (Otsuka and Larson, 2013). For instance, while maize yields increased by 60 and 56% in South-East Asia, and Latin American and Caribbean countries respectively, between 1970 and 2012, sub-Saharan Africa has only seen a 22% increase (FAOSTAT, 2014).

Among the causes of these productivity differentials, structural market failures have been demonstrated to play a fundamental role as they prevent farmers from optimally combining all the elements necessary for the best agricultural responsiveness of MVs (Dercon and Gollin, 2014; Collier and Dercon, 2013). In fact, modern seeds in isolation do not necessarily improve yields; rather, they are expected to outperform LLs only if accompanied by simultaneous use of complementary inputs such as chemicals fertilizers, pesticides or herbicides (Narloch et al., 2011; Teklewold et al., 2013). However, in sub-Saharan Africa, the access to these inputs is hampered by important and long lasting market frictions. High transport costs, failures to deliver credit to producers, price fluctuations, informational barriers and, in general, poor market infrastructures (Conley and Udry, 2010; Croppenstedt et al., 2003; Liverpool and Winter-Nelson, 2010), can radically reduce the returns of an investment in intensive agriculture. This translates in an extremely low adoption rate of agro-chemicals as pictured by the 12.9 kg per

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hectare utilized in the sub-Saharan African region against the 174.3 kg per hectare employed, on average, in South-East Asia (WBG, 2013).

A second driver of productivity gaps has recently been identified in non-market elements. Contradictory findings on the potential yield of MVs in sub-Saharan African have emerged as a result of their unsuitability to extreme agro-climatic conditions regardless of the use of recommended rates of agro-chemicals (Lipper and Cooper, 2009; Tittonell and Giller, 2013; Cavatassi et al., 2011). In fact, while the new varieties are genetically uniform and developed for high responsiveness and simplified monoculture systems (Perrings et al, 2006; Smale, 2005), LLs are the outcome of an evolutionary selection process driven by local agro-ecological characteristics as well as the farmers' subsistence requirements (Altieri, 1999). The heterogeneity of this selection process makes LL incredibly adaptable to degraded and poor soils, water scarcity, droughts, and biotic/abiotic stresses. This motivates marginalized farmers to still cultivate a diversified portfolio of traditional crops as a strategic asset to face agricultural shocks and climate change (Bellon, 2004; Jarvis et al., 2008; Mercer and Perales, 2010). Exploiting the ecological services supplied by the crop variability, farmers can minimize agricultural risks (Di Falco and Chavas, 2009; Di Falco and Perrings, 2005) and indirectly operate as “custodians” of the local agricultural biodiversity stock for future bioprospecting activities (Narloch et al., 2011; Quaas and Baumgärtner, 2008).

The described behavioural pattern might be extremely relevant in the creation of development policies for sub-Saharan African countries, where around the 63% of the population still live in rural areas. In fact, except for the promotion of modern agriculture, the questions of how to increase food security and reduce poverty in such areas remain at the top of international agenda. In view of agro-environmental insights, the “silver-bullet” approach of incentivizing the intensification and the adoption of standardized MVs, irrespective of the socio-economic constraints and/or the ecological context, is increasingly criticized in favour of a best-fitting sustainable strategy to be implemented at farm level (Conway and Barbier, 2013; Giller et al., 2009). Since the distribution of costs and benefits associated with a new agricultural technology is heterogeneous (Suri, 2011; Narayanan, 2014), it is therefore likely to observe groups of adopters facing real or financial returns lower than their expectations (Duflo et al., 2008; Dercon and Christiaensen, 2011). The heterogeneous outcome can be the direct consequence of a not-fully informed adoption of new technologies by the farmers. For instance, farmers can be unaware of how a MV will perform in the long term or under a specific agro-ecological and market access framework, or they may be unable to consistently adjust the input utilization rates to soil nutrient requirements (Barham et al., 2014; Isik and Khanna, 2003; Feder, 1980).

In this paper we empirically explore under which circumstances the adoption of MVs is a strictly optimal strategy for smallholder farmers in terms of welfare and, further, we verify the effects of such adoption decisions on the conservation of crop diversity. The assessment of non-adopters' and adopters' relative performances, in the counterfactual scenario of the observed individual strategy, has scope for providing suggestions to design agricultural policies that could address rural development and crop biodiversity conservation problems simultaneously.

To address this issue, we use the nationally representative Uganda Panel Survey of the Living Standard Measurement Survey on Agriculture (LSMS-ISA), consisting of 3123 households, carried out in 2009–2010. As we do not have a randomized control experiment, we employ an endogenous switching regression model. This empirical framework allows us to overcome the challenges associated with the unobserved heterogeneity and the potential endogeneity that may affect the consistent estimation of welfare and crop biodiversity outcome variables.

Therefore, while this paper adds to the growing recent literature on drivers of MVs adoption in sub-Saharan Africa (Asrat et al., 2010; Cavatassi et al., 2011; Kassie et al., 2011; Asfaw et al., 2012; Teklewold et al., 2013; Shiferaw et al. 2014), our first contribution is the investigation of the cross-impact of adoption on crop diversity conservation at the farm level by simultaneously verifying the effects of market and agro-ecological constraints. There is still insufficient empirical studies conducted on the impact of crop diversity on welfare (Di Falco et al., 2007, Di Falco and Chavas, 2009; Di Falco et al, 2010), however, in respect to existing studies, we provide further evidence by treating crop diversity as an indirect outcome of the farmers' livelihood strategies, and for this reason, directly affected by the adoption decisions. We examine the implication of MVs adoption on different outcome variables. More specifically, net crop income and food expenditure per capita are used as welfare indicators, and the crop richness and evenness as indicators of crop diversity.

Second, we explore and discuss the results' sensitivity to variations of an aggregate relative index of intensification. This index is an adaptation from agronomic studies (Herzog et al., 2006) and has never been utilized in empirical economic assessments. Nonetheless, it is particularly relevant to determine the complementary effects of a mixed combination of external inputs on a MV responsiveness and on the depletion of diversity.

Third, we supply an assessment of the impact of adoption according to different Ugandan agro-ecological zones as well as soil quality levels. Finally, by characterizing the nature of the beneficiaries and losers of the adoption of MVs, we can identify, on one hand, the target population for a proper sustainable intensification approach and, on the other hand, those farmers who face no opportunity cost for the cultivation of LLs, and should be sustained for their conservation of crop biodiversity.

The rest of this paper is organized as follows. The next section presents the conceptual framework and explains the empirical strategy, Section 3 illustrates the data, Section 4 explores and discusses the results, while Section 5 concludes.

2. Conceptual Framework and Estimation Procedure

The adoption of a MV can be viewed as a binary voluntary decision by farmers who maximize their expected utility according to their individual heterogeneous characteristics, as well as according to local structural factors (Suri, 2011). Adopting farmers should optimize this objective through the intensification of their land endowment so as to obtain the best average yield response, expressed in terms of agricultural welfare, from a single or few MVs. However, while the adoption of the new technology is a decision that creates two mutually exclusive groups, the properly implemented intensification level is not purely deterministic. For example, we can observe MV cultivation in low intensive agro-ecosystems or a higher than average crop diversification in high intensive farms. In fact, as pointed out by the seminal paper of Feder (1980), the choice to adopt a MV is subject to a certain degree of uncertainty determined by the fact that a farmer builds an expectation on which will be the optimal intensification “package” for the best responsiveness of the new technology. The extent to which such expectations will be consistent with the achievable real performance depends on market failures and agro-ecological factors (Altieri, 2004; Kijima et al., 2011). The larger the market constraints, and the less the suitability of the MV to the agricultural local system and poor soil quality, the greater will be the gap between expectations and current returns.

Alternatively, a farmer can decide to not-adopt the MV and continue to rely on the cultivation of a diversified LLs portfolio in a framework of risk minimization behaviour. Farmers, aware of the potential negative effects stemming from their inability to optimally support the MV cultivation, cultivate the LLs to avoid facing financial vulnerability associated to the intensification strategy (Weitzman, 2000; Di Falco and Chavas, 2009).

In this context, the individual MV adoption pattern not only affects the overall agricultural outcome, but also indirectly drives the crop diversity that is conserved *on-farm*. In fact, while non-adopters maintain a high crop richness to minimize the impacts of market and climatic shocks, if adopters could perfectly adjust the inputs rates to the new variety requirements, hence, just one MV should be cultivated to obtain the best yield response (Omer et al., 2010). The diversity of crops cultivated is therefore an outcome of the decision to adopt and, like