Is there an economic case for legume-cereal rotation? A Case of Faba-beans in the Moroccan Wheat – Based Production Systems

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Abstract:

While the impacts of legume-cereal rotations on soil health are well documented, the literature on their economic benefits, especially in dry areas is scanty. By applying the propensity score matching and endogenous switching regression methods to a nationally representative sample of 1,230 farm households from Morocco, this paper provided empirical evidence that the individual and combined adoption of improved varieties of faba-beans and legume-wheat rotations lead to higher yields, farm income and household consumption. Considering a two-year period, the simultaneous adoption of both faba-bean-wheat rotation and improved faba-bean varieties led to $875/ha (136%%) higher net returns relative to wheat mono-cropping. In the face of these very high benefits, high risk of losing faba-bean crops due to pests, diseases or drought explain the low adoption of rotation and improved varieties which are at 26% and 16% respectively. For reaping both the economic and environmental benefits of faba-beans, Morocco and other similar countries in the dry areas will need to invest on the development of varieties with better pest and diseases resistance, introduce crop insurance and different incentive systems, and create better access to extension and certified seed delivery services that induce wider adoption of improved varieties and legume-cereal rotations.

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While the impacts of legume-cereal rotations on soil health are well documented, the literature on their economic benefits, especially in dry areas is scanty. By applying the propensity score matching and endogenous switching regression methods to a nationally representative sample of 1,230 farm households from Morocco, this paper provided empirical evidence that the individual and combined adoption of improved varieties of faba-beans and legume-wheat rotations lead to higher yields, farm income and household consumption. Considering a two-year period, the simultaneous adoption of both faba-bean-wheat rotation and improved faba-bean varieties led to $875/ha (136%%) higher net returns relative to wheat mono-cropping. In the face of these very high benefits, high risk of losing faba-bean crops due to pests, diseases or drought explain the low adoption of rotation and improved varieties which are at 26% and 16% respectively.

For reaping both the economic and environmental benefits of faba-beans, Morocco and other similar countries in the dry areas will need to invest on the development of varieties with better pest and diseases resistance, introduce crop insurance and different incentive systems, and create better access to extension and certified seed delivery services that induce wider adoption of improved varieties and legume-cereal rotations.

Key words: improved varieties; rotation; faba-beans; wheat; adoption; impact.

1. Introduction

Faba beans are of great importance in legume–cereal rotations in various cropping systems. It is used as a break crop for cereals (Amanuel et al., 2000; Lopez-Bellido et al., 2006) and has the potential to enhance N and P nutrition of cereals when grown in rotation (Habtemichial et al., 2007; Nuruzzaman, et al., 2005). Faba bean can also improve the economic value of a subsequent cereal crop by enhancing the yield and increasing the protein content of the grain. It can also provide a range of other potential rotational benefits that are not directly related to N such as enhanced P availability (Pypers et al., 2007; Jemo et al., 2006; Nuruzzaman et al., 2005), favourable microbial community in the rhizosphere (Marschner et al., 2004; Yusuf et al., 2009) and breaking soil-borne disease cycles (Jensen et al., 2010; Peoples et al., 2009).

During the growth of faba bean, a high amount of N_2 is fixed often resulting in a positive N balance when crop residues are incorporated in the soil after grain harvest. Net N gains due to residue incorporation of about 84 kg N ha-1 have been reported (Amanuel et al., 2000). Several studies reported savings of up to 100–200 kg N ha-1 in the amount of N-fertilizers applied to cereals following faba beans. Kirkegaard et al. (2008) and Habtemichial et al. (2007) have also found wheat yield increases of 20–36 % in the faba bean–wheat rotation compared to a barley–wheat rotation. Legume-cereal rotations are also known to reduce the demand for labour for weed control as well as in reducing soil erosion (Lawson et al., 2007; Reddy et al., 1986; Becker and Johnson, 1998; Tarawali et al., 1999).

Faba bean is one of the most important legumes for its high protein content and nutritional value (Crepona et al., 2010). The crop is widely cultivated for use in both human food and animals feed. Faba bean seeds contain relatively high proteins, carbohydrates, vitamins B, antioxidants and minerals. Protein content in different varieties varies from 26% to 41% (Picard, 1977).

Carbohydrate contents varies from 51% to 68%, of which major proportion (41–53%) is contributed by starch (Cerning et al., 1975). Common bean exhibits significant antioxidant activities such as flavonoids, polyphenols and phenolics which may provide excellent dietary source for natural antioxidant for chronic disease prevention and health promotion (Oomah et al., 2006).

As briefly described above, the biophysical impacts of legume-cereal rotations are well documented in the literature. However, the choice of crops grown in any season is largely influenced by market forces, and farmers are under pressure to maximize profits by growing the same crop repeatedly on the same land. Holding all other thins constant, this is leading to monoculture or shortened rotations in many parts of the world with its resultant effect of declining soil health and hence yield potentials as well as expected profits.

Some work has been done on the economic impacts of legume-rotations which is mostly in the developed world (see the review by Preissel et al., 2015). However, little is known about their economic and nutritional impacts in the context of smallholders especially in the developing world in general and in Morocco in particular. The results of Schilizzi and Pannell (2001) which is a case study from Australia may be of some relevance to the Mediterranean countries, but the landholding size and economic conditions of farmers in Australia and the Mediterranean countries in the North African and West Asian regions are different. Moreover, none of the previous studies assessed the combined economic impacts of adoption of improved varieties and rotations. The objective of this study is therefore to document the individual and combined impacts of the adoption of improved faba bean varieties and their rotation with cereals on farm income and food and nutrition security of smallholder farmers in Morocco. By so doing, this paper aims at providing evidence on the economic viability of legume-cereal rotations and adoption of improved legume varieties. The findings of this research are expected to be instrumental in influencing policy and reorienting extension in favour of diversification to reverse the current trend of increased mono-cropping in Morocco as well as well as many other developing countries with similar socio-economic and agro-ecological characteristics.

2. Faba Beans in Morocco

Morocco is a lower-middle-income country in North Africa with a population of 33 million people, a per capita GDP of US$3,054 and a GINI index of 40.9 (World Bank, 2012). Two thirds of the rural population are poor earning less than US$1.25/day. Agriculture plays an important role in the Moroccan economy. Its contribution to GDP and total national employment during the 2010-2014 period averaged about 17% and 45% respectively. The sector also provides indirect support for 60% of the population and generates almost 25% of export revenue. Eighty per cent of the 14 million rural inhabitants depend on revenues from the agricultural sector for their livelihoods. Reducing poverty is an important priority of the government of Morocco and is a necessary condition to improve the state of food security, sustainable development and improve livelihoods.

Faba bean is an important crop in Morocco providing nutritional, biological and economic benefits to smallholder farmers. In the late 1970s, a collaborative program between Institut National de la Recherche Agronomique (INRA) called Station Centrale des Légumineuses Alimentaires and the Food Legume Improvement Program of the International Centre for Agricultural Research in the Dry Areas (ICARD) was established. From 1989 to 1991, ICARDA decentralized the faba bean program to Morocco with the purpose to serve the North African faba bean breeding programs.

Two faba bean projects Réseau Maghrébin de Recherche sur Fève (REMAFEVE) and Amélioration de la Culture de Légumineuses Alimentaires (ACLA) were implemented from 1992-2002, to develop improved varieties of faba bean and other legume species (Fatemi et al., 2006). Since 1982, several INRA varieties of faba bean were registered in the national catalogue including other crops. Among these are three small-seeded faba bean varieties called Alfia5, Alfia17 and Alfia21 and three large-seeded faba bean varieties called Defes, Karabiga and Loubab (Fatemi et al., 2006). Similar efforts have been exerted for the release of improved varieties of other leguminous crops such as chickpeas and lentils and cereals such as wheat and barley.

While the area under cereals increased by 19% from an average of 4.4 million ha in the period 1961 - 1979 to an average of 5.2 million ha in the period 2001 – 2014, area under grain legumes dropped in the same period by 13% from an average of about 458 thousand ha to about 400 thousand ha. Particularly, the area dedicated to faba-beans has dwindled where it declined from an average of about 200 thousand hectares between the late 1980s and early 1990s to an average of about 120 thousand ha in Mid-1990s and more recently rebounded to an average of about 190 thousand ha between 2010 and 2014.

In general, the cultivation of faba beans leads to higher net returns than the cultivation of wheat. However, owing to the high pest, disease and drought-related risks involved in the cultivation of faba-beans, Moroccan farmers continue to plant wheat as a monocrop. In Morocco, more than 60% of total faba bean cultivation takes place in the northern parts of the country where the annual average rainfall is above 400 mm. Over the years, the area under faba-beans has significantly decreased because of drought, Orobanche, Botrytis, Stem nematodes, and insect damages. To encourage farmers to plant faba beans. the Moroccan government has allowed domestic faba bean prices to trade at 18 percent above the world (European Union) market equivalent. While this is expected to encourage wider production of faba-beans, continued development and release of newer varieties which better pest and disease resistance and drought tolerance will be important.

Likewise, while adoption of improved varieties of cereals showed modest increases, the adoption of improved varieties of legumes in general and Faba-beans in particular remains very low with very low yields. For example, the average yields of faba-beans during the period 2001 and 2014 was about 0.71 ton/ha which is 58% lower than the world average of 1.7 ton/ha (FAOStat, 2016).

This study targets only the wheat-based production systems in Morocco. In this system, wheat mono-cropping is the dominant practice. However, some farmers also practice faba-bean-wheat rotations.

3. 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 favourable zone, intermediate zone, unfavourable south and the mountains zone. Provinces in the remaining two agro-ecological zones in Morocco (the Saharan zone and the Unfavourable Oriental Zone) are excluded from the survey as wheat production in these zones is either non-existent or less important.

A total sample of 1230 wheat growing 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 in 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 goes about here>

The primary purpose of the survey was to determine the adoption and impacts of improved wheat varieties in Morocco. As a result, production and marketing related data was collected from a total of 2296 plots cultivated by all the 1230 sample wheat producers. Data on wheat consumption was also collected from each of the 1230 wheat producing households. The study team also was interested to analyse the economic viability of legume-cereal rotations in the wheat-based production system. While discussions with Moroccan wheat farmers revealed that most of them seem to agree on the importance of legume-cereal rotations on soil health, the increasing trend in wheat mono-cropping is puzzling and also becoming a major concern to researchers and policy makers alike. As a result, the study team decided to collect data on whether each of the plots planted with wheat in 2012 were planted to faba-beans or to wheat in the previous (2011) season. Moreover, each of the 1230 sample wheat producers were asked if they have plots which are planted to faba-beans in 2012. A total of 326 farmers responded yes and the study team collected faba-beans production and marketing related data from a total of 347faba-bean fields cultivated by all of the 326 farm households. Moreover, faba-bean consumption related data was collected. The summary statistics for important variables are provided in Table 2.

< Table 2 goes about here>

4. Methodology

4.1 Endogenous switching regression (ESR) model

The endogenous switching regression model can be used to estimate and make pairwise comparisons of: (1) the expected net income of a typical adopter farm household (2) the expected net income of the typical non-adopter household; and to investigate the expected net income in the counterfactual hypothetical cases of (3) if the typical adopter did not actually adopt and (4) if the typical non-adopter were to adopt. Following Di Falco (2011) and Shiferaw et al. (2014), the conditional expectations for net income in the four cases are presented in Table 2 and defined as follows:

$$E(y1i|Ai = 1) = \boldsymbol{X1i\beta1} + \sigma1\eta\lambda1i \quad (1)$$

$$E(y2i|Ai = 0) = \boldsymbol{X2i\beta2} + \sigma2\eta\lambda2i \quad (2)$$

$$E(y2i|Ai = 1) = \boldsymbol{X1i\beta2} + \sigma2\eta\lambda1i \quad (3)$$

$$E(y1i|Ai = 0) = \boldsymbol{X2i\beta1} + \sigma1\eta\lambda2i \quad (4)$$

Cases (1) and (2) along the diagonal of Table 2 represent the expectations for the typical farmers in each of the adopter and non-adopter categories respectively based on actual observations in the sample. Cases (3) and (4) represent the counterfactual expected net incomes. Suppose that:

TT = treatment effect which measures the effect of the treatment (i.e., adoption) on the treated (i.e., farm households that actually adopted) which, when averaged across all adopter households gives the average treatment effect on the treated (ATT).

TU = treatment effect on the untreated which measures the effect of the treatment (i.e., adoption) on the untreated (i.e., farm households that actually did not adopt), which when averaged across all non-adopter households gives the average treatment effect on the untreated (ATU).

BHi = the average effect of base heterogeneity for farm households that adopted (i =1), and that did not adopt (i =2)

TH= Transitional heterogeneity = BH1 - BH2

Then, we can estimate each of these effects as follows:

$$ATT = E(y_{1i} | A_i = 1) - E(y_{2i} | A_i = 1) = \mathbf{X_{1i}} * (\boldsymbol{\beta_1} - \boldsymbol{\beta_2}) + (\sigma_{1\eta} - \sigma_{2\eta}) * \lambda_{1i} \quad \ldots\ldots\ldots (5)$$

$$ATU = E(y_{1i} | A_i = 0) - E(y_{2i} | A_i = 0) = \mathbf{X_{2i}} * (\boldsymbol{\beta_1} - \boldsymbol{\beta_2}) + (\sigma_{1\eta} - \sigma_{2\eta}) * \lambda_{2i}. \quad \ldots\ldots\ldots (6)$$

$$BH_1 = E(y_{1i} | A_i = 1) - E(y_{1i} | A_i = 0) = (\mathbf{X_{1i}} - \mathbf{X_{2i}}) * \boldsymbol{\beta_{1i}} + \sigma_{1\eta} * (\lambda_{1i} - \lambda_{2i}). \quad \ldots\ldots\ldots (7)$$

$$BH_2 = E(y_{2i} | A_i = 1) - E(y_{2i} | A_i = 0) = (\mathbf{X_{1i}} - \mathbf{X_{2i}}) * \boldsymbol{\beta_{2i}} + \sigma_{2\eta} * (\lambda_{1i} - \lambda_{2i}) \quad \ldots\ldots\ldots (8)$$

Where $Ai = 1$ If farm households actually adopted improved faba bean; $Ai = 0$ if farm households did not actually adopt;

$Y1i$: Net income if farm households were to adopt;

$Y2i$: Net income if farm households were to not adopt; The summary of the treatment and heterogeneity effects are provided in Table 3 below.

<Table 3 goes about here >

4.2 Propensity Score Matching (PSM)

Assessment of the impacts of technology adoption either by examining the differences in mean outcomes of adopters and non-adopters or by using simple regression procedures which control for adoption status was common in the literature (Nguezet, et al., 2011). Critics have pointed out that such simple procedures are flawed because they fail to appropriately deal with problems associated with selection biases in observational data collected through household surveys (Rubin, 1974; Rosenbaum and Rubin, 1983; Rosenbaum, 2002; Lee, 2005). Such approaches often lead to the establishment of causality between adoption and other variables that are subjected to confounding errors.

Propensity score matching (PSM) is one of the multivariate methods used in comparative studies to construct treated and matched control samples that have similar distributions on many covariates. The purpose of propensity score matching is to reduce bias due to observed covariates in comparative observational studies (Rubin and Thomas 2000). PSM is one of the non-parametric estimation techniques that do not depend on functional form and distributional assumptions. The method is intuitively attractive as it can be used to compare the observed outcomes of technology adopters with the outcomes of counterfactual non-adopters (Heckman et al., 1998). The details of the PSM method are well documented in several studies (e.g., Rosenbaum and Rubin 1983; Heckman et al., 1998; Daheja and Wahba, 2002; Caliendo and Kopeinig, 2008).

In this paper, we use PSM to find a group of treated individuals (adopters) similar to the control group (non-adopters) in all relevant pre-treatment characteristics, where the only difference is that one group adopted the improved faba bean and the other did not. The semi-parametric matching method which does not require an exclusion restriction or a particular specification of the selection equation is used to construct the counterfactual and reduce the effects of selection bias on impact estimates.

The propensity score is most often estimated using a logistic regression model, in which treatment status (which in our case is the dummy variable for adoption of faba bean taking a value of 1 when the farmer is an adopter and 0 when the farmer is a non-adopter) is regressed on observed characteristics of the farmer. The estimated propensity score is therefore the predicted probability of a farmer adopting improved faba bean given his characteristics (which are captured by the explanatory variables included in the logistic regression). The propensity score for each observation is then obtained by substituting the corresponding values of each covariate for each observation into the estimated logistic regression where the estimated coefficients are used in the computation (Rosenbaum and Rubin 1985). In this study, the logistic model is estimated to identify the factors influencing adoption of improved faba bean as follows:

$$Prob\ (Adoption\ = 1)\ =\ 1/(1 + e^{-z}) \qquad (1)$$

where $Z = \beta_0\ +\ \sum_{i=1}^{n} \beta_i\ X_i +\ \varepsilon_j$ (2)

Adoption is a dichotomous dependent variable taking a value of 1 if the improved faba bean takes place and 0 otherwise; Xi is the vector of observed farmer, farm and non-farm characteristics that are believed to determine adoption and hence are included in the model (See Table 2 for the list and descriptive statistics of the explanatory variables included in the model); βi are parameters to be estimated; ε_j is error term of the model; and e is the base of natural logarithms.

The main purpose of the propensity score estimation is to balance the observed distribution of covariates across the groups of adopters and non-adopters (Lee, 2013). Since we do not condition on all covariates but on the propensity score, balancing test is normally required after matching to ascertain whether the differences in the covariates in the two groups in the matched sample have been eliminated, in which case, the matched comparison group can be considered a plausible counterfactual (Ali and Abdulai, 2010). Several versions of balancing tests exist in the literature: test for mean differences within strata (Dehejia and Wahba, 2002), test for standardized differences (Rosenbaum and Rubin 1985), test for the joint equality of covariate means between treatment and comparison groups using the Hotelling or F-tests (Smith and Todd 2005), comparison of the pseudo R2 and p-values of the likelihood ratio test of the joint insignificance of all the covariates (Sianesi, 2004) and the mean absolute standardized bias (MASB) between adopters and non-adopters (Rosenbaum and Rubin, 1985). We use the mean absolute standardized bias (MASB) between adopters and non-adopters because it has key advantage where as opposed to model-based methods, outcome data is not involved in the matching for which repeated attempts to balance covariates do not bias estimates of the treatment effect on outcome variables. The intuition behind this check for balance within strata is the close analogy between randomized block experiments and propensity score methods.

The main problem with using the MASB approach is that there is no clear criterion for testing the success of PSM. However, in empirical studies, it is often assumed that MASB below 3% or 5%

after matching is acceptable (Caliendo and Kopeinig, 2008). Rosenbaum and Rubin (1985) argue that, after matching, total bias in excess of 20% should be considered as large.

Following Sianesi (2004), we also make comparison of the pseudo R-square and p-values of the likelihood ratio test of the joint significance of all the regressors obtained from the logistic regression before and after matching the samples. After matching, there should be no systematic differences in the distribution of covariates between the two groups. As a result, the pseudo-R2 should be lower and the joint significance of covariates should be rejected (or the p-values of the likelihood ratio should be insignificant).

5. Results and Discussions

5.1 Results from the Propensity Score Matching Model

5.1.1 Impacts of improved faba bean varieties on yield and food security

Results from the propensity score matching (PSM) model show that the use of improved faba-bean varieties led to an average yield gain of 155.5 kg/ha (13.1%) for those who adopted (Table 4). If non adopters were to adopt the improved varieties, they would have obtained 113 kg/h higher yields. These results show that the improved faba-bean varieties have the potential to provide even higher benefits to those who have not yet adopted.

<Table 4 goes about here >

5.1.2 Impacts on net-returns from faba-bean production

Estimates of the treatment effects on net margins from PSM are provided in Table 4. The results show that adoption of improved faba bean varieties provide on the average 896.3 MAD/ha (11.6%) higher net returns from faba-bean production for adopters. If non adopters were to adopt the improved varieties, they would have earned 426.9 MAD/ha more net returns - showing that the benefit to both adopters and non-adopters is almost the same. Given the average area under improved varieties per family of 2 ha, a typical adopter family currently earns 1792.6 MAD of additional income each year from the production of faba-beans.

5.1.3 Impacts on faba-beans consumption

The results from the PSM model show that the adoption of improved varieties of faba-beans lead to 13.2 kg/capita/year (23%) higher consumption of faba-beans by members of the adopter families (Table 4). If non adopters were to adopt the improved varieties, their family members would have consumed 10.3 kg/capita/year (19%) more faba-beans - showing that the benefit to those who already adopted is higher, which may provide part of the explanation for why only those farmers adopted the improved faba bean varieties while a larger proportion of farmers did not.

5.2 Results from the endogenously switching regression (ESR) model

5.2.1 Impacts of improved faba bean varieties on yield and food security

Results from the full information maximum likelihood estimation of the endogenous switching regression model are provided in Table 5. The associated estimates of average expected treatment and heterogeneity effects are provided in Table 6. The results show that adopters of improved varieties on the average obtain about 171.7 kg/ha (14%) more yield than the counterfactual (i.e., what they would have obtained if they had not adopted). Taking an average grain price of 7.31 MAD/kg and ignoring the cost implications of adoption of improved faba bean varieties, this yield gain would translate into a gain in gross revenue of 1,255 MAD/ha (US$1146/ha)[1]. At the current average adoption level of 2 ha/family, each adopter farm household obtained about 343.3 kg more yield and 2,509.6 MAD (US$291.5) more revenue per year.

<Table 5 goes about here >

<Table 6 goes about here >

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. Quantities of DAP fertilizers are found to have positive and significant effects on yield for both adopters and non-adopters. This finding is in line with other studies which showed that application of phosphorus to leguminous food crops increases grain yields (El Kalla et al., 1999; Bolland et al., 2000). The quantities of nitrogen fertilizers (N) have positive and significant effects on yield for adopter while it's negative and significant for non-adopter. Although faba beans can fix N, it is often suggested to apply small amounts of N fertilizers at planting. This seems to be inconsistent with other studies where the application of nitrogen fertilizers at a rate of 20 kg/ha at planting time has been shown to be beneficial for faba bean to enhance biological fixation (R'kiek, 1994). Size of plot also have positive and significant effects on yields. Farmers who used certified seeds obtained higher yields than those who used uncertified seeds - showing clear advantage to the use of certified seeds.

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

Given that ESR is potent in correcting for biases both from observable and unobservable factors, the 10 % higher yield effects from ESR relative to PSM shows that unobservable factors such as skills of the farmers who have adopted the technology are important in explaining the differences in yield effects. In this particular case, the unobservable factors led to underestimation of the yield impacts when PSM was used but ESR was able to correct for that.

5.2.2 Impacts on net-returns from faba-bean production

The Estimates of the Endogenous Switching Regression (ESR) are provided in Table 5 below. Like the yield equation, DAP fertilizer has positive and significant effects on net margins while nitrogen fertilizer has negative and significant effects on net margins for non-adopters.

Table 6 presents the estimates of treatment effects from ESR. The results show that adoption of improved faba bean varieties provide on the average 942.2 MAD/ha (11.6%) higher net faba bean income for adopters. If non adopters were to adopt the improved varieties, they would have earned 593 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. Once again, the 5% higher effects on net income from ESR relative to PSM shows that unobservable factors are important in explaining differences in net income.

5.1.3 Impacts on faba-bean consumption

Estimates of treatment effects from ESR are provided in Table 6. The results show that adopters of improved varieties on the average consume about 20 kg/capita/year (35%) more faba bean than the counterfactual (i.e., what they would have consumed if they had not adopted). If non adopters were to adopt the improved varieties, they would have consumed 16.3 kg/capita/year more faba bean showing that the benefit to those who already adopted is much higher – a possible explanation for why a large number of farmers did not adopt the improved faba bean varieties yet. The 1% higher consumption effects from ESR relative to PSM shows that unobservable factors are important in explaining the differences in consumption.

5.3 National-level potential impacts of improved faba-bean varieties

In 2012, total area under faba-beans was estimated at 187 thousand ha where only 16% were covered by improved varieties. Assuming that on the average, the adoption levels and yield impacts in the other faba bean growing areas that are not covered by the survey are also the same, Morocco has been producing a total of 5,134 tons (2.3%) more faba bean due to the adoption of improved varieties. Likewise, the introduction of improved faba-bean varieties has led to national net income gain of about $ 2 million. This shows that there is substantial benefit that Morocco can reap if the country invests on the promotion of improved varieties to achieve wider diffusion (Table 7).

< Table 7 goes about here>

5.5. Impacts of wheat –faba bean rotation on the subsequent wheat production

ESR model results showed that 37% (389.5 kg/ha) higher yields were obtained by wheat farmers rotating with faba-beans than those planting wheat after wheat. Faba-bean-wheat rotations also increased net return from the subsequent wheat production by 46% (1284.9 MAD/ha) (Table 8).

The results also show that Faba-bean-wheat rotations also increased wheat consumption by 26.6 kg/capita/year.

< Table 8 goes about here>

5.6 Impacts of the simultaneous adoption of faba-bean-wheat rotations and improved faba-bean varieties on net returns

Considering a two-years planning horizon and assuming that there were no significant differences in the biophysical and socio-economic production conditions including rainfall, input quantities and other agronomic practices, the impacts on net returns from the simultaneous adoption of faba-bean-wheat rotations and improved faba-bean varieties is computed as follows. First, we compute the total two-year income from non-adoption of faba-bean-wheat rotation as two times the average wheat income of these group of farmers which is 2779.4/ha (from the ESR model results for adoption of improved faba-bean varieties – Table 8). Then, we compute the two-year income of the simultaneous adopters of improved faba-bean varieties and rotation as the sum of the average net income from the cultivation of improved varieties of faba-beans by adopters which is 9045.3MAD/ha (Table 6) and the wheat income of the adopters of rotation which is 4064.3 MAD /ha. Accordingly, the simultaneous adoption of improved faba-bean varieties and faba-bean rotations leads to a two-year total additional net returns of 7550 MAD/ha. These figures clearly show that the adoption of improved or even local varieties of faba-beans has substantial impact on income. If farmers lose their faba-bean crop due to pests or diseases, they run a risk of losing about 25% of their total two-years net returns (relative to wheat mono-cropping). Mechanisms for reducing this risk would go long distance in convincing farmers that rotation is beneficial not only in terms of improving the biophysical conditions of soils but also in terms of farm income.

6. Conclusion

This study found that only 3 out of 13 faba bean varieties in farmers' hands were improved varieties covering only 16% of total faba beans area. Farmers reported that only 17% of total faba bean seeds used was certified originating from seed companies while the remaining 83% was uncertified - 63% kept from previous harvest and 20% bought from local seed retailers.

The adoption of improved faba bean varieties leads to 171.7 kg/ha (13.9%) increase in yields, US$109.3/ha (11.6%) higher net returns and 19.9 kg/capita/year (35%) increase in faba bean consumption and hence equivalent gains in protein, carbohydrate and starch intakes for every household member of the adopter households. All these results show that the improved varieties of faba-beans are contributing to livelihoods improvements and nutrition security at household level. Moreover, 37% higher yields were obtained by wheat farmers rotating with faba-beans than cereal-cereal and other rotations.

Wheat-faba bean rotations also increased wheat net returns by 46%. At the same time the results show that the combined effect of the adoption of improved varieties of faba beans and rotations is an increase in total farm income of 7550 MAD/ha. At current adoption level of 16%, improved varieties of faba beans led to additional production of about 5.13 thousand tons (2.3%) per year.
All these results show that along with the soil health benefits and hence the sustainability of farming documented elsewhere, legume-cereal rotation can be justified on economic grounds with clear contribution to national food and nutrition security. If farmers lose their faba-bean crop due to pests or diseases, they run a risk of losing about 25% of their total two-years income (relative

to wheat mono-cropping). Mechanisms for reducing this risk would go long distance in convincing farmers that rotation is beneficial not only in terms of improving the biophysical conditions of soils but also in terms of farm income.

The main lessons drawn from these findings are that: 1) there is an urgent need for more research to develop new improved varieties that are resistant to pests and diseases and tolerant to drought; and 2) there is a need to strengthen the extension service and certified seed delivery systems to enhance the adoption of improved varieties and develop farmers' awareness and appreciation towards legume-cereal rotation. These findings point to the need for policy and extension intervention to strengthen the national research system, enhance diversification among smallholders, and reverse the current trend of increasing monoculture in the wheat-based production systems of Morocco.

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Table 1: Distribution of Sample Households across the 21 Provinces

Region	Province	Sample statistics				
				Number of Households		
		# of districts	# of villages	Male headed	Women headed	Total
Chaouia-Ouardigha	Benslimane	3	10	26	1	27
	Berrechid	2	13	40	3	43
	Settat	3	33	80	2	82
Doukkala-Abda	El Jadida	3	16	70	6	76
	Sidi Bennour	2	17	63	5	68
	Safi	3	19	128	2	130
Fes-Boulemane	Fes	1	1	8	0	8
	Moulay Yacoub	2	7	52	0	52
Gharb-Chrarda-Bni Hces	Kenitra	3	17	49	10	59
	Sidi Slimane	1	8	17	1	18
	Sidi Kacem	5	22	63	4	67
Marrakech-Tensift-Alhaouz	El Kelaa	2	12	36	2	38
	Rehamna	2	12	75	2	77
Meknès-Tafilalet	El Hajeb	3	7	22	0	22
	Khenifra	2	11	58	0	58
	Meknes	1	11	29	0	29
Rabat-Salé	Khemisset	4	25	61	6	67
Tadla-Azilal	Beni Mellal	3	7	89	1	90
Taza-Alhoceima-Taounate	Taounate	4	24	117	7	124
	Taza	5	14	75	0	75
	Guercif	2	6	20	0	20
Total Sample		56	292	1178	52	1230

Table 2: Descriptive statistics on important variables

Variable	For farmers who cultivated Faba-beans (FB) in 2012			For farmers who cultivated wheat in 2012:		
	Non-Adopters of improved varieties of FB	Adopters of improved varieties of FB	Total	but did not cultivate FB in the previous season^	Farmers who cultivated FB in the previous season ^	Total
Number of households	282	44	326	755	475	1230
Number of plots	295	52	347	1481	815	2296
Average age (Years)	59.2	58.5	59.1	59.9	58.6	59.4
Average number of years of education	1.6	2.3***	1.7	1.7	2.1***	1.9
Average amount of family labor (Person days/ha)	4.0	3.9	4.0	4.2	4.5	4.3
Average faba-bean area (Ha)	1.8	3.6***	2.0	0.72	2.5***	1.6
Average wheat area (Ha)	2.1	5.3***	3.6	2.6	6.2***	3.9
Average total cropped area (Ha)	8.9	10.8	9.2	10.9	15.4***	12.5
Average walking distance from seed sources (km)	21.1	19.4	20.8	19.3	13.4***	17.2
Average price paid for seed (MAD/kg)	9.8	7.5	9.4	2.3	2.2	2.3
Average quantity of DAP fertilizer used (kg/ha)	98.7	144.2***	105.5	27.2	33.4***	29.4
Average quantity of nitrogen fertilizer used (kg/ha)	3.5	17.6***	5.6	35.5	50.4***	40.8
Average amount of seed used(kg/ha)	100.5	106.1***	101.4	168.0	179.9***	172.2
Average faba-bean consumption (kg/capita/year)	56.7	77.6***	59.8	57.1	77.2***	66.3
Average wheat consumption (kg/capita/year)	51	84***	66.1	50.5	84.7***	62.6
Average net income from faba-bean production (MAD/ha)	7773.2	8998.5***	7956.8	7909	8763.6***	8301
Average net income from wheat production (MAD/ha)	3590.6	5800***	4603.2	3439.6	5772.9***	4267.9
Average faba-bean Yield (kg/ha)	1155.3	1407.2***	1193.1	1170	1348.3***	1252
Average wheat yield (kg/ha)	1202	1860	1503.6	1190.6	1863.6***	1429.5
Was the seed you used certified? {1=yes, 0=No}	3.7	44.2***	9.8	43.1	60.5***	49.3
Farm is in favourable zone{1=yes, 0=No} (% of yes)	48.1	34.6**	46.1	30.3	49.3***	37.1
Farm is in intermediate zone {1=yes, 0=No}(% of yes)	25.4	61.5***	30.8	31.5	25.5***	29.4
Are you active or leader in the community (% of yes)	9.2	48.1***	15.0	13.5	31.9***	20
Did you get a credit from a bank {1=yes, 0=No} (% of yes)	35.9	44.2	37.2	40.2	60***	47.3
Do you have off-farm employment {1=yes, 0=No} (% of yes)	14.6	23.1*	15.9	16.6	17.9	17.1

***, ** and * represent significance at 0.1, 0.05 and 0.01 levels.

^For each plot planted to wheat in 2012, farmers were asked if it was planted with faba-beans in the previous (2011) season.

Table 3: Treatment and Heterogeneity Effects

	Decision Stage		
Subsamples Effects	To Adopt	Not to Adopt	Treatment
Farm households that adopted	(a) $E(y1i\|Ai\ = 1)$	(c)$E(y2i\|Ai\ = 1)$	TT
Farm households that did not adopt	(d)$E(y1i\|Ai\ = 0)$	(b)$E(y2i\|Ai\ = 0)$	TU
Heterogeneity effects	BH1	BH2	TH

Table 4: Treatment Effects on faba-bean yields, net returns and consumption: results from the propensity score matching (PSM) model

	Impacts on Faba-bean yields (kg/ha)				Impacts on Net returns from Faba-bean production (MAD/ha)				Impacts on Faba-bean consumption (kg/capita/year)			
Group	Treatment group	Control group	Difference	S.E.	Treatment group	Control group	Difference	S.E.	Treatment group	Control group	Difference	S.E.
Unmatched	1352.6	1151.8	200.8	14.9 [a]	8961.2	7742.4	1218.7	112.6 [a]	74.9	55.2	19.6	2.23 [a]
ATT	1339.4	1183.9	155.5	25.6 [a]	8604.2	7707.9	896.3	359.9 [a]	71.9	58.7	13.2	5 [a]
ATU	1152.9	1265.9	113		7707.9	8134.8	426.9		54.9	65.2	10.3	
ATE			118.3				479.0				11.1	

[a] indicates significance at 0.01 level

Table 5: Full information maximum likelihood estimates of the endogenous switching regression model for yields (kg/ha), Net returns from faba-bean production (MAD/ha) and faba-bean consumption (kg/capita/year)

Independent Variables	Adoption of improved faba bean varieties (No=0,Yes=1)		Yield Equation for:				Net-return Equation for:				Consumption Equation for:			
			Adopters		Non-Adopters		Adopters		Non-Adopters		Adopters		Non-Adopters	
	Coef.	Std.Er	Coef.	Std.Er	Coef.	Coef.	Std.Er	Std.Er	Coef.	Std.Er	Coef.	Std.Er	Coef.	Std.Er
Age (Years)	0.635	0.739	0.042	0.036	0.010	0.010	0.017	0.040	0.004	0.012	0.103	0.146	-0.013	0.050
Number of years of education	1.342	0.490***	0.103	0.024***	0.005	0.006	0.061	0.028**	0.004	0.008	0.040	0.099	-0.037	0.032
Number of family members working on own farm (Person days/ha)	0.090	0.268	0.006	0.016	0.003	0.005	0.032	0.018*	0.001	0.006	0.042	0.063	-0.018	0.026
Get a credit from a bank {1=yes, 0=No}	0.002	0.388	0.004	0.017	0.001	0.005	-0.012	0.018	0.000	0.006	0.085	0.068	0.045	0.024*
Off-farm employment {1=yes, 0=No}	0.088	0.337												
Faba-bean area (Ha)	3.036	0.447***	0.200	0.025***	0.006	0.008	0.235	0.029***	0.001	0.010	0.749	0.107***	-0.024	0.043
Total cropped area (Ha)	1.030	0.597*	-0.047	0.022**	-0.008	0.009	-0.041	0.023*	-0.011	0.011	-0.141	0.082*	-0.031	0.047
Walking distance from seed sources (km)	-0.372	0.199*												
Was the seed you used certified? {1=yes, 0=No}	2.129	0.432***	0.034	0.018**	0.002	0.012	0.049	0.019***	0.006	0.015	0.105	0.069	-0.049	0.065
Price of seed	-3.989	9.094												
Farm in favourable zone{1=yes, 0=No}	2.038	0.692***	-0.085	0.055	0.017	0.005***	-0.051	0.065	0.016	0.006***	-0.108	0.231	0.002	0.027
Farm in intermediate zone {1=yes, 0=No}	1.939	0.651***	-0.062	0.055	0.025	0.007***	-0.023	0.065	0.026	0.008***	-0.067	0.224	0.014	0.033
Quantity of nitrogen fertilizer used (kg/ha)			0.008	0.005*	-0.005	0.002**	0.004	0.006	-0.005	0.003*	0.041	0.021**	0.004	0.012
Quantity of DAP fertilizer used (kg/ha)			0.060	0.017***	0.141	0.005***	0.041	0.019**	0.158	0.006***	0.016	0.094	0.221	0.025***
Amount of seed used(kg/ha)			-0.018	0.059	0.021	0.014	-0.058	0.068	0.029	0.017*	-0.275	0.230	-0.002	0.073
N(0,1)	1.406	0.481***												
pesticides (0,1)	-0.865	0.353***												
herbicides (0,1)	-1.071	0.483**												
Constant	-2.519	18.949	6.633	0.336***	6.281	0.078*	8.810	0.389***	8.113	0.093***	4.303	1.327***	3.176	0.389***
Log likelihood														

[a, b], and [c] indicate significance at 0.01, 0.05 and 0.1 levels respectively

Table 6: Average Expected Treatment and Heterogeneity Effects on Yield, net-returns and consumption of faba-beans: results from the endogenous switching regression

Sub-sample Effects	Yield (kg/ha) Decision Stage To Adopt	Yield (kg/ha) Decision Stage Not to Adopt	Yield (kg/ha) Treatment	Net-returns from faba-bean production Decision Stage To Adopt	Net-returns from faba-bean production Decision Stage Not to Adopt	Net-returns from faba-bean production Treatment	Consumption of faba-beans (kg/capita/year) Decision Stage To Adopt	Consumption of faba-beans (kg/capita/year) Decision Stage Not to Adopt	Consumption of faba-beans (kg/capita/year) Treatment
Farm households that adopted	1408.1	1236.5	171.7***	9045.3	8103.1	942.2***	76.7	56.8	19.9***
Farm households that did not adopt	1212.0	1085.7	126.2***	7707.9	7115.3	592.6***	55.1	38.9	16.3***
Heterogeneity effects	196.1	150.7	45.4	1337.4	987.8	349.6	21.6	18.0	3.6

*** indicate significance at 0.01

Table 7: Potential impacts of improved faba bean varieties with different levels of assumed Adoption levels

Assumed adoption level of improved faba-bean varieties	Realized/Potential gain: Production (tons)	Realized/Potential gain: Net Income (million MAD)	Realized/Potential gain: Net Income (million US$)
Current level (16%)	5,134	18	2.0

30%	9,627	33	3.8
50%	16,045	55	6.4
70%	22,462	77	8.9
80%	25,671	88	10.2
90%	28,880	99	11.5
100%	32,089	110	12.8

Table 8: Average Expected Treatment and Heterogeneity Effects of wheat –faba-bean rotation on the subsequent wheat production from Endogenous Switching Regression

	Yield of wheat (kg/ha)			Net-returns from wheat production			Consumption of wheat (kg/capita/year)		
	Decision Stage			Decision Stage		Treatment	Decision Stage		Treatment
Sub-sample Effects	To Adopt	Not to Adopt	Treatment	To Adopt	Not to Adopt		To Adopt	Not to Adopt	
Farm households that adopted rotation	1422.3	1032.8	389.5***	4064.3	2779.4	1284.9***	79.0	52.5	26.6***
Farm households that did not adopt rotation	1339.4	982.4	357.0***	3904.9	2697.3	1207.7***	71.5	46.5	25.0***
Heterogeneity effects	82.8	50.4	32.5	159.4	82.1	77.2	7.5	5.9	1.6

*** indicate significance at 0.01