Adoption and Impacts of Improved Wheat Varieties in Morocco

1. Introduction

Agriculture in general and wheat production in particular play an important role in the Moroccan economy. With a total area of 3.2 million ha and production of seven million tons in 2013, wheat is the single most dominant crop in the country (GMP, 2014). In 2013, the contribution of all cereals to agricultural value added was about US$1.8 billion out of which the share of wheat was about US$ 850 million (47%) - making it the second most important crop next to olives (GMP, 2014; FAOSTAT, 2015). In light of the rapid population growth and shifts in consumption habits, wheat and particularly bread consumption has over the years become central in Morocco's food security agenda.

Wheat yields in Morocco remained low at about 0.9 tons per ha until the seventies. With the introduction of improved wheat varieties in the 1980's, significant increases in yields were observed which, after the new millennium, reached a 10-year average of about 1.5 tons/ha for durum wheat and 1.6 tons/ha for bread wheat (ICARDA, 2014). However, these yield levels are far below both the global average of over 3 tons/ha and the African average of 2.3 tons/ha. Low productivity along with increased demand for wheat have made Morocco heavily dependent on large volumes of imports which reached about 3.7 million tons in 2012 (FAOSTAT, 2015) that costed the country over US$1.3 billion. Unfavorable weather in 2016 is expected to increase the 2016/2017 wheat imports to 5 million tons (GIEWS, 2016). This trend has made wheat the most important item among all agricultural imports both in quantity and value.

Partnerships between the Institut National de la Recherche Agronomique (INRA) and international agricultural research centers (IARC) including the International Center for Agricultural Research in the Dry Areas (ICARDA) and the International Maize and Wheat Improvement Center (CIMMYT) and various local and international private companies has provided Morocco the access to wide range of germplasm. As a result, a total of 88 bread (69% foreign) and 83 durum (58% foreign) - an average of six wheat varieties per year were registered in the national catalogue since 1982. A significant increase in the number of foreign varieties, particularly those introduced by the private sector, has been observed particularly during the last two decades. Among a total of 60 bread and durum wheat varieties released between 2001 and 2012, only nine (seven bread and two durum) that represented 15% of total releases are from the joint INRA - IARC breeding programs while the rest are foreign varieties introduced by the private sector.

Morocco was home for various local wheat land races that have been used by Moroccan farmers since before the 1920's. However, these varieties had a number of limitations including poor yield potential, lack of adaptive capacity and instability of traits for which most of them are now out of production (Nsarellah, 2012). The local varieties were predominantly late maturing, tall and hence susceptible to lodging and had poor resistance to diseases. While national level data on wheat varietal adoption is scanty in Morocco, most of the new varieties are feared to not have reached farmers and very old varieties with more than 25 years of age released by INRA and other old varieties of European and American origin recently introduced by private seed companies are a common scene in the Moroccan wheat fields. Access to seeds of improved varieties in general and certified seeds of more recent varieties in particular are often cited by breeders, development practitioners and extension agents as the major constraints for achieving wider adoption and hence higher impacts of improved wheat varieties in Morocco.

This paper aims at providing credible evidence for the current levels of adoption of improved wheat varieties and their impacts. The paper also provides evidence on farmer utilization of seeds and evaluates the validity of the blame on access to seed as the most important factor constraining wider adoption and impacts of more recently released wheat varieties in Morocco.

Data

Data for this study came from a large sample household survey conducted in 2013 covering twenty one major wheat producing provinces in Morocco. These provinces account for about 79% of total number of wheat growing farmers and 81% of national wheat area in the country. They are found in the four agro-ecological zones suitable for wheat production namely: the favorable zone, intermediate zone, unfavorable south and the mountains zone. Provinces in the remaining two agro-ecological zones in Morocco (the Saharan zone and the Unfavorable Oriental Zone) are excluded from the survey as wheat production in these zones is either non-existent or less important.

Using power analysis, the minimum sample size required to ensure 95% confidence and at least 3% precision levels for capturing adoption of improved wheat varieties of up to 53% (the national maximum estimate by experts) was determined to be 1061 households. To buffer the effects of possible higher adoption levels, missing values, non-response, and erroneous entries, the sample was inflated upwards by about 15%. Therefore, a total sample of 1230 farm households was drawn for this study using a stratified sampling approach where provinces, districts and villages were used as strata. The total sample was distributed proportionally across 292 villages which are distributed across 56 districts that were randomly drawn from the 21 study provinces. Distribution of samples across the 21 provinces selected for the survey is provided in Table 1 below.

Table 1: Statistics on Wheat Area and Number of Farmers and Distribution of Sample Households across the 21 Provinces

Region	Province	Wheat area (in 1000 ha), average for 2002-2011			Total number of wheat growers in 2011 (in 1000)	Sample statistics				
								Number of Households		
		Bread wheat	Durum wheat	Total		No. of districts	No of villages	Male headed	Women headed	Total
Chaouia-Ouardigha	Benslimane	54.96	25.41	80.37	13.92	3	10	26	1	27
	Berrechid	131.96	133.9	90.39	20.70	2	13	40	3	43
	Settat			175.47	40.19	3	33	80	2	82
Doukkala-Abda	El Jadida	95.98	79.46	92.98	64.08	3	16	70	6	76
	Sidi Bennour			82.46	56.82	2	17	63	5	68
	Safi	74.74	73.59	148.33	63.25	3	19	128	2	130
Fes-Boulemane	Fes	69.79	29.72	12.94	3.64	1	1	8	0	8
	Moulay Yacoub			86.57	24.34	2	7	52	0	52
Gharb-Chrarda-Bni Hces	Kenitra	94.03	13.36	85.97	30.66	3	17	49	10	59
	Sidi Slimane			21.42	7.67	1	8	17	1	18
	Sidi Kacem	144.94	32.59	177.53	44.40	5	22	63	4	67
Marrakech-Tensift-Alhaouz	El Kelaa	155.36	67.91	73.68	20.33	2	12	36	2	38
	Rehamna			149.59	41.27	2	12	75	2	77
Meknès-Tafilalet	El Hajeb	48.95	9.88	58.83	9.02	3	7	22	0	22
	Khenifra	67.09	37.25	104.34	28.05	2	11	58	0	58
	Meknes	71.78	4.49	76.27	13.73	1	11	29	0	29
Rabat-Salé	Khemisset	127.62	29.58	157.2	32.67	4	25	61	6	67
Tadla-Azilal	Beni Mellal	153.68	37	190.68	46.06	3	7	89	1	90
Taza-Alhoceima-Taounate	Taounate	103.26	80	183.26	61.16	4	24	117	7	124
	Taza	32.83	70.34	82.54	39.24	5	14	75	0	75
	Guercif			20.63	9.81	2	6	20	0	20
Total Sample		**1,426.97**	**724.48**	**2,151.45**	**671.01**	**56**	**292**	**1178**	**52**	**1230**
Total National		**1930.07**	**979.90**	**2,909.97**	**Not available**					
Sample as % National Total				**73.9%**						

Methodology

Estimation of local average treatment effects (Imbens and Angrist, 1994) has been the focus in the program evaluation literature. The main challenges in this pursuit are related to selection bias in establishing counterfactuals. Several econometric approaches can be used to address the problem of selection bias in program evaluation using quasi-experimental data. Imbens and Wooldridge (2009) provide a good review of the literature and the developments in causal inference and impact assessment. Propensity score matching (PSM) due to Rosenbaum and Robin (1983) is by far the most widely used for improving causal inference and estimation of local average treatment effects (El Shater et al., 2016, Morgan and Winship, 2014, Henderson and Chatfield, 2011; Jalan and Ravallion, 2003). , Propensity Score Matching (PSM) helps in correcting biases introduced only by observable covariates (Heckman and Vytlacil, 2007). Therefore, results from PSM can sometimes be difficult to justify since unobservable factors such as skills and motivation can influence not only the outcome but also the program participation decision thereby leading to confounding errors (See Austin 2008 for critical review of PMS). To overcome this problem, two other methods, namely the endogenous switching regression (ESR) and instrumental variables (IV) methods both of which account for the endogeneity of the participation decision and are potent to correct for selection bias introduced by both observable and unobservable factors are used in this paper. While IV is arguably the best evaluation method among all quasi-experimental methods, it may perform poorly especially if all necessary conditions for its implementation are not fulfilled. On the other hand, the requirements for the implementation of ESR are less stringent but it may not be fully effective in establishing the counterfactuals. This shows that there are trade-offs between the two models – and hence the reason for estimating both ESR and IV in this paper. By estimating both ESR and IV, the authors of this paper hope to provide a range rather than a point estimate for impacts.

Endogenous Switching Regression

The Endogenous Switching Regression (ESR) has been widely used to measure impacts of agricultural technologies (Shiferaw et al., 2016; El Shater et al., 2016; Shiferaw et al., 2014; Asfaw et al., 2012; and Di Falco et al, 2011). The main rationale for the use of ERS is that the difference in the outcomes of interest between adopters and non-adopters may not only be due to observable heterogeneity but also due to unobserved heterogeneity. The endogenous switching regression due to Maddala and Nelson (1975) attempts to overcome this problem by simultaneously estimating the equation for adoption decision and the outcome equation of interest for each group.

Suppose d_i and d_i^* respectively are the observable and unobservable (latent) participation decision variables, $\boldsymbol{z}_i$ is a matrix of observed farm and non-farm characteristics which are believed to explain variations in adoption and ϵ_i is the error term associated with participation. The selection decision can then be described as:

$$d_i = \begin{cases} 1 & if\ z_i^* > 0 \\ 0, & otherwise \end{cases}$$

$$d_i^{\ *} = z_i \beta + \epsilon_i \quad (1)$$

Suppose also that $\boldsymbol{y}_i$ is a vector of dependent variables representing program outcomes where y_1 represents the outcome for participants and y_0 () that of non-participants (); $\boldsymbol{X_i}$ is a matrix of explanatory variables, $\boldsymbol{\omega}_i$ is a vector of parameters to be estimated, and $\epsilon_1$and ϵ_0 are error terms. Then, the outcome equations can be described as:

$$y_1 = \boldsymbol{X}_1\boldsymbol{\omega}_1 + \boldsymbol{\epsilon}_{1i} \; if \; d = 1 \tag{2}$$

$$y_0 = \boldsymbol{X}_0\boldsymbol{\omega}_0 + \boldsymbol{\epsilon}_{0i} \; if \; d = 0 \tag{3}$$

Simultaneous estimation of equations 1- 3 represents the Endogenous switching regression (ESR) where the model assumes that the error terms from the three equations ε, ϵ_1, and ϵ_0 have a trivariate normal distribution with mean vector of zero and the following covariance matrix:

$$cov(\varepsilon, \epsilon_{1,} \epsilon_0) = \begin{bmatrix} \sigma_{\epsilon 0}^2 & \sigma_{\epsilon 1 \epsilon 0} & \sigma_{\epsilon 0 \varepsilon} \\ \sigma_{\epsilon 1 \epsilon 0} & \sigma_{\epsilon 1}^2 & \sigma_{\epsilon 1 \varepsilon} \\ \sigma_{\epsilon 0 \varepsilon} & \sigma_{\epsilon 1 \varepsilon} & \sigma_{\varepsilon}^2 \end{bmatrix} \tag{4}$$

Where σ_{ε}^2 is the variance of the selection equation (equation 1), $\sigma_{\epsilon 0}^2$ and $\sigma_{\epsilon 1}^2$are the variances of the outcome equations for non-participants and participants respectively with $\sigma_{\epsilon 0 \varepsilon}$ and $\sigma_{\epsilon 1 \varepsilon}$ representing the covariance between , ϵ_1, and ϵ_0. This paper strictly follows El Shater et al. (2016) to estimate the average treatment effect on the treated (ATT) and the average treatment effect on the Untreated (ATU).

Instrumental variables (IV) Regression

Similar to the Endogenous Switching Regression (ESR), the instrumental variables regression (IV) approach for measuring causal effects of a treatment on an outcome (Angrist et al., 1996) is designed to remove both overt and hidden biases and deal with the problem of endogenous treatment. IV methods are becoming common in program evaluation and comparative effectiveness research (He and Perloff, 2016, Kumar and Mangyo, 2011; Heckman and Vytlacil, 2005; Manski and Pepper, 2004). The IV method requires that the “instrument” meets three important conditions: (1) the instrument has to be associated with the treatment, (2) the instrument does not affect the outcome except through the treatment (also known as the exclusion restriction assumption), and (3) the instrument does not share any causes with the outcome. The reliability of the results from instrumental variables regression depends on the fitness of the instrument in fulfilling the above conditions (Imbens 2004; Abadie, 2003). Therefore, for measuring the impacts of agricultural technologies, it is important to identify an instrument(s) which is (are) correlated with the decision to adopt but uncorrelated with the unobserved factors that influence the outcome (Alene and Manyong, 2007, Shiferaw et al. 2014, Heckman, 1996).

Suppose that there is endogeneity between the treatment variable X_1 and the outcome variable Y. Suppose also that $\boldsymbol{V}$ is a matrix of exogenous covariates which qualify as valid instruments for X_1. Then the instrumental variables (IV) model can be described by equations 4 and 5.

$$y = X\beta + \vartheta \qquad (4)$$

$$X_1 = V\Pi + \mu \qquad (5)$$

Where β and Π are vectors of coefficients associated with the covariates in equation 4 and the instruments in equation 5, $\mathbb{E}[X^T \vartheta] \neq 0, \mathbb{E}[Z^T\mu] = \mathbb{E}[Z^T \vartheta] = 0, Var(\vartheta) = \sigma_\vartheta^2, Var(\mu) = \sigma_\mu^2$ and $Cov(\vartheta, \mu) = \sigma_{\mu\vartheta}$ measures the level of endogeneity.

The two-stages least square (2SLS) estimation procedure is then used to estimate equations 4 and 5 simultaneously where equation 5 is estimated first and then the predicted values used in equation 4 in place of the observed values of X.

For a farmer to adopt a new variety, it is necessary that the farmers first hears about the technology and gets adequate information about it. Therefore, whether farmers participated in hosting demonstration trials, or attending field days under different projects that attempted to introduce improved wheat varieties is believed to affect farmers' adoption decisions. As demonstration trials on farmers' own fields are done with less intervention from researchers and the field days are often organized to show the results of the use of the new varieties and not to teach the farmers on the mechanics of cultivating the new varieties, participation in either or both of the demonstration trials and field days is not expected to directly influence yield except through its effect on the adoption of the improved varieties. Therefore participation in either or both of hosting demonstration trials and participation on field days are used as instruments in this study.

A number of factors such as varieties used and the amounts of fertilizers, seed, and labor and tillage type are important in determining yield which in turn will affect income and consumption.

The Hausman test for endogeneity, was carried to determine whether endogenous regressors in the model are in fact exogenous. For creating a more homogenous dataset, logarithmic transformation has been made on all continuous variables included in the ESR and IV regressions (such as income, consumption, farmer age, years of education, distance to the nearest seed market, farm size, wheat area, and all quantities of inputs). The Stata software (StataCorp, 2011) was used for all econometric estimation in this study.

Results and Discussion

Impacts on Yield

In line with theoretical expectation, quantities of inputs (DAP fertilizers, Total amount of labour used and seeds) are found to have positive and significant effects on yield which is expected in the ESR and IV estimates. Irrigated plots also give higher yields than non-irrigated as farms with larger wheat area. The use of certified seeds also leads to higher yields than uncertified seeds showing clear advantage to certified seeds.

Farm in intermediate zone leads to higher yields in the two models, the average rainfall and the average temperature have also positive and significant effects on yield which is expected in the ESR and IV estimates. Table 2

Estimates of treatment effects from ESR are provided in Table 3 below. The results show that adopters of improved varieties on the average obtain about 478.4.4kg/ha (49%) more yield than the counterfactual (i.e., what they would have obtained if they had not adopted). Taking an average grain price of 3.15 MAD/kg and ignoring the cost implications of adoption of improved wheat varieties, this yield gain would translate into a gain in gross revenue of 1,506 MAD/ha (US$175/ha)[1]. At the current average adoption level of 1.6ha/family, each farm household obtains about 765.4 kg per year more yield and 2,411 MAD (US$280) per year.

Given that IV is potent in remove both overt and hidden biases and deal with the problem of endogenous treatment, the 23% higher yield effects from IV relative to ESR shows that unobservable factors such as skills of the farmers who have adopted the technology are important in explaining the differences in yield effects.

[1] The exchange rate in 2012 was: 1US$= 8.62 Moroccan Dirhams (DH)

Table 2: Full information maximum likelihood estimates of the endogenous switching regression model for yields (kg/ha)

	Endogenous switching						Instrumental Variables	
Independent Variables	Yield Equation for Adopter		Yield Equation for Non-Adopter		Adoption of ImpvVar (No=0,Yes=1)		Yield Equation	
	Coef.	Std.Er	Coef.	Std.Er	Coef.	Std.Er	Coef.	Std.Er
ImpvVar (No=0,Yes=1)	-	-	-	-	-	-	0.412	0.018***
Age (Years)	-0.037	0.025	0.024	0.021	0.728	0.272***	0.000	0.016
Sex (0=Male, 1=Female)	0.040	0.020**	0.026	0.031	0.351	0.292	0.028	0.018
Number of years of education	0.002	0.022	0.002	0.016	3.993	0.361***	-0.005	0.014
Total amount of labour used (Person days/ha)	0.078	0.018***	0.031	0.015***	0.402	0.206**	0.048	0.011***
Off-farm employment {1=yes, 0=No}					-0.362	0.166**		
Irrigated {1=yes, 0=No}	1.289	0.023***	1.313	0.019***	-0.164	0.267	1.301	0.015***
Wheat area (Ha)	0.017	0.009**	0.055	0.010***	-0.823	0.138***	0.040	0.007***
Total cropped area (Ha)					-0.004	0.027		
Walking distance from seed sources (km)					-1.435	0.098***		
Hosted wheat demonstration trials 1=yes,0=No}					1.660	0.554***		
Visited demonstration fields or attended field days {1=yes, 0=No}					0.505	0.543		
Seed from formal sources,1=yes, 0=No	-0.001	0.013	0.029	0.010***	0.415	0.129***	0.021	0.008***
Price of seed					0.140	0.179		
Farm in favourable zone{1=yes, 0=No}	0.051	0.022***	-0.001	0.014	1.587	0.170***	0.000	0.011
Farm in intermediate zone {1=yes, 0=No}	0.078	0.024***	0.032	0.011***	0.749	0.179***	0.033	0.010***
Quantity of nitrogen fertilizer used (kg/ha)	-0.011	0.009	0.001	0.007	-0.160	0.093	-0.002	0.006
Quantity of DAP fertilizer used (kg/ha)	0.057	0.007***	0.065	0.005***	0.018	0.075	0.063	0.004***
Amount of seed used(kg/ha)	0.060	0.018***	0.086	0.015***	0.169	0.195	0.077	0.011***
Avrain (mm)	0.150	0.022***	0.140	0.016***	0.834	0.220***	0.151	0.013***
Avtem (oC)	0.178	0.030***	0.031	0.024	-0.326	0.309	0.075	0.019***
Constant	4.966	0.204***	4.794	0.178***	-8.745	2.388***	4.706	0.136***
Rho	-0.135	0.08	-0.101	0.142				
sigma	-1.877	0.025***	-1.689	0.018***				

Table 3: Average Expected Treatment and Heterogeneity Effects on Yield (kg/ha) from Endogenous Switching Regression

	Decision Stage		
Subsamples Effects	To Adopt	Not to Adopt	Treatment
Farm households that adopted	(a) 1454.9	(c) 976.5	478.4***
Farm households that did not adopt	(d) 1448.7	(b) 978.5	470.2***
Heterogeneity effects	6.24	-1.96	8.2

<u>Impact on Net Margins</u>

The Estimates of the Endogenous Switching Regression (ESR) and the instrumental *variable* (IV) are provided in Table below. As the main objective of this section is one of measuring the impacts of adoption of improved varieties, we will provide only a brief discussion of the regression estimates. From among the inputs, quantities of DAP fertilizers and seed quantity used are found to have positive and significant effects on net margins in the two models (ESR, IV) while quantity of nitrogen fertilizer is not, Irrigated plots also give higher net income than non-irrigated plots which could be explained purely by the yield gains which might offset any additional costs of irrigation. Farm in favourable zone and average rainfall have positive and significant effects on net margins that's which explained by reducing the irrigation quantity and therefore the cost of irrigation which effect on the net margin. Table 4

Table 5 presents the estimates of treatment effects from ESR. The results show that adoption of improved wheat varieties provide on the average 1420 MAD/ha (54%) higher net wheat income for adopters. If non adopters were to adopt the improved varieties, they would have earned 1574 MAD/ha more net income showing that the benefit to those who already adopted is higher, which may explain why they adopted while the others have not.

Given that IV is potent in remove both overt and hidden biases and deal with the problem of endogenous treatment,   the 35% higher net wheat income effects from IV relative to ESR shows that unobservable factors such as skills of the farmers who have adopted the technology are important in explaining the differences in net wheat income.

The adoption of improved varieties has positive and significant effect on net wheat income. After controlling for all the above confounding factors, our results show that by adopting improved varieties of wheat, the typical Moroccan wheat farmer which adopted improved wheat varieties earned about 1420 Moroccan Dinars (MD) (US$164.7) more per ha than if they did not adopt.. Given the average area under improved varieties per family of 1.6 ha, a typical adopter family currently earns 2,272 MAD (US$264) of additional net wheat income each year.

Independent Variables	Endogenous switching						Instrumental Variables	
	Net income Equation for Adopter		Net income Equation for Non-Adopter		Adoption of ImpvVar (No=0,Yes=1)		Net income Equation	
	Coef.	Std.Er	Coef.	Std.Er	Coef.	Std.Er	Coef.	Std.Er
ImpvVar (No=0,Yes=1)	-	-	-	-	-	-	0.449	0.039***
Age (Years)	-0.095	0.045**	0.025	0.047	0.714	0.271***	-0.013	0.035
Sex (0=Male, 1=Female)	0.067	0.035**	0.097	0.069	0.372	0.290	0.071	0.038*
Number of years of education	-0.051	0.039	0.028	0.036	3.992	0.360***	0.012	0.030
Total amount of labour used (Person days/ha)	0.071	0.032**	0.004	0.033	0.397	0.204**	0.028	0.025
Off-farm employment {1=yes, 0=No}					-0.361	0.166**		
Irrigated {1=yes, 0=No}	1.435	0.040***	1.731	0.043***	-0.205	0.269	1.630	0.032***
Wheat area (Ha)	0.029	0.017*	0.082	0.022***	-0.827	0.137***	0.057	0.014***
Total cropped area (Ha)					-0.005	0.027		
Walking distance from seed sources (km)					-1.441	0.098***		
Hosted wheat demonstration trials 1=yes,0=No}					1.650	0.550***		
Visited demonstration fields or attended field days {1=yes, 0=No}					0.558	0.537		
Seed from formal sources,1=yes, 0=No	-0.009	0.024	0.060	0.022***	0.413	0.129***	0.034	0.017**
Price of seed					0.132	0.180		
Farm in favourable zone{1=yes, 0=No}	0.076	0.040*	0.091	0.031***	1.587	0.170***	0.069	0.025***
Farm in intermediate zone {1=yes, 0=No}	0.037	0.043	0.031	0.025	0.745	0.180***	0.031	0.021
Quantity of nitrogen fertilizer used (kg/ha)	-0.013	0.017	-0.010	0.015	-0.150	0.094	-0.011	0.012
Quantity of DAP fertilizer used (kg/ha)	0.055	0.012***	0.065	0.012***	0.017	0.076	0.063	0.009***
Amount of seed used(kg/ha)	0.117	0.032***	0.031	0.033	0.185	0.195	0.058	0.025**
Avrain (mm)	0.183	0.039***	0.178	0.036***	0.832	0.221***	0.187	0.027***
Avtem (oC)	0.111	0.053**	0.020	0.054	-0.315	0.310	0.044	0.040
Constant	5.990	0.365***	5.789	0.402***	-8.756	2.395***	5.673	0.293***
Rho	-0.057	0.093	-0.103	0.135				
sigma	0.274	0.007***	0.417	0.008***				

Table 5: Average Expected Treatment and Heterogeneity Effects on Net income (MAD/ha) from Endogenous Switching Regression

	Decision Stage		
Subsamples Effects	To Adopt	Not to Adopt	Treatment
Farm households that adopted	(a) 4064.3	(c) 2643.9	1420.4***
Farm households that did not adopt	(d) 4064.3	(b) 2489.9	1574.4***
Heterogeneity effects	0	154	-154

<u>Impact on Consumption</u>

The Estimates of the Endogenous Switching Regression (ESR) and the instrumental *variable* (IV) are provided in Table 38 below. As the main objective of this section is to measure the impacts of adoption of improved wheat varieties, only a brief discussion of the regression estimates is provided here. Total wheat area and whether or not the plot is irrigated seem to have positive and significant effects on wheat consumption among both adopters and not adopters while all other variables including quantities of inputs (nitrogen and DAP fertilizers and seeds) are found to have differential effects on wheat consumption between adopters and non-adopters. Table 6

Estimates of treatment effects from ESR are provided in Table 7 below. The results show that adopters of improved varieties on the average consume about 27.1 kg/capita/year (52%) more wheat than the counterfactual (i.e., what they would have consumed if they had not adopted

Given that IV is potent in remove both overt and hidden biases and deal with the problem of endogenous treatment, the 36% higher net wheat income effects from IV relative to ESR shows that unobservable factors such as skills of the farmers who have adopted the technology are important in explaining the differences in net wheat income.

	Endogenous switching						Instrumental Variables	
Independent Variables	Consumption Equation for Adopter		Consumption Equation for Non-Adopter		Adoption of ImpvVar (No=0,Yes=1)		Consumption Equation	
	Coef.	Std.Er	Coef.	Std.Er	Coef.	Std.Er	Coef.	Std.Er
ImpvVar (No=0,Yes=1)	-	-	-	-	-	-	0.592	0.026***
Age (Years)	-0.060	0.048	-0.056	0.024**	0.629	0.260**	-0.079	0.024***
Sex (0=Male, 1=Female)	-0.015	0.038	0.028	0.035	0.284	0.287	-0.016	0.026
Number of years of education	-0.055	0.042	0.056	0.022***	3.497	0.347***	-0.031	0.020
Total amount of labour used (Person days/ha)	0.030	0.035	-0.034	0.017**	0.354	0.199*	-0.012	0.016
Off-farm employment {1=yes, 0=No}					-0.206	0.160		
Irrigated {1=yes, 0=No}	0.416	0.044***	0.595	0.022***	-0.015	0.253	0.539	0.021***
Wheat area (Ha)	0.397	0.018***	0.576	0.011***	-0.852	0.161	0.512	0.010***
Total cropped area (Ha)					-0.012	0.026		
Walking distance from seed sources (km)					-1.357	0.092***		
Hosted wheat demonstration trials 1=yes,0=No}					1.800	0.537***		
Visited demonstration fields or attended field					0.120	0.566		
Seed from formal sources,1=yes, 0=No	-0.048	0.025**	-0.003	0.011	0.405	0.125***	-0.027	0.011***
Price of seed					0.110	0.169		
Farm in favourable zone{1=yes, 0=No}	0.015	0.043	-0.015	0.017	1.540	0.164	-0.069	0.016***
Farm in intermediate zone {1=yes, 0=No}	0.035	0.046	0.014	0.013	0.698	0.171	-0.013	0.014
Quantity of nitrogen fertilizer used (kg/ha)	-0.003	0.018	-0.025	0.008***	-0.154	0.093	-0.018	0.008**
Quantity of DAP fertilizer used (kg/ha)	-0.031	0.013*	0.015	0.006***	0.035	0.075	-0.001	0.006
Amount of seed used(kg/ha)	0.054	0.034	-0.010	0.017	0.180	0.188	0.013	0.016
Avrain (mm)	-0.019	0.042	0.059	0.018***	0.769	0.212***	0.034	0.018**
Avtem (oC)	0.193	0.057***	0.042	0.027	-0.302	0.297	0.078	0.027***
Constant	3.240	0.396***	2.860	0.204***	-7.760	2.328***	2.947	0.195***
Rho	-0.559	0.070***	0.276	0.217				
sigma	0.301	0.008***	0.210	0.004***				

Table 7: Average Expected Treatment and Heterogeneity Effects on Consumption from Endogenous Switching Regression

	Decision Stage		
Subsamples Effects	To Adopt	Not to Adopt	Treatment
Farm households that adopted	(a) 79	(c) 51.9	27.1***
Farm households that did not adopt	(d) 83.1	(b) 46.5	36.6***
Heterogeneity effects	-4.1	5.4	-9.5

Conclusions

Using a nationally representative sample of 1,230 farm households from 21 provinces distributed across 56 districts and 292 villages, this study attempted to provide accurate estimates of current national and provincial adoption levels of improved varieties with special attention to their release date. Analysis of factors influencing adoption of improved wheat varieties and measuring the impacts of the adoption of improved varieties on the livelihoods of households.

The national adoption rates for more recent varieties generally stand at very low levels. Only 16% of Moroccan wheat growers cultivate varieties which were released 10 or less years ago while 48% of the farmers cultivate varieties which are 20 or less years old on 41% of total wheat area. With an area-weighted national average varietal replacement rate of 22 years, very old varieties still dominate the Moroccan farmers' portfolio where more than 58% of the growers are still cultivating varieties which were released before 20 years. This raises a number of important questions on whether: 1) there are new improved INRA/CGIAR varieties which are superior to these old varieties; 2) there are indeed new and better varieties from INRA/CGIAR but the farmers are not aware of them or are not reaching them; or 3) these old varieties are indeed performing well and better than more recent INRA/CGIAR varieties and hence farmers prefer them.

The adoption of improved wheat varieties leads to improvements in livelihoods indicators including: 478kg/ha (49%) increase in yields, 1420 MAD/ha (54%) higher net income and 27.1 kg/capita/year (52%) increase in wheat consumption. Given an average area per farm household under the improved wheat varieties of 1.6 ha, the typical adopter farm households are obtaining 765.4 kg per year more yield and 2,411 MAD (US$280) additional net income - all clearly showing that the improved varieties are contributing to livelihoods improvements.

The results clearly showing that IV is potent in remove both overt and hidden biases and deal with the problem of endogenous treatment, which shows that unobservable factors such as skills of the farmers who have adopted the technology are important in explaining the differences in net wheat income.

Acknowledgements: Funding for this research was obtained from CRP-WHEAT and the EU-IFAD project on Enhanced small holder wheat cropping systems to improve food security under changing climate in the drylands of West Asia and North Africa.

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