Can improved food legume varieties increase technical efficiency in crop production?

A Case Study in Bale Highlands, Ethiopia

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Outline

- Motivation
- The key questions
- Methodology
- Results and discussion
- Conclusion and more questions

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Motivation

- Faba bean (broad bean), field pea, and lentil are very important legumes in the highlands of Ethiopia.
  - Ethiopia is the largest producer of faba bean in SSA.
    - **In 2012/13, about 4.4 million smallholder farmers planted 574,000 ha of faba bean producing 0.9 million tons at an average productivity of 1.6 tons per ha.**
  - Field pea is also an important source of protein in Ethiopia.
    - In 2012, the crop ranked fourth in area coverage with an acreage of 212,890 ha and annual production of 2.6 million tons (FAO, 2012).
- We all agree (it seems) that legumes are essential for the regeneration of nutrient-deficient soils.
  - They fix nitrogen!
- Bale highlands in south Eastern Ethiopia is known for mono-cropping production system: wheat and barley dominated.

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Motivation

Mono-cropping:

- Growing one crop year after year on the same plot of land
- Non-diverse rotations – Only a single crop is grown at a time within a field.
- Associated with two problems:
  - Soil degradation
  - Increased vulnerability to risk
- Implies lower efficiency [broadly defined] compared to poly-cropping systems.

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The key questions

- Our question(s)
  - How efficient are improved legume growers compared to non-growers?
  - If there is a considerable difference in efficiency, can we attribute this to the inclusion of improved legume crops?
  - Does crop productivity [crop output per unit of the most limiting input] vary between improved food legume growers and non-growers?
- Our objective
  - To empirically show whether the adoption of improved food legume varieties increases the technical efficiency of crop production.

Methodology

- Sampling
  - Multi-stage (mixed) sampling
    - 3 of the 4 major legume producing districts in Bale highlands were selected.
    - 4 peasant associations in each district were selected randomly.
    - 200 farm households from the 4 PAs/District selected using proportionate random sampling.
    - Total sample size 600 farm HHs.

Analytical framework

1. Efficiency analysis (SF Model)

$$y_i = \alpha + x_i'\beta + \varepsilon_i, \quad i = 2,..,N$$

$$\varepsilon_i = v_i - u_i$$

$$v_i \sim N(0, \sigma_v^2)$$

$$u_i \sim F$$

y_i is log of total crop yield
x_i vector of (log of) inputs
ε_i composite error
υ_i idiosyncratic error
u_i inefficiency (one-side disturbance)

The assumption about the distribution (F) of u_i term is needed to make the model estimable. Four options so far:

1. Half normal distribution $u_i \sim N^+(0, \sigma_u^2)$ (Aigner et al., 1977).
2. **Exponential distribution $u_i \sim \varepsilon(\sigma_u)$ *(Meesun and van den Broeck ,1977)***
3. **Truncated normal (Stevenson, 1980)**
4. Gamma distribution (Greene, 1980, 2003).

SF Model (2)

- Two step estimation

  1- estimates of the model parameters $\hat{\text{h}}$ are obtained by maximizing the LL-function $l(\hat{\text{h}})$

  2 – point estimates of inefficiency can be obtained thru the mean (or the mode) of the conditional distribution $f(u_i \mid \hat{\varepsilon}_i)$ where $\hat{\varepsilon}_i = y_i - \hat{\alpha} - x_i'\hat{\beta}$

- *Post-estimation procedures to compute efficiency parameters:*
  - *Jondrow et al (1982): E= exp(-E(s.u|ε)*
  - *Battese and Coelli (1988): E= E[exp (-s.u|ε)]*

SFA models

- Y= bread wheat equivalent in birr
  - Efficiency model 1
    - *Jondrow et al (1982)*
    - Stoc. frontier normal/tnormal model
  - Efficiency model 2
    - *Battese and Coelli (1988)*
    - Stoc. frontier normal/tnormal model
  - Efficiency model 3
    - *Jondrow et al (1982)*
    - Stoc. frontier normal/exponential model
  - Efficiency model 4
    - *Battese and Coelli (1988)*
    - Stoc. frontier normal/exponential model

Analytical framework
2. Impact analysis

$$\delta_i = Y_i^A - Y_i^N$$

Where $\boldsymbol{\delta_i}$ is impact on individual '*i*';

Y_i^A Is potential outcome of adoption for individual 'i'.

Y_i^N Is potential outcome of non-adoption for individual 'i'.

Let **D** denotes adoption decision (assumed to be binary) and takes the value 1 for adopters (*A*) and 0 for non adopters (*N*).

Any problem in estimating this?

- YES! - B/C only one of the potential outcomes is observed for each individual *i*. Missing data problem!!
- **Therefore, estimating the individual trt effect δ_i is not possible because it is unobservable.**
  - **Hence we concentrate on (population) average trt effects.**

2. Impact analysis

$$Y_i = \begin{cases} Y_i^A & if\ D_i = 1 \\ Y_i^N & if\ D_i = 0 \end{cases}$$

$$ATET = E[\delta_i \mid D_i = 1] = E[Y_i^A \mid D_i = 1] - E[Y_i^N \mid D_i = 1]$$

$$ATU = E[\delta_i \mid D_i = 0] = E[Y_i^A \mid D_i = 0] - E[Y_i^N \mid D_i = 0]$$

$$ATE = E[\delta_i] = E[Y_i^A - Y_i^N] = ATT * P(D=1) + ATU * P(D=0)$$

$$POM_D = E[Y_i \ ]$$

ATET is identified only if $E[Y^N|D=1]-E[Y^N|D=0]=0$: That is the TEs of HHs from the adopter and non-adopter groups would not differ in the absence of the improved food legume varieties.

Assumptions for Matching Methods

- Identifying assumption (untestable) – selection on observables (conditional exogeneity)
  - Implies: all the relevant differences b/n treated and non-treated are captured in 'X'
  - ATT: $E[Y_i^N \mid X, D=1] = E[Y_i^N \mid X, D=0]$
  - ATU: $E[Y_i^A \mid X, D=1] = E[Y_i^A \mid X, D=0]$
  - ATE: Both
- Common support
  - Implies: We observe adopters and non-adopters with the same characteristics
  - ATT: $P(D=1|X)<1$
  - ATU: $0<P(D=1|X)$
  - ATE: $0<P(D=1|X)<1$

Treatment-effects estimators employed

- Adjustment and weighting
  - Regression adjustment [see: Lane and Nelder (1982); Cameron and Trivedi (2005, chap. 25); Wooldridge (2010, chap. 21); and Vittinghoff, Glidden, Shiboski, and McCulloch (2012, chap. 9).]
  - Inverse probability weighting [see: Imbens (2000); Hirano, Imbens, and Ridder (2003); Tan (2010); Wooldridge (2010, chap. 19); van der Laan and Robins (2003); and Tsiatis (2006, chap. 6).]
  - Inverse probability weighting with regression adjustment (IPWRA) [see: Wooldridge, 2007; Wooldridge, 2010]
  - Augmented inverse probability weighting (AIPW) [see:Robins, Rotnitzky, and Zhao (1995); Bang and Robins (2005); Tsiatis (2006) and Tan (2010).]
- Matching estimators
  - Nearest neighbor matching [see: Abadie et al. (2004); Abadie and Imbens (2006, 2011)].
  - Propensity score (treatment probability) matching [See: Rosenbaum and Rubin (1983); Abadie and Imbens (2012)].

Results and Discussion

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Description of the sample population

- HHs – 90% male headed and 10% female headed.
- Average land holding/hhd: 2.81 ha (reported)
- On average 37% of the farm plot is allocated to faba bean and 12% for field pea by the sample households.
- Legume producers
  - **Faba bean: 50.95%**
  - **Field pea: 31.37%**
  - **Faba bean or field pea: 67.76%**
- Adopters of improved faba bean and field pea varieties:
  - **Improved faba bean or field pea: 23.13%**

Efficiency results

Variable	Model 1	Model 2	Model 3	Model 4
Frontier				
lncultland	0.182*** (3.36)	0.17*** (2.93)	0.182*** (3.36)	0.17*** (2.93)
lnhumlabor	**-0.029 (-1.65)**	**-0.013 (-.75)**	**-0.029 (-1.65)**	**-0.013 (-0.75)**
Lnoxenlabor	0.308*** (7.41)	0.285*** (6.63)	0.308*** (7.41)	0.285*** (6.63)
Lntotureadapbiofe	0.027** (2.58)	0.034*** (3.25)	0.027** (2.58)	0.034*** (3.25)
Lnherbic	0.28*** (5.39)	0.27*** (5.28)	0.28*** (5.39)	0.27*** (5.29)
Lnfungic	0.18*** (4.9)	0.169*** (4.64)	0.18*** (4.9)	0.169*** (4.64)
Lnmachintime	0.067*** (7.05)	0.063*** (6.71)	0.067*** (7.05)	0.063*** (6.71)
Constant	-0.291**(-2.47)	-0.239* (-1.86)	-0.291** (-2.48)	-0.24* (-1.87)
_μ	-404.25 (-53.75)	-362.15 (-20.57)		
σu	4.76 (34.66)	4.54 (24.49)	-2.49(-9.62)	-2.71 (-8.81)
σv	-2.19 (-15.51)	-2.08 (-15.4)	-2.192 (-15.46)	-2.07 (-15.38)
Statistics				
N	575	575	575	575
Ll	-332.62	-335.08	-332.61	-335.07
Aic	687.24	692.16	685.22	690.14
Bic	735.14	740.06	728.76	733.68

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The outcome variables

Variable	N	Mean	Std. Dev.	Min	Max
Efficiency measure 1	575	0.781	0.108	0.094	0.937
Efficiency measure 2	575	0.794	0.103	0.101	0.939
Efficiency measure 3	575	0.782	0.108	0.094	0.937
Efficiency measure 4	575	0.794	0.103	0.100	0.939
Total bread wheat eqvt (kcl/ha)	575	2.936	2.993	0.030	29.872
Total bread wheat eqvt (birr/ha)	575	3.047	3.137	0.030	31.648

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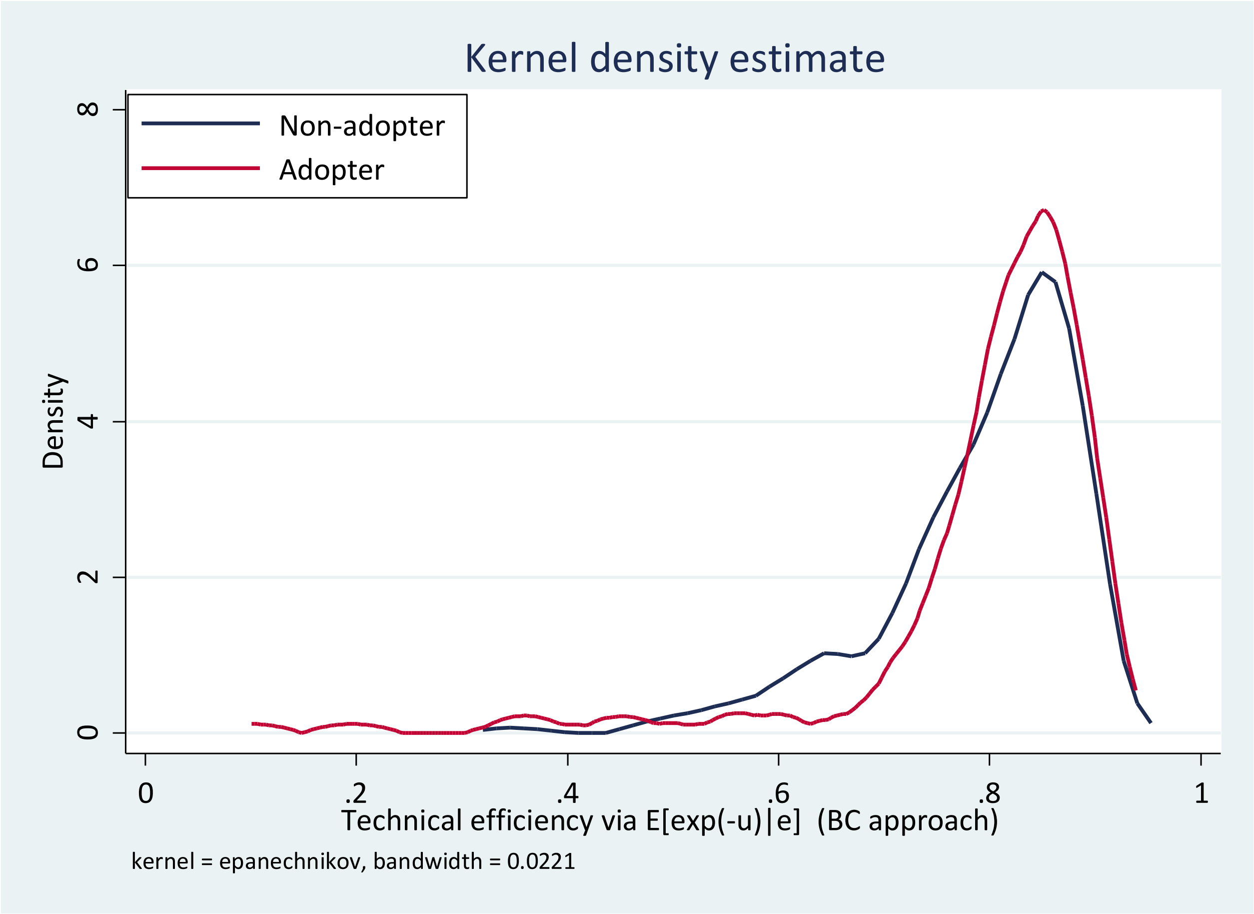
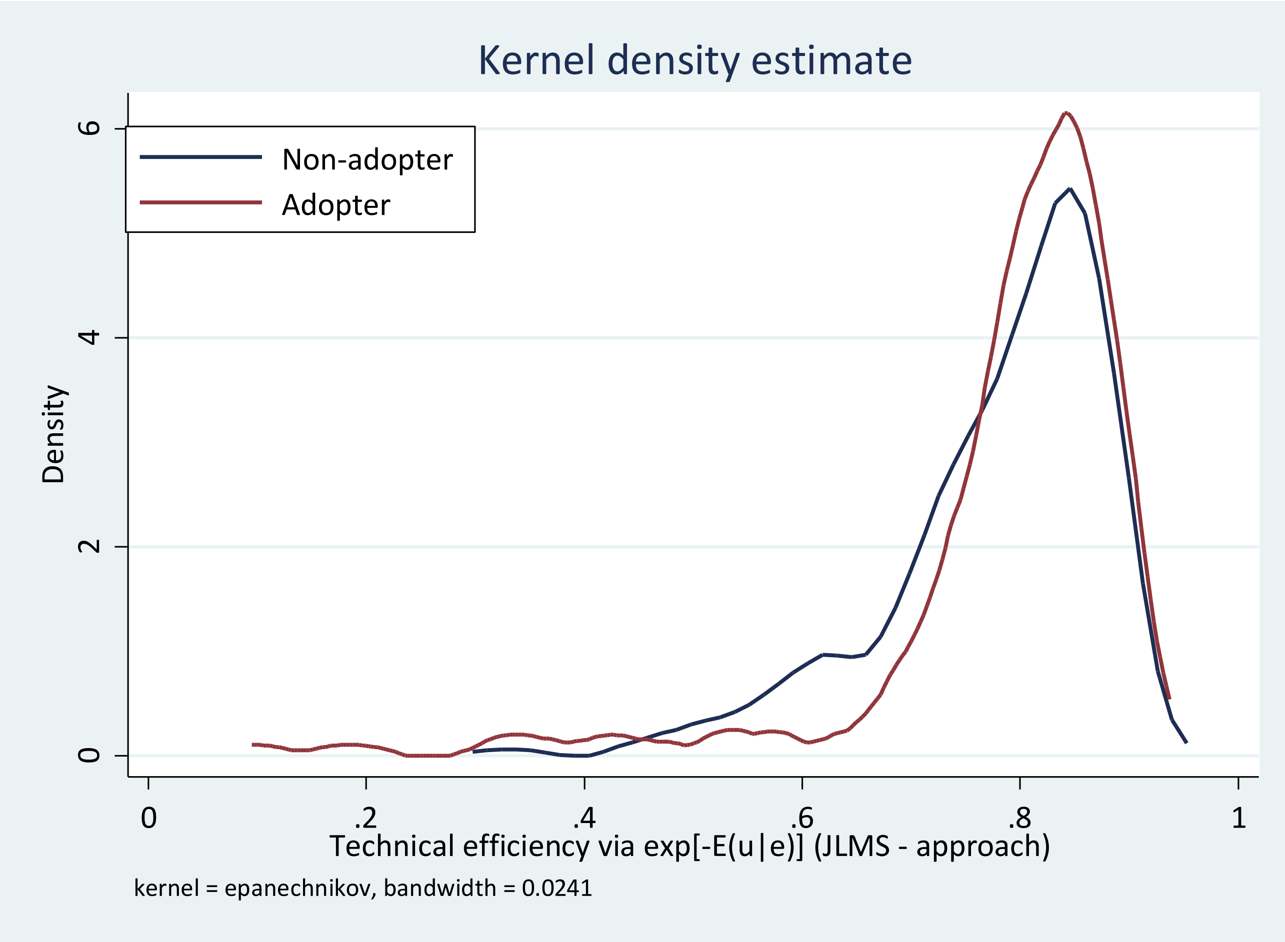
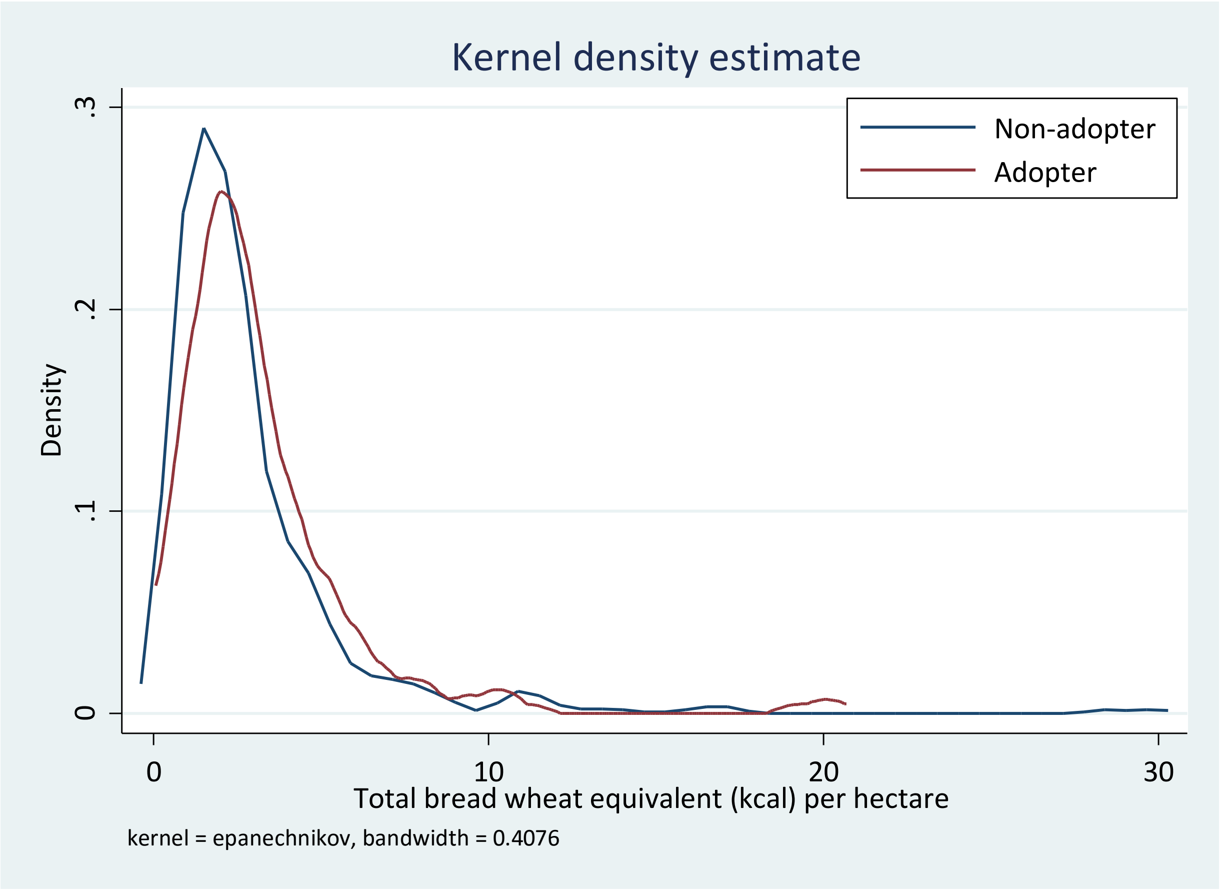
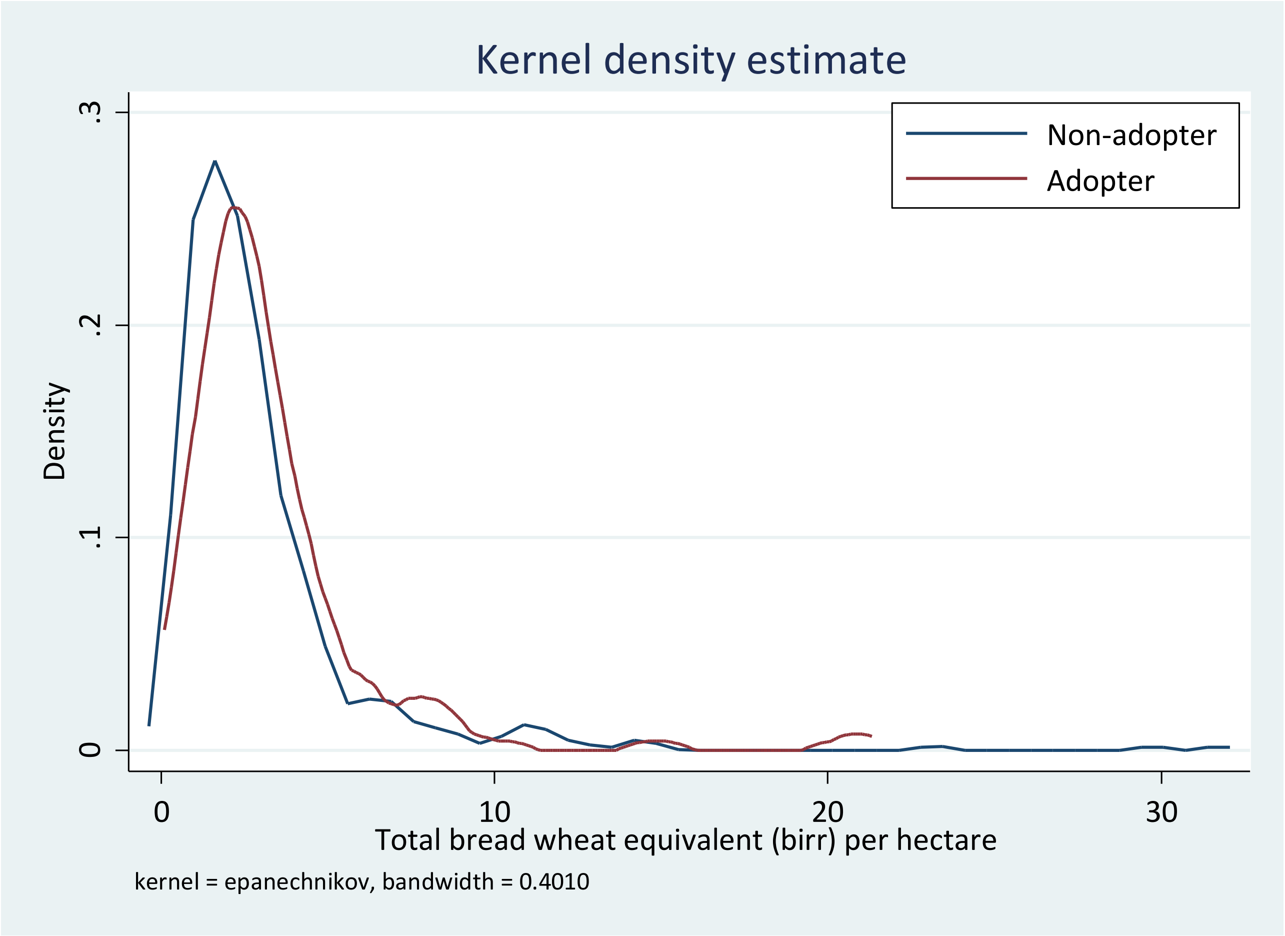
Simple comparison of adopters and non-adopters





Simple comparison of adopters and non-adopters





Average trt effect and Average trt effect on the treated

		RA	IPW	AIPW	IPWRA	NNMATCH	PSMATCH
Efficiency measure 1	ATET	-.004 (-0.27)	-.003 (-0.25)		-0.006 (-.48)	-.008 (-.51)	-.010 (-.69)
	ATE	.002 (0.16)	-.01 (-0.49)	0.002 (0.07)	0.006 (0.56)	0.016 (1.01)	-.001 (-.04)
Efficiency measure 2	ATET	-.004 (-0.35)	-.003 (-0.3)		-0.006 (-.52)	-.008 (-.54)	-0.009(-.69)
	ATE	.001 (0.07)	-.01 (-0.52)	0.002(0.08)	0.005 (0.50)	0.014 (0.95)	-.002(-.09)
Efficiency measure 3	ATET	-.004 (-0.28)	-.003 (-0.25)		-0.006 (-.46)	-.008 (-.51)	-.010 (-.69)
	ATE	.002 (0.16)	-.01 (-0.49)	0.002 (0.07)	0.006 (0.55)	0.016 (1.01)	-.001 (-.04)
Efficiency measure 4	ATET	-.004 (-0.35)	-.003 (-0.3)		-0.006 (-.52)	-.008 (-.54)	-0.009(-.69)
	ATE	.001 (0.07)	-.01 (-0.52)	0.002(0.08)	0.005 (0.49)	0.014 (0.95)	-.002(-.09)
Total bread wheat eqvt (kcl/ha)	ATET	.088 (0.33)	-.067 (-.16)		-.298 (-.99)	0.337 (1.03)	-.778 (-1.13)
	ATE	-.109 (-.44)	-.392 (-1.50)	-.194 (-.72)	-.298 (-1.51)	0.117 (0.49)	-.113 (-.31)
Total bread wheat eqvt (birr/ha)	ATET	0.171(0.59)	-.046 (-.09)		-.180 (-.55)	0.510 (1.59)	-1.034 (-1.08)
	ATE	-.053(-.20)	-.364 (-1.21)	-.151 (-.49)	-.264 (-1.25)	0.215 (0.92)	-.109 (-.26)

Conclusions and further questions

- Very low adoption of improved legume varieties – particularly faba bean and faba bean.
  - No relationship with efficiency no matter how the latter was measured.
  - No relationship with productivity per unit of limiting factor no matter what conversion [energy or price] was used.
- We observed that complementary inputs are not being used as per the recommendations.

Conclusions and further questions

- Human labor is not rewarding in crop production in the study area. Legumes are still dependent on human labor. Would they have any future in mechanized farming?
- Would simply disseminating the 'improved varieties' help? How?
- Bale highlands is known for farmers heavily dependent on machinery for their crop production. How will legumes – produced manually – fit into this system?
  - Are they meant to continue as break crops?

Thank You so much!!

2016 INTERNATIONAL YEAR OF PULSES

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