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RTG 1666 GlobalFood

Transformation of Global Agri-Food Systems:
Trends, Driving Forces, and Implications for Developing Countries

Georg-August-University of Göttingen

GlobalFood Discussion Papers

No. 12

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May 2012

RTG 1666 GlobalFood · Heinrich Düker Weg 12 · 37073 Göttingen · Germany
www.uni-goettingen.de/globalfood

ISSN (2192-3248)

Seed market liberalization, hybrid maize adoption, and impacts on smallholder farmers in Tanzania

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May 2012

Abstract: *Since the early 1990s, liberalization of the seed market in Tanzania has attracted several foreign companies that now market maize hybrids in the country. In this article, we analyze the impacts of proprietary hybrids on maize yields, production, and household living standards. We build on a recent survey of smallholder maize farmers in two zones of Tanzania. Hybrid adoption rates are 48% and 13% in the North and East, respectively. Average net yield gains of hybrids are 50-60%, and there are also significant profit effects. Geographical disaggregation reveals that the benefits have mostly occurred in the North, which also explains higher adoption there. In the North, hybrid adoption caused a 17% increase in household living standards. We conclude that proprietary hybrids can be suitable for semi-subsistence farms and that seed market liberalization has generated positive socioeconomic developments.*

JEL classification: I31, Q12, Q13, Q16

Key words: seed market liberalization, farm survey, technology adoption, household living standards, Tanzania

Acknowledgments: The household survey for this research was financially supported by the Australian Center for International Agricultural Research (ACIAR) under the CIMMYT led project Sustainable Intensification of Maize-Legume Cropping Systems in Eastern and Southern Africa (SIMLESA).

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1. Introduction

In the 1980s and 1990s, many developing countries began to liberalize their seed markets. This has led to an increasing role of private sector companies. In some parts of Asia and Latin America, the private sector seed market share is already bigger than the public sector share (Naseem et al., 2010). Although still lower in magnitude, a growing private sector role can also be observed in Africa. Especially in maize, private sector breeding budgets and the production of proprietary seeds have increased remarkably over the last 20 years (Hassan et al., 2001; Langyintuo et al., 2010).

The wider implications of liberalizing seed markets are not yet sufficiently understood and have been the subject of controversy. As private technology development and delivery mechanisms are often more efficient than public systems, farmers' access to new seed technologies might improve. Yet, especially where market imperfections are widespread, as in most parts of rural Africa, liberalizing and privatizing seed markets might introduce a bias against smallholder farmers. Proprietary seeds may potentially increase farmers' dependence on private companies, especially when the industry is highly concentrated. Depending on prices of proprietary seeds and their suitability for smallholder conditions, some farmers may also be excluded from access to new crop technologies, which could exacerbate rural poverty and inequality (Lipton, 2010).

Maize is the most important staple food in Eastern and Southern Africa (Shiferaw et al., 2011). Most farmers in this region grow maize semi-subsistently. Despite the crop's importance, average maize yields in Africa are low – around 2 t/ha, compared to a global average of over 5 t/ha (FAOSTAT, 2012). This yield gap is largely due to poor soils, drought, temperature stress, and low use of fertilizer and other agricultural inputs. Modern varieties (MVs), including improved open-pollinated varieties (OPVs) and hybrids, are grown on less than half of the total African maize area. In some countries, such as Zimbabwe and Kenya, adoption rates are above 70%, while in many others they are only around 20% (Langyintuo et al., 2010).

In most of the scientific literature, it is assumed that MVs are more beneficial to adopters than traditional varieties. Many studies also argue that nonadopters could benefit from adoption, particularly in cases where farmers face information or credit constraints. However, several activist groups claim that smallholder farmers would not benefit from MVs, especially not from private sector hybrids (GRAIN, 2010). This claim is based on several assumptions, namely that seed companies disseminate biased information about their products, that farmers are forced to buy seeds from monopolistic seed suppliers, or that farmers have trouble in understanding the suitability of new technologies for their particular context. Skepticism about the merits of commercial plant breeding has accompanied the diffusion of hybrid maize since its discovery a century ago (Kingsbury, 2009; Paarlberg, 2008).

So what is the empirical evidence concerning impacts of modern maize varieties on farmers in Africa? Much of the literature cites large yield and income gains, but estimates are often based on trial data, partial budgeting from farm surveys, or correlation between aggregate production levels and MV adoption (Heisey and Smale, 1995; Byerlee and Heisey, 1996; Hassan et al., 2001; Smale and Jayne, 2003). Potentially confounding factors, such as differences in soil quality, fertilizer use, or crop management, are usually not controlled for (Morris, 2002). Econometric estimates of production models are rare; those that exist sometimes attribute little yield gains to MVs as opposed to fertilizer (De Groote et al., 2005). Hardly any study on modern maize varieties in Africa looked beyond farm productivity to analyze impacts on household living standards.[1] Hence, the available literature on MV impacts remains inconclusive.

Here, we address this research gap, focusing on the maize sector in Tanzania. While different authors have examined liberalization effects in fertilizer and grain markets in Tanzania (Putterman, 1995; Ponte, 2001; Jayne et al., 2002; Cooksey, 2011), seed market issues have hardly been analyzed. We describe seed market liberalization in Tanzania, pointing at the growing role of private seed companies and proprietary hybrids. Furthermore, we use recent household survey data and econometric techniques to assess the impact of

[1] With very few exceptions (e.g., Kassie et al., 2011; Amare et al., 2012) this also holds for MVs of other crops.

hybrid maize on crop yields, production, profits, and living standards. The results can also be interpreted as the impacts of seed market liberalization and privatization, because all maize hybrids that farmers in our sample used were developed by private companies, whereas all improved OPVs stem from public breeding programs.

The rest of this article is structured as follows. Section 2 provides an overview of liberalization in Tanzania's maize seed market. Section 3 presents the household survey data and some descriptive analyses. Section 4 introduces the econometric approach, while estimation results are presented and discussed in section 5. Section 6 concludes.

2. Background

2.1 Seed market liberalization

Liberalization refers to the removal of government regulations that impede the entry of private companies into a market that is dominated by state-owned enterprises (SOEs). Thus, liberalization can increase competition and consumer choice. In contrast, privatization has been given a variety of definitions (Dinavo, 1995). The most common use of the term relates to the sale of all or part of a government's equity in SOEs to the private sector, or the placing of SOEs under private management through leases and management contracts (Vickers and Yarrow, 1988). In contrast, Dinavo (1995) lists liberalization or deregulation as one of eight commonly used forms of privatization. Others stress that liberalization does not necessitate privatization in the narrow sense and that privatization may be ineffective unless it is accompanied by liberalization, because privatization alone does not automatically entail more competition (Van de Walle, 1989). In this article, the two terms liberalization and privatization are used interchangeably, because it is the reduction or removal of policy barriers and the resulting entry of private companies in a seed market formerly dominated by SOEs that we are particularly interested in.

A common avenue for private companies to participate in the seed market is via hybrids. Hybrid seeds refer to the first generation (F1) cross of two distinct lines of a plant. Through heterosis, F1 hybrids exhibit more vigor than OPVs, leading to higher vitality and yields. However, sowing the harvest of F1 hybrids (recycling) results in a reduction in vigor and consequently lower yields as compared to the F1. Yields of recycled F1 hybrids may still exceed those of OPVs for several generations (Japhether et al., 2006), although this depends on a number of factors. In any case, the hybrid vigor in the F1 provides an incentive for farmers to purchase seeds more frequently. Thus, private seed companies can recover their costs and make profit from regular sales even without legal restrictions to seed recycling (Pray and Ramaswami, 1991).

Several studies have analyzed the situation in India, where seed markets have been liberalized since the 1980s (Pray et al., 1991; Tripp and Pal, 2001; Pray et al., 2001; Matuschke et al., 2007; Matuschke and Qaim, 2008; Kolady et al., 2012). Pray et al. (2001) and Kolady et al. (2012) noted a significant increase in research and development investments by private seed companies in India, which they largely attribute to policy reforms. Matuschke et al. (2007) and Matuschke and Qaim (2008) showed that innovation rates in seed markets increased after liberalization, and that proprietary hybrids of wheat and millet are superior to most public sector varieties. Tripp and Pal (2001) found that the private sector also engaged in multiplication and marketing of publicly bred varieties and hybrids. A common finding of these studies is that the entry of private companies in seed markets has brought sizeable benefits to many Indian farmers, including smallholders.

Much less evidence is available for the consequences of seed market liberalization in Sub-Saharan Africa. The evidence from India may not be easily transferrable, because the conditions are quite different.

2.2 Seed market liberalization in Tanzania

After independence in 1961, Tanzania turned to African Socialism. The Arusha Declaration of 1967 was followed by a massive nationalization of the major means of production. Smallholder farmers were supposed to live in groups and share basic services (villagization).

By 1979, a total of 380 parastatals had been registered, and by June 1990 the number had increased to 425. During this era of socialism, private sector involvement in agriculture was very small. In the 1980s, the international donor community (the IMF and the World Bank in particular) increasingly demanded economic reforms due to severe structural problems. Tanzania ultimately accepted to take measures of structural adjustment (Due, 1993; Limbu and Mashindano, 2002). In the agricultural sector, input markets were liberalized and fertilizer subsidies were removed, resulting in a steep increase in fertilizer prices (Ponte, 2001).

Public maize research in Tanzania began in the 1960s. The National Maize Research Program (NMRP) was launched in 1974 and released about 15 improved maize varieties until the mid-1990s, including several hybrids. The government-owned Tanzania Seed Company (Tanseed) was the only producer of certified maize seeds until the early-1990s, when private companies were for the first time allowed to enter the market (De Groote et al., 2002).

In 1993, Cargill became the first private company to release a maize hybrid in Tanzania. Pannar, a South African company, entered the market in 1995. They were followed in 1999 by Monsanto and Pioneer, in 2000 by Kenya Seed, and in 2001 by Seed Co Limited from Zimbabwe. Fica Seed, Tanseed International (founded in 2002 after the government-owned company collapsed), and Western Seed released their first maize hybrids in subsequent years (Table 1). Langyintuo et al. (2010) report that the number of registered maize seed companies grew from 2 in 1997 to 14 in 2007. Based on seed sales, they estimate that 18% of the national maize area was under MVs in 2007, up from 4% in 1997. If farmer recycled seeds are included, the MV share will be somewhat larger, but nationally representative data are not available. Hybrids and improved OPVs respectively made up 65% and 35% of the total volume of MV sales in 2006/07 (Langyintuo et al., 2010).

[Table 1]

3. Data and Descriptive Analysis

3.1 Survey

A household survey was conducted in the Eastern and Northern zones of Tanzania in late 2010. These two zones represent two main agroecological climates of Tanzania: the dry highlands (North) and the humid lowlands (East). Within these two zones, four districts (Mvomero, Kilosa, Karatu, Mbulu) from three regions (Morogoro, Arusha, Manyara) were deliberately selected. Then, 30 wards and 60 villages were randomly selected. At the village level, households were sampled randomly, taking district level population sizes into account. In each zone, 350 households were selected, resulting in a total sample size of 700 households. Out of these, 695 grew maize.

The household head of each household was taken through a structured interview, providing detailed information on household composition, location and infrastructure, social capital, asset ownership, agricultural production, and other economic activities. Input and output data for cropping activities were captured for all plots on a farm, so the number of plot observations is larger than the number of households surveyed. Cropping details refer to the 2008/2009 season. Household level food consumption data were collected through a 7-day recall and non-food consumption data through a 12-months recall for 2009/2010. Thus, the consumption data can be linked to the previous agricultural season.

3.2 Descriptive analysis

The average farm size in our sample is around 5 acres. This is in line with census data from Tanzania. Of all maize growers, 30% used maize hybrids at least on a part of their total maize area; 9% were partial adopters and 21% were full adopters in 2008/2009. Adoption patterns differ between zones. In the North, partial adoption was observed for 14% and full adoption for 34%, whereas in the East, partial and full adoption was observed for only 5% and 8%, respectively. Considering the total maize area of farms in our sample, 23% was cultivated with hybrids. This includes recycled hybrids, which were grown on almost one-quarter of the total hybrid area. All hybrids used by sample farmers were of private origin, and all seeds of private origin were hybrids (all improved OPVs were of public origin). We can thus equate private origin with hybrids for the purpose of this analysis.

The relatively low adoption rates of hybrids may be due to the fact that suitable hybrids are not available for all locations. Thus, available maize hybrids may not be beneficial for all farmers (Suri, 2011). On the other hand, limited awareness may also play a role. Of all farmers in our sample, 38% reported that they had never heard about any maize hybrid. This share is higher in the East than in the North.

Seven different hybrids were used on the 291 hybrid maize plots in our sample. The dominant hybrid was SC627, which was grown on 56% of the plots, followed by DK8031 with a share of 19%. The other five hybrids were from Pannar and Kenya Seed, each accounting for less than 10% of the hybrid plots in our sample.

Some sample descriptive statistics at the plot level are shown in Table 2. Each farmer has 1.6 maize plots on average. The amount of seed used was higher on hybrid plots than on nonhybrid plots. Around one-quarter of the hybrid plots were planted with recycled hybrids, whereas seed recycling was observed on two-thirds of the nonhybrid plots. Intercropping of maize, mostly with legumes, was practiced on 82% and 57% of the hybrid and nonhybrid plots, respectively. Intercropping can potentially contribute to higher maize yields due to the ability of legumes to fix atmospheric nitrogen. On the other hand, intercropping might reduce the amounts of other nutrients and water available for maize, especially under dry conditions. Virtually all maize was produced under rainfed conditions. Mineral fertilizer was applied to only 3-4% of all maize plots, with no significant difference between hybrids and nonhybrids. Likewise, pesticide use was very low. Manure application was more common, especially on hybrid plots. Maize yields were quite low in an international comparison, but they were significantly higher for hybrid than for nonhybrid maize (Table 2).

[Table 2]

The cost of production was also higher on hybrid than on nonhybrid plots. This is partly due to seed costs, which were twice as high for hybrids. Moreover, some differences in the cost of other inputs were observed. Nonetheless, the higher yields and revenues (including the market value of home-consumed maize) of hybrids outweighed the higher costs, so that hybrid adoption was associated with significant profit advantages (Figure 1).

[Figure 1]

Table 3 shows some descriptive statistics at the household level, disaggregated by hybrid adoption status. While full adopters were slightly more educated than partial adopters and nonadopters, there were no significant differences in terms of farm size and total maize area cultivated. Yet, due to yield differences, maize production is higher among full and partial adopters, as compared to nonadopters. About half of all households sell some maize; the rest produce maize only for home consumption. These shares were almost equal across the three groups. But in quantity and value terms, maize sales and consumption were significantly higher among adopters than among nonadopters. We use household expenditure and consumption data to assess living standards. Expenditures for market consumption were slightly higher among adopters than among nonadopters. On the other hand, and somewhat surprisingly, the value of nonmarket consumption was lowest among the full adopters. In terms of total consumption values, no significant differences could be observed.

[Table 3]

As there were notable differences in hybrid adoption in the North and East, Tables 4 and 5 analyze plot and household level characteristics separately for these zones. Significant differences in maize yield between hybrids and nonhybrids were observed in the North but not in the East (Table 4). Likewise, total maize production and home consumption were higher among hybrid adopters in the North, but not in the East (Table 5). This suggests that hybrid maize adoption is not beneficial in the East, which also explains the low adoption rates in that zone. Interestingly, mostly the same hybrids were used in both zones, although the agroecological conditions are different. It appears that the hybrids available are much better suited to the higher altitudes in the North, while there is no productivity advantage in lowland areas. Suitable hybrids for the Eastern zone have hardly been commercialized up till now.

[Table 4]

[Table 5]

4. Econometric Approach

The previous section has shown that there were differences in maize yields and production values between hybrid adopters and nonadopters, while there were no significant differences in household consumption. However, these comparisons do not necessarily reveal net impacts of hybrid adoption, because potentially confounding factors have to be controlled for. This requires an econometric approach. We assume that farmers choose between using hybrid or nonhybrid seeds on a given maize plot and thus try to maximize their utility from growing maize. We model the decision in a random utility framework, in which a household *h* chooses hybrid over nonhybrid seeds on plot *p* if the utility from adopting hybrids, U_{hpA}, exceeds the utility of not adopting hybrids, U_{hpN}. The difference between these two utilities can be written as $T_{hp}^{*} = U_{hpA} - U_{hpN}$. Because utilities cannot be observed directly, we express T_{hp}^{*} as a function of a vector of observable variables V_{hp}:

$$T_{hp}^{*} = \sigma V_{hp} + \varepsilon_{hp.}$$

Using a binary specification, T_{hp} is a dummy variable that equals 1 if the household uses hybrid seeds on plot *p*, and zero otherwise. σ is a vector of parameters, and ε_{hp} is a random disturbance term. Note that the number of adoption decisions a household faces is equal to the number of maize plots. Since T_{hp}^{*} may differ between plots, a utility-maximizing household could opt for hybrids on some but not all plots.

We examine the impacts of hybrid adoption on three outcome variables, namely maize yield per acre, maize production per household, and household living standard. Living standard is measured in terms of household consumption, including market expenditures and the value of home consumption. The basic econometric model is as follows:

$$Y = \gamma X + \beta Z + \mu$$

where *Y* is the outcome variable of interest, and *X* is the treatment variable capturing hybrid adoption. In the plot-level yield model, *X* is a dummy that is equal to T_{hp}. In contrast, *X* is a truncated continuous variable measuring the number of acres under hybrid maize in the household-level production and consumption models. The estimates of the coefficients *γ* are used to infer the impacts of hybrid maize adoption on the various outcome variables. *Z* is a vector of covariates, including plot-level inputs such as fertilizer and labor, as well as household-level characteristics such as education and farm size (further details below). *μ* is a random error term. The functional form is chosen according to theoretical and empirical fit. Several specifications are implemented in order to check the robustness of the results.

One methodological issue is whether hybrid adoption is endogenous in any of these models. A common source of endogeneity in impact assessment is non-random selection into treatment, which can lead to selection bias (Winters et al., 2011). The underlying cause of such bias is usually an omitted variable that is correlated both with the treatment variable (hybrid adoption in our case) and the error term. To avoid selection bias, one should include observed variables that are expected to be correlated with hybrid adoption and the error term. Yet, there may also be relevant unobserved variables, such as motivation or ability that are difficult to capture. Identifying possible sources of heterogeneity may help to identify observed variables that are correlated with relevant unobserved variables. For example, ability or motivation may be correlated with education, which can then be included into the model to test and correct for unobserved heterogeneity.

Another common method to address issues of endogeneity is instrumental variable (IV) regression, but this works only if valid instruments are available. An instrument is an observed variable that is uncorrelated with the error term and correlated with the potentially endogenous variable. These two prerequisites for validity can be assessed statistically using tests of under- and overidentification (Kennedy, 2008). We will test and control for potential endogeneity of hybrid adoption by including various covariates and using an IV approach.

5. Regression Results and Discussion

5.1 Impact on maize yield

Estimation results for the plot-level maize yield model are shown in Table 6. We employ a Cobb-Douglas type functional form with inputs and output expressed in natural logarithms. This form allows for decreasing marginal returns to inputs and showed the best empirical fit in comparison to alternative functional forms. In the first specification, where we use an ordinary least squares (OLS) estimator, we control for several inputs such as fertilizer, pesticides and labor, and for farmer characteristics such as age and education of the household head. In addition, we include the treatment dummy (hybrid adoption on the particular plot) and dummies for intercropping, irrigation, and good soil quality. The coefficient of the hybrid dummy in column (1) indicates that hybrids raised yields by 48%.[2] In column (2), we add an additional dummy for recycled hybrids. While the coefficient of this additional dummy is not statistically significant, it is negative and causes the hybrid treatment effect to increase. The coefficient of 0.46 implies a hybrid yield gain of 58%. Comparison with column (1) suggests that higher productivity can be achieved when fresh F1 seeds are used every season. On the other hand, these results also suggest that recycled hybrids still outperform OPVs on average.

In column (3) of Table 6, we add a dummy for the Northern zone. As pointed out above, agroecological conditions differ between the North and the East, which may affect maize yields. There may also be other geographical differences including relevant unobserved factors that are controlled for by the North dummy.[3] However, the estimates reveal no

[2] Coefficients of dummies in models with a log-dependent variable are interpreted as in Halvorsen and Palmquist (1980).

[3] For instance, there may be geographical differences in farmers' motivation to achieve high maize yields. If maize is the dominant staple food, farmers may put more effort into this crop than if maize is only one among several important food crops. Analysis of crop production patterns in our sample shows that farmers in the North produced a smaller range of staples than farmers in the East. In the North, maize, haricot bean, and pigeonpea

significant effect of the North dummy; and the coefficient of hybrid adoption remains almost unaffected. In column (4), we add an interaction term of hybrid adoption and East, This is instructive to analyze geographical differences in the hybrid treatment effect, which we expect based on the descriptive analysis discussed above. Indeed, the coefficient of this interaction term is negative and highly significant. At the same time, the coefficient of the hybrid dummy itself increases substantially. These results confirm geographical differences in impact. In the North, hybrid adoption increases yield by 80%, while in the East adoption is not associated with a significant yield effect. A Wald test failed to reject the null hypothesis that the sum of the coefficients on hybrid and the interaction term is equal to zero. As mentioned, this is likely due to the fact that maize hybrids well suited for the agroecological conditions in the East have not been developed. This also explains the low hybrid adoption rates in the East.

[Table 6]

Even though we tried to include a comprehensive set of covariates that help to avoid selection bias, hybrid adoption may still be endogenous if unobserved heterogeneity is not properly controlled for. To test for this, we use an IV approach, results of which are shown in column (5) of Table 6. We use the North dummy and education as instruments for hybrid adoption. These variables are strongly correlated with adoption, but have no effect on yields, as the previous estimation results have shown. In the IV regression in column (5), the treatment effect of hybrid adoption remains significant and in a similar magnitude as in previous models. The treatment effect is even bigger than in column (3), which is the relevant OLS reference.

Tests for proper model identification and weak instruments are also reported in column (5) of Table 6. The null hypothesis of underidentification is rejected. Overidentification was already tested before by including the instruments into OLS estimates of the outcome equation; the

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were dominating crop production, while farmers in the East frequently grew rice, potatoes, cassava, tomatoes, and bananas, in addition to maize. Hence, the geographical dummy may capture unobserved motivational factors that could potentially bias the hybrid treatment effect if not controlled for. We can assess potential bias by comparing the coefficients on hybrid adoption in regressions with and without the geographical dummy.

coefficients were not significant. This is confirmed by the Sargan test statistic, which is not significant, so that the null hypothesis of no correlation between the instruments and the error term cannot be rejected. The Cragg-Donald Wald test looks at instrument validity. The resulting F statistic is larger than the critical values suggested by Stock and Yogo (2005), confirming a strong correlation between the instruments and hybrid adoption. Finally, we use a Hausman test to check for endogeneity. Based on the test statistic we cannot reject the null hypothesis that hybrid adoption is exogenous and uncorrelated with the error term. Hence, the OLS results seem to be unbiased. This is also underlined by the similarity between the estimated OLS and IV treatment effects. When endogeneity is not an issue, OLS is more efficient than the IV estimator.

5.2 Impact on maize production

We now examine the impact of hybrid adoption on maize production at the household level. Given the yield gains of hybrids at the plot level, a positive treatment effect is expected. We use a linear functional form and measure the treatment variable in terms of the number of acres under hybrid maize on a given farm. Since we control for total maize area on the farm, the treatment effect can be interpreted as the change in maize production resulting from a switch from nonhybrids to hybrids on one acre of maize land. Other control variables include the size of land owned by the household, household size, and revenue from crops other than maize. Furthermore, education and age of the household head are included in the model.

Estimation results in column (1) of Table 7 confirm that the treatment effect is positive and significant. Converting one acre of maize from nonhybrid to hybrid seeds increases the production of maize by 242 kg per year and household. Note that this is on top of the 239 kg produced on one acre of maize. In other words, hybrid adoption contributes to a doubling of maize production on a given acre of land. This effect is somewhat bigger than the yield gain reported above, which is due to a different model specification and interpretation. In the yield function discussed above, we analyzed the net yield gain of hybrid seeds, controlling for other inputs. Knowing this net yield effect is interesting, but it underestimates the impact of innovation adoption if the use of hybrid seeds also induces farmers to change their use of other inputs. Since we do not control for input use in Table 7, the total production effect of innovation adoption is captured in the hybrid coefficient.

In column (2) of Table 7, we control for possible geographical effects by adding a dummy for North. The coefficient of this geographical dummy is positive and significant, while it was not significant in the yield models reported above. This difference is probably again due to not controlling for input use in the model specifications in Table 7. Given the positive correlation between hybrid adoption and North, it is not surprising that the coefficient of hybrid area is somewhat smaller in column (2) than it was in column (1). Nonetheless, the treatment effect remains large and highly significant.

In column (3) of Table 7, we add an interaction term of hybrid area and East. The coefficient for this interaction term is negative and significant, while the treatment effect itself increases substantially in magnitude. In the North, hybrid adoption increases maize production by 323 kg per acre, while no significant production effects are observed in the East (coefficients of treatment variable and interaction term cancel out). These results are in line with the differential yield impacts at the plot level discussed above. An IV regression for this household-level production model was not possible, because of the lack of suitable instruments for hybrid adoption. The previously used geographical dummy could not be used as an instrument here, because it is directly correlated with household maize production. However, since hybrid adoption was found to be exogenous in the yield model, it is unlikely that a significant endogeneity bias would occur here in the household level production model.

[Table 7]

5.3 Impact on household living standard

We now turn to the analysis of potential impacts of hybrid adoption on household living standards. Household living standard is measured in terms of the value of total annual household consumption, including goods and services purchased from the market as well as subsistence consumption. Households with higher maize yields and more production are able to consume and/or sell more maize. Higher profits and incomes may also lead to more consumption of other goods. We use a linear specification and control for household size in terms of the number of adult equivalents. For living standard assessment, the use of adult equivalents is more precise than just counting the number of household members independent of their sex and age. The treatment variable is again the number of acres under hybrid maize, and we control for total maize area cultivated, so that the treatment effect can be interpreted on a per-acre basis. Other control variables are size of land owned, non-maize crop revenue, age, and education.

The estimation results are shown in Table 8. The treatment effect in column (1) is positive but insignificant. Hence, hybrid adoption does not seem to affect household living standards significantly in this specification. In column (2), the North dummy is added, but the treatment effect remains insignificant. In column (3), a hybrid adoption and East interaction term is added, which has a negative and significant coefficient. Now the treatment effect increases and turns highly significant. These results suggest that one acre of hybrid adoption in the North increases household consumption by 107 TSh (71 US$). In the East, no significant consumption effect through hybrid adoption can be observed. A Wald test failed to reject the null hypothesis that the sum of the coefficients on hybrid area and the interaction term is significantly different from zero.

The coefficient of the North dummy is negative and significant in column (3), indicating that – holding other factors constant – living standards are lower in the North than in the East. This may be due to less favorable agroecological conditions and differences in cropping patterns. Hybrid adoption can partly compensate for this geographical disadvantage, suggesting that this technology contributes to a reduction in spatial inequality in Tanzania.

[Table 8]

We can also use the estimates from column (3) of Table 8 to assess the contribution of hybrids to overall household living standards in the North. The average adopter in the North had 2.99 acres of maize hybrids (see Table 5). Multiplying the estimated per-acre coefficient from the consumption function with this average hybrid area results in a household-level increase in annual consumption of 319 TSh (211 US$) through hybrid adoption. The average nonadopter in the North had a total annual consumption value of 1,834 TSh (1215 US$). This means that households in the North increased their average living standard by 17% through hybrid maize adoption.

6. Conclusion

We have analyzed the impacts of hybrid maize adoption in the small farm sector of Tanzania, building on survey data from two different agroecological zones. In the North, hybrid adoption rates are around 50%, while in the East only 13% have adopted hybrid seeds. The analysis has shown that hybrid adoption is associated with significant gains in maize yields per acre and also in total maize production. Controlling for differences in the use of other inputs, average net yield gains of hybrids are in a magnitude of 50-60%. Cost increases are only moderate, so that adopting farmers realize much higher profits. A geographical disaggregation revealed that the benefits have mostly occurred in the North. Farmers in the East have so far not experienced yield and profit increases, which can explain the lower adoption rates there. Hybrid maize adoption caused a 17% increase in household living standards in the North, while significant effects were not observed in the East. It appears that the hybrids available in Tanzania are much better adapted to the agroecological conditions in the North. Since living standards of nonadopting households tend to be somewhat lower in the North than in the East, hybrids help to reduce spatial inequality in this particular case.

All of the maize hybrids that farmers in our sample used were developed by private companies, whereas all improved OPVs were released by the public sector. Therefore, the impacts of hybrid adoption analyzed here can also be interpreted as the impacts of seed market liberalization and privatization. Private seed companies were only allowed to enter the market in Tanzania after structural reforms in the early-1990s. Since then, foreign and domestic companies have released an increasing number of maize hybrids. Our results demonstrate that the growing private sector involvement has led to sizeable productivity and welfare gains for smallholder farmers. The findings contradict the notion that improved seeds in general, and proprietary hybrids in particular, would always require higher use of other external inputs. Almost none of the maize plots in our sample were irrigated, only very few farmers applied chemical fertilizer or pesticides, and many planted hybrid maize intercropped with legumes. Our results also show that hybrids can still outperform traditional varieties when they are recycled and not freshly purchased every year.

Why suitable hybrids for the Eastern zone of Tanzania were not available is not clear to us. Agroecological differences require adaptation to local conditions. But it is also unclear why half of the maize farmers in the Northern zone, to which the available hybrids are well adapted, did not yet adopt in spite of sizeable benefits. Further research is necessary to better understand adoption patterns and constraints. In addition to aspects related to seed market efficiency and access to credit, adoption studies should also consider the role of information flows, learning, social networks, and behavioral biases (Foster and Rosenzweig, 1995; Duflo et al., 2008; Matuschke and Qaim, 2009). Another important facet of further research should be impacts of hybrid adoption on varietal diversity and in situ conservation of genetic resources (Van Heerwaarden et al., 2009).

Seed market liberalization and privatization have benefited smallholder maize farmers in Tanzania. However, this does mean that there is no role for the public sector anymore. Many private breeding programs build on germplasm developed in the public sector. Especially with a view to marginal areas, relying on the private sector alone may not suffice to ensure sustainable innovation. Complementarities between private and public breeding efforts should be exploited wherever possible. Moreover, public organizations are vital to undertake efficiency-enhancing functions in seed testing, registration, certification, and in the provision of intellectual property rights (Tripp and Louwaars, 1997). Finally, in some situations there may be a role for governments to stimulate demand for proprietary seeds through targeted subsidies or other interventions (e.g., Dorward and Chirwa, 2011). Hence, liberalization and greater participation of the private sector should not imply complete elimination of all public sector programs and regulations. Rather, the focus should be on removing restrictive barriers to market entry.

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Figure 1: Profit analysis

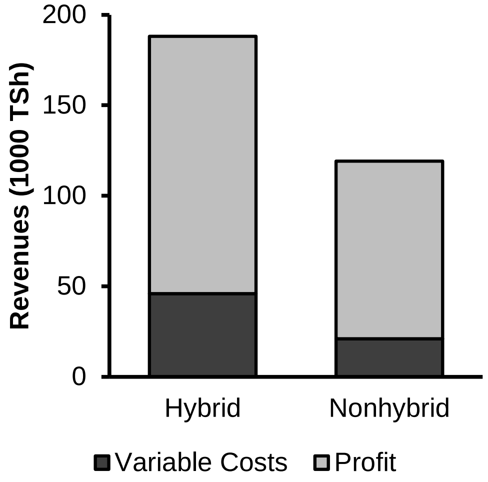

Table 1: Maize hybrids released by the private sector, 1993-2007

Company (year of first release)	1993-1997	1998-2002	2003-2007
Cargill (1993)	3	1	-
Pannar (1995)	4	4	5
Monsanto (1999)	-	5	-
Pioneer (1999)	-	3	-
Kenya Seed (2000)	-	5	4
Seed Co (2001)	-	1	4
Fica Seed (2003)	-	-	3
Tanseed International [a] (2006)	-	-	3
Western Seed (2007)	-	-	3
Total	7	18	22

Source: Data obtained from the Tanzania Official Seed Certifying Institute (more recent data not available).

[a] Tanseed International was founded in 2002 after the parastatal Tanseed collapsed.

Table 2: Descriptive statistics at the plot level

	Hybrids	Nonhybrids
	Mean (standard deviation)	
Seed rate (kg/acre)	9.99** (31.21)	7.49 (5.94)
Intercropped (share of plots)	0.82*** (0.38)	0.57 (0.49)
Fertilizer use (share of plots)	0.03 (0.18)	0.04 (0.21)
Fertilizer (kg/acre)	1.99 (11.73)	1.33 (8.70)
Manure use (share of plots)	0.45*** (0.50)	0.23 (0.42)
Manure (kg/acre)	533.93*** (1,128.11)	179.42 (584.80)
Pesticide (l/acre)	0.025*** (0.125)	0.006 (0.055)
Irrigation (share of plots)	0.01 (0.10)	0.005 (0.07)
Labor (days/acre)	19.05* (14.44)	17.75 (14.42)
Yield (kg/acre)	742.66*** (916.78)	437.09 (755.26)
Total cost [a] (1000 TSh/acre)	45.9*** (52.6)	21.0 (33.5)
Number of plots	291	826

Note: All data refer to the 2008/2009 season.

*, **, *** Means are statistically different at the 10%, 5%, and 1% level, respectively.

[a] This includes costs of purchased fertilizer, manure, seed, herbicide, pesticide, and hired labor.

Table 3: Descriptive statistics at the household level

	(1) Full adopter	(2) Partial adopter	(3) Nonadopter
	Mean (standard deviation)		
Household size (head)	5.91[(3)] (2.53)	6.08[(3)] (2.19)	5.39 (2.36)
Education [a] (years)	6.01[(2),(3)] (3.15)	5.23 (3.11)	5.03 (3.21)
Land owned (acres)	5.52 (10.58)	5.12 (3.90)	5.19 (5.39)
Maize area (acres)	3.21 (3.02)	3.76 (1.55)	3.53 (1.55)
Hybrid maize area (acres)	3.21[(2),(3)] (3.02)	1.46[(3)] (0.79)	0.00 (0.00)
Maize production (kg/year)	2,530[(3)] (6,681)	1,704[(3)] (1,558)	1,301 (2,286)
Own maize consumption (kg/year)	975[(3)] (1,350)	899[(3)] (722)	701 (987)
Maize sold (share of households)	0.53 (0.50)	0.51 (0.50)	0.51 (0.50)
Maize sold (1000 TSh/year)	302[(3)] (103)	235[(3)] (910)	121 (273)
Other crops sold (1000 TSh/year)	609[(3)] (2,622)	325[(3)] (552)	198 (414)
Food expenditures (1000 TSh/year)	938 (925)	911 (940)	867 (914)
Nonfood expenditures (1000 TSh/year)	649[(3)] (1,048)	494 (295)	480 (564)
Nonmarket consumption (1000 TSh/year)[b]	388.98 (31.83)	623.58[(1)] (130.29)	566.23[(1)] (39.87)
Total consumption (1000 TSh/year)	1,975 (1,742)	2,029 (1,480)	1,948 (1,653)
Number of households	146	64	485

Note: All data refer to the 2008/2009 season, except for sales and expenditures data (2009/2010).
[(x)] Mean is significantly greater than mean in column x at the 10% level.
[a] Education of household head.
[b] Food consumption from own production valued at local market prices.

Table 4: Descriptive statistics at the plot level, by zone

	North		East	
	Hybrids	Nonhybrids	Hybrids	Nonhybrids
	Mean (standard deviation)			
Seed rate (kg/acre)	10.92 (34.97)	9.70 (6.47)	5.41 (4.14)	6.09 (5.22)
Intercropped (share of plots)	0.90 (0.30)	0.88 (0.32)	0.48 (0.50)	0.39 (0.49)
Fertilizer use (share of plots)	0.04** (0.19)	0.01 (0.10)	0.02 (0.14)	0.06* (0.24)
Fertilizer (kg/acre)	2.08** (11.46)	0.52 (6.42)	1.85 (13.61)	1.60 (9.29)
Manure use (share of plots)	0.56 (0.50)	0.55 (0.50)	0.06 (0.23)	0.04 (0.21)
Manure (kg/acre)	674.98*** (1,233.86)	455.78 (876.36)	12.81 (71.31)	14.55 (148.39)
Pesticide (l/acre)	0.03* (0.12)	0.01 (0.09)	0.00 (0.00)	0.002 (0.001)
Irrigation (share of plots)	0.01 (0.11)	0.01 (0.004)	0.00 (0.00)	0.002 (0.04)
Labor (days/acre)	19.41** (15.32)	17.17 (13.99)	18.11 (11.43)	18.17 (14.93)
Yield (kg/acre)	805.63*** (919.84)	546.68 (982.60)	429.97 (781.46)	374.62 (587.29)
Total cost [a] (1000 TSh/acre)	51.8*** (55.5)	25.3 (36.3)	15.2 (24.3)	18.1 (31.1)
Number of plots	230	304	54	492

Note: All data refer to the 2008/2009 season.
*, **, *** Means are statistically different within a zone at the 10%, 5%, and 1% level, respectively.
[a] This includes costs of purchased fertilizer, manure, seed, herbicide, pesticide, and hired labor.

Table 5: Descriptive statistics at the household level, by zone

	North			East		
	(1) Full adopter	(2) Partial adopter	(3) Nonadopter	(4) Full adopter	(5) Partial adopter	(6) Nonadopter
	Mean (standard deviation)					
Household size (head)	6.03 (2.49)	6.62$^{(1),(3)}$ (2.09)	5.98 (2.63)	5.37 (2.60)	4.56 (1.82)	4.99 (2.12)
Education [a] (years)	6.20$^{(2),(3)}$ (3.21)	5.26 (3.16)	4.61 (3.46)	5.07 (3.01)	5.06 (3.11)	5.33 (3.02)
Land owned (acres)	5.40 (11.51)	5.26$^{(3)}$ (4.36)	4.09 (5.00)	5.39 (3.57)	4.84 (2.32)	5.92 (5.61)
Maize area (acres)	2.99 (2.61)	3.64$^{(1),(3)}$ (1.50)	2.81 (2.67)	3.65 (3.47)	4.19 (1.69)	3.98 (5.10)
Hybrid maize area (acres)	2.99$^{(2),(3)}$ (2.62)	1.48$^{(3)}$ (0.84)	0.00 (0.00)	3.65$^{(5),(6)}$ (3.65)	1.44$^{(6)}$ (0.66)	0.00 (0.00)
Maize production (kg/year)	2,284$^{(3)}$ (3,681)	1,823 (1,717)	1,479 (3,367)	1,129 (1,141)	1,336 (981)	1,222 (1,332)
Own maize consumption (kg/year)	1,087$^{(3)}$ (1,487)	991 (765)	872 (1,310)	523 (409)	580 (471)	623 (746)
Maize sold (share of hh)	0.53$^{(3)}$ (0.50)	0.45 (0.50)	0.40 (0.49)	0.52 (0.51)	0.75$^{(4),(6)}$ (0.45)	0.58 (0.49)
Maize sold (1000 TSh/year)	273$^{(3)}$ (684)	279$^{(3)}$ (106)	100 (288)	65 (114)	120$^{(1)}$ (112)	132$^{(1)}$ (261)
Other crops sold (1000 TSh/year)	490$^{(3)}$ (1,261)	356$^{(3)}$ (625)	139 (341)	116 (204)	254$^{(1)}$ (263)	231$^{(1)}$ (440)
Food expenditures (1000 TSh/year)	945$^{(3)}$ (993)	974 (1,067)	768 (1,192)	905 (634)	769 (400)	942 (717)
Nonfood expenditures (1000 TSh/year)	675$^{(3)}$ (1,164)	488 (290)	430 (636)	546 (395)	526 (322)	520 (528)
Nonmarket consumption (1000 TSh/year)[b]	402.17 (35.95)	733.96$^{(1),(3)}$ (170.16)	551.25$^{(1)}$ (54.57)	330.84 (67.40)	292.44 (57.34)	575.30$^{(1)}$ (575.30)
Total consumption (1000 TSh/year)	2,019 (1,888)	2,176 (1,650)	1,834 (2,066)	1,782 (829)	1,587 (633)	2,017 (1,341)
Number of households	115	47	175	27	16	292

Note: All data refer to the 2008/2009 season, except for sales and expenditures data (2009/2010).
$^{(x)}$ Mean is significantly greater than mean in column x at the 10% level.
[a] Education of the household head.
[b] Food consumption from own production valued at local market prices.

Table 6: Estimated coefficients of the yield function

	Maize yield in 2008/2009 (kg/acre)				
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) IV [c]
	Coefficient (standard error)				
Hybrid	0.39*** (0.09)	0.46*** (0.10)	0.47*** (0.11)	0.59*** (0.12)	0.53* (0.30)
Hybrid recycled		-0.28 (0.18)	-0.29 (0.18)	-0.19 (0.19)	-0.35 (0.27)
Intercropping	-0.16* (0.09)	-0.15* (0.09)	-0.15 (0.10)	-0.15 (0.10)	-0.16* (0.09)
Seed amount (kg)	0.11** (0.05)	0.12** (0.05)	0.12** (0.05)	0.12** (0.05)	0.12** (0.05)
Fertilizer (kg)	-0.04 (0.16)	-0.04 (0.16)	-0.04 (0.16)	-0.03 (0.16)	-0.02 (0.16)
Manure (kg)	0.17*** (0.05)	0.17*** (0.05)	0.17*** (0.05)	0.16*** (0.05)	0.16*** (0.05)
Herbicide (kg)	0.55 (0.68)	0.56 (0.68)	0.57 (0.68)	0.57 (0.68)	0.55 (0.68)
Pesticide (kg)	-0.08 (0.13)	-0.08 (0.13)	-0.08 (0.13)	-0.10 (0.13)	-0.12 (0.13)
Irrigation	0.49 (0.54)	0.55 (0.53)	0.56 (0.53)	0.52 (0.53)	0.54 (0.53)
Labor (days)	0.50*** (0.06)	0.50*** (0.06)	0.50*** (0.06)	0.50*** (0.06)	0.50*** (0.06)
Good soil quality	0.26*** (0.10)	0.25** (0.10)	0.25** (0.10)	0.25** (0.10)	0.25** (0.10)
Age [a] (years)	0.002 (0.004)	0.001 (0.004)	0.001 (0.004)	0.001 (0.004)	-0.003 (0.003)
Education [a] (years)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	
Maize experience [a] (years)	-0.01* (0.004)	-0.01* (0.004)	-0.01* (0.004)	-0.01* (0.004)	
North [b]			-0.01 (0.11)	-0.10 (0.12)	
Hybrid * East				-0.54** (0.22)	
Constant	3.89*** (1.02)	3.93*** (1.02)	3.93*** (1.02)	3.93*** (1.02)	3.96*** (1.01)
Number of observations	1117	1117	1117	1117	1117
R^2	0.15	0.15	0.15	0.15	0.15
Underidentification test					124.30***
Sargan statistic					0.74
Cragg-Donald Wald F statistic					68.74***
Hausman statistic					0.02

Notes: Maize yield, seed amount, fertilizer, manure, herbicide, pesticide, and labor are expressed in natural logarithms. Dummies for zero input use were used, as suggested by Battese (1997), but are not shown here for brevity.

*, **, *** Coefficient is statistically significant at the 10%, 5%, and 1% level, respectively.

[a] These variables refer to the household head.

[b] The base zone is East.

[c] North and education are used as instruments for hybrid adoption.

Table 7: Estimated coefficients of the household maize production function

	Household maize production in 2008/2009 (kg/year)		
	(1) OLS	(2) OLS	(3) OLS
	Coefficient (standard error)		
Hybrid maize area (acres)	241.57*** (54.46)	206.14*** (56.91)	322.53*** (69.24)
Maize area (acres)	239.24*** (37.68)	258.06*** (38.65)	257.13*** (38.44)
Land owned (acres)	6.33 (14.88)	8.51 (14.88)	5.65 (14.83)
Household size (AE [a])	269.06*** (95.15)	224.21** (97.31)	223.33** (96.78)
Nonmaize crop revenue (1000 TSh/year)	1.78*** (0.08)	1.78*** (0.08)	1.71*** (0.08)
Education [b] (years)	29.83 (30.40)	33.43 (30.38)	23.61 (30.40)
Age [b] (years)	4.40 (6.48)	4.32 (6.46)	2.73 (6.45)
North [c]		410.56** (196.54)	192.31 (209.29)
Hybrid maize area * East			-330.05*** (113.11)
Constant	-1,086.60** (451.66)	-1,228.56*** (455.67)	-992.59** (460.35)
Number of observations	688	688	688
R^2	0.59	0.60	0.60

*, **, *** Coefficient is statistically significant at the 10%, 5%, and 1% level, respectively.
[a] AE = adult equivalent. The modified OECD scale is used: the first adult is weighed by a factor of 1, each additional adult (child under 14) is weighed by 0.5 (0.3).
[b] These variables refer to the household head.
[c] The base zone is East.

Table 8: Estimated coefficients of the household consumption function

	Household consumption in 2009/2010 (1000 TSh/year)		
	(1) OLS	(2) OLS	(3) OLS
	Coefficient (standard error)		
Hybrid maize area (acres)	41.69 (36.16)	59.36 (37.84)	106.75** (46.22)
Maize area (acres)	5.69 (25.02)	-3.69 (25.70)	-4.06 (25.66)
Land owned (acres)	44.45*** (9.88)	43.36*** (9.89)	42.19*** (9.90)
Household size (AE [a])	363.28*** (63.18)	385.63*** (64.70)	385.27*** (64.60)
Nonmaize crop revenue (1000 TSh/year)	-0.00003 (0.00005)	-0.00003 (0.00005)	-0.0001 (0.00006)
Education [b] (years)	77.13*** (20.19)	75.33*** (20.20)	71.34*** (20.29)
Age [b] (years)	2.41 (4.30)	2.44 (4.30)	1.80 (4.31)
North [c]		-204.68 (130.69)	-293.55** (139.70)
Hybrid maize area * East			-134.39** (75.51)
Constant	143.71 (299.90)	214.66 (302.99)	310.89 (307.30)
Number of observations	688	688	688
R^2	0.12	0.12	0.13

*, **, *** Coefficient is statistically significant at the 10%, 5%, and 1% level, respectively.
[a] AE = adult equivalent. The modified OECD scale is used: the first adult is weighed by a factor of 1, each additional adult (child under 14) is weighed by 0.5 (0.3).
[b] These variables refer to the household head.
[c] The base zone is East.