Web Appendix for "Market Access, Trade Costs, and Technology Adoption: Evidence from Northern Tanzania"

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Appendix A: Technical Appendix

A1: Remoteness and Market Access

Below, we show that a population-weighted average distance to hubs can be justified as an approximation for the market access measure in Donaldson and Hornbeck (2016). To see this, market access in Donaldson and Hornbeck is written as:

$$MA_v = \sum_h \tau_{hv}^{-\theta} N_h$$

where h indexes hubs, v indexes villages, τ is the iceberg trade cost, θ a trade elasticity to be estimated, and N_h is the share of population h in total population. Suppose that we can write the iceberg cost as $\tau_{hv} = f(d_{hv})$, where d_{hv} is distance. Then, market access becomes:

$$MA_v = \sum_h (f(d_{hv}))^{-\theta} N_h$$

A first-order approximation of this market access function, around the some point in space (with distance to each hub d_h), we have

$$MA_v \approx \sum_h (f(d_h))^{-\theta} N_h - \theta \sum_h (f(d_h))^{-\theta-1} N_h f'(d_h) (d_{hv} - d_h)$$

Collecting terms:

$$
\begin{aligned}
MA_v &\approx \underbrace{\sum_h (f(d_h))^{-\theta} N_h + \theta \sum_h (f(d_h))^{-\theta-1} N_h f'(d_h) d_h}_{\alpha_0} - \theta \sum_h (f(d_h))^{-\theta-1} N_h f'(d_h) d_{hv} \\
&\approx \alpha_0 - \theta \sum_h (f(d_h))^{-\theta-1} N_h f'(d_h) d_{hv}
\end{aligned}
$$

Assuming that the point in space that we choose is equidistant from all hubs ($d_h = d \ \forall h$), we can simplify market access as:

$$
\begin{aligned}
MA_v &\approx \alpha_0 - \theta (f(d))^{-\theta-1} f'(d) \sum_h N_h d_{hv} \\
&\approx \alpha_0 - \alpha_1 \sum_h N_h d_{hv}
\end{aligned}
$$

Standardizing this equation gives us:

$$
MA_v^z \approx -\alpha_z \left(\sum_h N_h d_{hv} \right)^z
$$

Thus, population weighted average distance can be justified as a first-order approximation to market access, after appropriate standarization.

A2: Model Appendix

Deriving farmer profits, revenues, and input expenditures

The production function under basic technology is:

$$Y_{fi} = \widetilde{\theta}_{fi0} K_{fi}^{\alpha_0} L_{fi}^{\beta_0} \tag{22}$$

Here, $\widetilde{\theta}_{fi0}$ is baseline productivity without fertilizer, K_{fi} is land held (which is assumed to be fixed), and L_{fi} is labor hired/used by farmer f in village i. Farmers who choose the baseline technology maximize the following profit function:

$$\mathit{\Pi}_{fi0} = \max_{L_{fi}} \left\{ p_i \widetilde{\theta}_{fi0} K_{fi}^{\alpha_0} L_{fi}^{\beta_0} - w_i L_{fi} \right\} \tag{23}$$

where p_i is the output price and w_i is the local wage. The first-order condition with respect to labor is written as:

$$\beta_0 p_i \widetilde{\theta}_{fi0} K_{fi}^{\alpha} L_{fi}^{\beta_0 - 1} = w_i \tag{24}$$

Multiplying both sides of the first order condition by L_{fi}, it is straightforward to show that expenditures on labor are linked to revenues (R_{fi0}) and profits ($\mathit{\Pi}_{fi0}$) by

$$w_i L_{fi} = \beta_0 p_i \widetilde{\theta}_{fi0} K_{fi}^{\alpha} L_{fi}^{1-\alpha} = \beta_0 R_{fi0} \tag{25}$$

and substituting into the profit function, we have:

$$\begin{aligned} \mathit{\Pi}_{fi0} &= (1 - \beta_0) R_{fi} \\ \Rightarrow w_i L_{fi} &= \frac{\beta_0}{1 - \beta_0} \mathit{\Pi}_{fi0} \end{aligned}$$

Thus, labor expenditures are proportional to profits and revenues, a feature that will prove convenient when aggregating the model. Explicitly solving for labor in the first order condition, and substituting into the profit function, we have:

$$\begin{aligned} \mathit{\Pi}_{fi0} &= (1-\beta_0)\,\beta_0^{\frac{\beta_0}{1-\beta_0}}\widetilde{\theta}_{fi0}^{\frac{1}{1-\beta_0}}\,p_i^{\frac{1}{1-\beta_0}}\,w_i^{-\frac{\beta_0}{1-\beta_0}}\,K_{fi}^{\frac{\alpha_0}{1-\beta_0}} \\ &= \theta_{fi0}\pi_{i0}K_{fi}^{\frac{\alpha_0}{1-\beta_0}} \end{aligned} \tag{26}$$

Here, we have defined $\theta_{fi0} = (1-\beta_0)\,\beta_0^{\frac{\beta_0}{1-\beta_0}}\widetilde{\theta}_{fi0}^{\frac{1}{1-\beta_0}}$ and $\pi_{i0} = p_i^{\frac{1}{1-\beta_0}}\,w_i^{-\frac{\beta_0}{1-\beta_0}}$. We return to these two terms momentarily when characterizing the adoption decision.

The production function *with* fertilizer splits variable inputs into labor and acquired fertilizer, X_{fijv}, and also provides a productivity shock, $\widetilde{\theta}_{fijv}$, which may vary by the agrovet j location v pair at which the fertilizer is purchased. Precisely, production is written as:

$$Y_{fi} = \widetilde{\theta}_{fijv}\,(\theta_i K_{fi})^{\alpha}\,L_{fijv}^{\beta\gamma}X_{fijv}^{\beta(1-\gamma)} \tag{27}$$

The profit maximization problem when using fertilizer is written as:

$$\mathit{\Pi}_{fi0} = \max_{L_{fi},X_{fijv}} p_i\widetilde{\theta}_{fijv}\,(\theta_i K_{fi})^{\alpha}\,L_{fijv}^{\beta\gamma}X_{fijv}^{\beta(1-\gamma)} - w_i L_{fijv} - r_{ijv}X_{fijv} \tag{28}$$

Since technology is Cobb-Douglas, including within variable inputs, similar results from above apply here. That is, writing expenditures on variable inputs as $c_{ijv}M_{fijv}$, where c_{ijv} is the unit cost of a bundle of variable inputs M_{fijv}, it is easily shown that

$$c_{ijv}M_{fijv} = \beta p_i\widetilde{\theta}_{fijv}\,(\theta_i K_{fi})^{\alpha}\,L_{fijv}^{\beta\gamma}X_{fijv}^{\beta(1-\gamma)} = \beta R_{fijv} \tag{29}$$

and

$$\begin{aligned} \mathit{\Pi}_{fijv} &= (1-\beta)R_{fijv} \\ \Rightarrow c_{ijv}M_{fijv} &= \frac{\beta}{1-\beta}\mathit{\Pi}_{fijv} \end{aligned}$$

Further, since labor and fertilizer have β and $1-\beta$ share in variable inputs, respectively, expenditures on each input are written as:

$$\begin{aligned} w_i L_{ijv} &= \gamma \frac{\beta}{1-\beta} \mathit{\Pi}_{fijv} \\ r_{ijv} X_{fijv} &= (1-\gamma) \frac{\beta}{1-\beta} \mathit{\Pi}_{fijv} \end{aligned}$$

Thus, any results related to profits will apply to input expenditures as long as factor shares do not change.

Solving for the optimal labor and quantity of fertilizer from agrovet j and location v, profits of i from adopting at jv are written as:

$$\mathit{\Pi}_{fijv} = \theta_{fijv} \pi_i r_{ijv}^{-\sigma} K_{fi}^{\sigma_k} \tag{30}$$

where $\sigma \equiv (1-\gamma)\frac{\beta}{1-\beta}$, $\sigma_k = \frac{\alpha}{1-\beta}$, $\pi_i = p_i^{\frac{1}{1-\beta}} w_i^{-\gamma \frac{\beta}{1-\beta}}$, and $\theta_{fijv} = \kappa_2 \widetilde{\theta}_{fijv}^{\kappa_1}$.[47] Here, the profitability of fertilizer at this location is a function of the productivity shock, θ_{fijv}, the (delivered) price of fertilizer itself, r_{ijv}, and profits based on local observables and technology π_{fi}.

Distributions of Fertilizer Expenditures

Above, we used the following property to generate a market clearing condition that can be taken to the data:

$$\mathbb{E}\left[rX_{fi} \mid adopt\ at\ j\ in\ v\right] = \mathbb{E}\left[rX_{fi} | adopt\right] \tag{31}$$

That is, that the expected fertilizer expenditures, conditional on adopting at location j, is the same as the expected fertilizer expenditure, conditional on adopting anywhere. This is a similar result to Eaton and Kortum (2002), where the price distribution conditional on being the lowest price supplier is the same as the unconditional price distribution at that destination. Here, we prove the similar result in the input adoption context.

In the model, fertilizer expenditures at a particular agrovet are a scalar function of

[47] κ_1 and κ_2 are constant functions of model parameters

ex-post profits when choosing that agrovet. Thus, we focus all proofs on the distribution of profits, and then the analogue to revenues and input expenditures follows directly. To begin, we derive the distribution of profits for farmer f in village i who buys from agrovet j in location v.

$$\Pr\left(\Pi_{fijv} > \pi\right) = \Pr\left(\theta_{fijv}\pi_i r_{ijv}^{-\sigma} K_{fi}^{\sigma_k} > \pi\right) \tag{32}$$

$$= \Pr\left(\theta_{fijv} > \frac{\pi}{\pi_i} r_{ijv}^{\sigma} K_{fi}^{-\sigma_k}\right) \tag{33}$$

$$= 1 - \exp\left(-T_{jv}\pi_i^{\varepsilon} r_{ijv}^{-\varepsilon\sigma} K_{fi}^{\varepsilon\sigma_k}\pi^{-\varepsilon}\right) \tag{34}$$

Defining $\gamma_{fijv} \equiv \pi_i^{\varepsilon} r_{fijv}^{-\varepsilon\sigma} K_{fi}^{\varepsilon\sigma_k}$

$$\Pr\left(\Pi_{fijv} > \pi\right) = 1 - \exp\left(-T_{jv}\gamma_{fijv}\pi^{-\varepsilon}\right) \tag{35}$$

Similarly, the distribution of profits for the outside option of not purchasing fertilizer are written as:

$$\Pr\left(\Pi_{fi0} > \pi\right) = 1 - \exp\left(-\tilde{\Phi}_{fi0}\pi^{-\varepsilon}\right) \tag{36}$$

where $\tilde{\Phi}_{fi0} = T_{i0}\gamma_{fi0} \equiv T_{i0}\pi_{i0}^{\varepsilon} K_{fi}^{\sigma_{k0}}$, and $\sigma_{k0} = \frac{\alpha_0}{1-\beta_0}$

Next, defining Π_{fi}^{max} as the profits available from the best *agrovet* option for farmer f from village i, we write the distribution of these profits as:

$$\Pr\left(\Pi_{fi}^{max} > \pi\right) = \Pr\left(\Pi_{fijv} > \pi \text{ for any } jv\right) \tag{37}$$

$$= 1 - \Pr\left(\Pi_{fijv} < \pi \ \forall \ jv\right) \tag{38}$$

Since θ's at each j, v pair are drawn from independent distributions, this probability is simplified as:

$$\Pr\left(\Pi_{fi}^{max} > \pi\right) = 1 - \Pr\left(\Pi_{fijv} < \pi \;\forall\; jv\right) \tag{39}$$

$$= 1 - \prod_{v' \in \mathcal{V}} \prod_{j \in \mathcal{J}_v} \Pr\left(\Pi_{fijv} < \pi\right) \tag{40}$$

$$= 1 - \prod_{v' \in \mathcal{V}} \prod_{j \in \mathcal{J}_v} \exp\left(-T_{jv}\gamma_{fijv}\pi^{-\varepsilon}\right) \tag{41}$$

Defining $\tilde{\Phi}_{fi} = \sum\limits_{v' \in \mathcal{V}} \sum\limits_{j \in \mathcal{J}_v} T_{jv}\gamma_{fijv}$, $\Pr\left(\Pi_{fi}^{max} > \pi\right)$ can be simplified to:

$$\Pr\left(\Pi_{fi}^{max} > \pi\right) = 1 - \exp\left(-\tilde{\Phi}_{fi}\pi^{-\varepsilon}\right) \tag{42}$$

Thus, the CDF of max profits for village i is written as:

$$G_{fi}^{max}(\pi) = \Pr\left(\Pi_{fi}^{max} < \pi\right) = \exp\left(-\tilde{\Phi}_{fi}\pi^{-\varepsilon}\right) \tag{43}$$

with pdf:

$$g_{fi}^{max}(\pi) = \varepsilon\tilde{\Phi}_{fi}\pi^{-\varepsilon-1}\exp\left(-\tilde{\Phi}_{fi}\pi^{-\varepsilon}\right) \tag{44}$$

Similarly, adding the option of not adopting, the distribution of profits considering all options, Π_i, is written as:

$$\Pr\left(\Pi_{fi} > \pi\right) = \Pr\left(\Pi_{fijv} > \pi \text{ for any } jv \cup \Pi_{fi0} > \pi\right) \tag{45}$$

$$= 1 - \Pr\left(\Pi_{fijv} < \pi \;\forall\; jv \;\cap\; \Pi_{fi0} < \pi\right) \tag{46}$$

Since θ's at each j, v pair and for not adopting are drawn from independent distributions, this probability is simplified as:

$$\begin{aligned}
\Pr\left(\mathit{\Pi}_{fi}>\pi\right) &= 1-\Pr\left(\mathit{\Pi}_{fijv}<\pi\ \forall\ jv\ \cap\ \mathit{\Pi}_{fi0}<\pi\right) && (47)\\
&= 1-\Pr\left(\mathit{\Pi}_{fi0}<\pi\right)\prod_{v'\in\mathcal{V}}\prod_{j\in\mathcal{J}_v}\Pr\left(\mathit{\Pi}_{fijv}<\pi\right) && (48)\\
&= 1-\exp\left(-T_{i0}\gamma_{fi0}\pi^{-\varepsilon}\right)\prod_{v'\in\mathcal{V}}\prod_{j\in\mathcal{J}_v}\exp\left(-T_{jv}\gamma_{fijv}\pi^{-\varepsilon}\right) && (49)
\end{aligned}$$

Using the definitions for $\tilde{\mathit{\Phi}}_{fi0}$ and $\tilde{\mathit{\Phi}}_{fi}$, this is simplified as:

$$\Pr\left(\mathit{\Pi}_{fi}>\pi\right) = 1-\exp\left(-\left(\tilde{\mathit{\Phi}}_{fi0}+\tilde{\mathit{\Phi}}_{fi}\right)\pi^{-\varepsilon}\right) \quad (50)$$

Thus, the CDF of max profits for farmer f from village i is:

$$G_{fi}\left(\pi\right) = \exp\left(-\left(\tilde{\mathit{\Phi}}_{fi0}+\tilde{\mathit{\Phi}}_{fi}\right)\pi^{-\varepsilon}\right) \quad (51)$$

with pdf:

$$gf_i\left(\pi\right) = \varepsilon\left(\tilde{\mathit{\Phi}}_{fi0}+\tilde{\mathit{\Phi}}_{fi}\right)\pi^{-\varepsilon-1}\exp\left(-\left(\tilde{\mathit{\Phi}}_{fi0}+\tilde{\mathit{\Phi}}_{fi}\right)\pi^{-\varepsilon}\right) \quad (52)$$

Profits conditional on adoption

Using this pdf, we now derive the CDF of agrovet profits, conditional on adoption. To do this, we start from the conditional probability formula:

$$\Pr\left(\mathit{\Pi}_{fi}^{max}<\pi\middle|adopt\right) = \frac{\Pr\left(\mathit{\Pi}_{fi}^{max}<\pi\cap\mathit{\Pi}_{fi}^{max}>\mathit{\Pi}_{fi0}\right)}{\Pr\left(\mathit{\Pi}_{fi}^{max}>\mathit{\Pi}_{fi0}\right)} \quad (53)$$

This can be re-written as:

$$\begin{aligned}
\Pr\left(\mathit{\Pi}_{fi}^{max}<\pi\middle|adopt\right) &= \frac{1}{\Pr\left(\mathit{\Pi}_{fi}^{max}>\mathit{\Pi}_{fi0}\right)}\int_0^\pi \Pr\left(s>\mathit{\Pi}_{fi0}\right)g_{fi}^{max}(s)ds\\
&= \frac{1}{\Pr\left(\mathit{\Pi}_{fi}^{max}>\mathit{\Pi}_{fi0}\right)}\int_0^\pi \exp\left(-\tilde{\mathit{\Phi}}_{fi0}s^{-\varepsilon}\right)\varepsilon\tilde{\mathit{\Phi}}_{fi}s^{-\varepsilon-1}\exp\left(-\tilde{\mathit{\Phi}}_{fi}s^{-\varepsilon}\right)ds\\
&= \frac{1}{\Pr\left(\mathit{\Pi}_{fi}^{max}>\mathit{\Pi}_{fi0}\right)}\int_0^\pi \varepsilon\tilde{\mathit{\Phi}}_{fi}s^{-\varepsilon-1}\exp\left(-\left(\tilde{\mathit{\Phi}}_{fi0}+\tilde{\mathit{\Phi}}_{fi}\right)s^{-\varepsilon}\right)ds \quad (54)
\end{aligned}$$

Mulitplying by $\frac{\tilde{\Phi}_{fi0}+\tilde{\Phi}_{fi}}{\tilde{\Phi}_{fi0}+\tilde{\Phi}_{fi}}$, and then factoring out $\frac{\tilde{\Phi}_{fi}}{\tilde{\Phi}_{fi0}+\tilde{\Phi}_{fi}}$, we have:

$$\begin{aligned}\Pr\left(\mathit{\Pi}_{fi}^{max} < \pi \middle| adopt\right) &= \frac{1}{\Pr\left(\mathit{\Pi}_{fi}^{max} > \mathit{\Pi}_{fi0}\right)} \\ &\cdot \left(\frac{\tilde{\Phi}_{fi}}{\tilde{\Phi}_{fi0}+\tilde{\Phi}_{fi}}\right)\int_0^{\pi} \varepsilon\left(\tilde{\Phi}_{fi0}+\tilde{\Phi}_{fi}\right) s^{-\varepsilon-1}\exp\left(-\left(\tilde{\Phi}_{fi0}+\tilde{\Phi}_{fi}\right)s^{-\varepsilon}\right) ds\end{aligned}$$

From standard derivations using Fréchet, $\Pr\left(\mathit{\Pi}_{fi}^{max} > \mathit{\Pi}_{fi0}\right) = \frac{\tilde{\Phi}_{fi}}{\tilde{\Phi}_{fi0}+\tilde{\Phi}_{fi}}$, and thus:

$$\begin{aligned}\Pr\left(\mathit{\Pi}_{fi}^{max} < \pi \middle| adopt\right) &= \int_0^{\pi} \varepsilon\left(\tilde{\Phi}_{fi0}+\tilde{\Phi}_{fi}\right) s^{-\varepsilon-1}\exp\left(-\left(\tilde{\Phi}_{fi0}+\tilde{\Phi}_{fi}\right)s^{-\varepsilon}\right) ds \quad (55)\\ &= \Pr\left(\mathit{\Pi}_{fi} < \pi\right) \quad (56)\end{aligned}$$

Profits conditional on adoption from j

Next, we derive the expected profits, conditional on adopting fertilizer from location j. Precisely, we will derive:

$$\Pr\left(\mathit{\Pi}_{fijv} < \pi \middle| adopt\ from\ jv\right) = \frac{\Pr\left(\mathit{\Pi}_{fijl} < \pi \cap \mathit{\Pi}_{fijv} > \mathit{\Pi}_{fij'l}\forall(j',l) \cap \mathit{\Pi}_{fijv} > \mathit{\Pi}_{fi0}\right)}{\Pr\left(\mathit{\Pi}_{fijv} > \mathit{\Pi}_{fij'l}\forall(j',l) \cap \mathit{\Pi}_{fijv} > \mathit{\Pi}_{fi0}\right)}$$

The denominator in this equation is simply λ_{ifjv}, and thus, we factor it out of the probability. The numerator is written similar to the previous derivation, where

$$\Pr\left(\mathit{\Pi}_{fijv} < \pi \middle| adopt\ from\ j\ in\ v\right) = \frac{1}{\lambda_{ifjv}}\int_0^{\pi} Pr\left(s > \mathit{\Pi}_{fij'l}\forall(j',l) \cap s > \mathit{\Pi}_{fi0}\right) g_{fijv}(s) ds$$

Defining $\tilde{\tilde{\Phi}}_{fijv} = \left(\sum_{v'\in\mathcal{V}}\sum_{j\in\mathcal{J}_v} T_{jv}\gamma_{fijv}\right) - T_{jv}\gamma_{fijv}$, we can simplify $\Pr\left(s > \mathit{\Pi}_{fij'l}\forall(j',l) \cap s > \mathit{\Pi}_{fi0}\right)$ as

$$\begin{aligned}\Pr\left(s > \mathit{\Pi}_{fij'l}\forall(j',l) \cap s > \mathit{\Pi}_{fi0}\right) &= \exp\left(-\tilde{\Phi}_{fi0}s^{-\varepsilon}\right)\exp\left(-\tilde{\tilde{\Phi}}_{fijv}s^{-\varepsilon}\right) \quad (57)\\ &= \exp\left(-\left(\tilde{\Phi}_{fi0}+\tilde{\tilde{\Phi}}_{fijv}\right)s^{-\varepsilon}\right) \quad (58)\end{aligned}$$

Thus, $\Pr\left(\Pi_{fijv} < \pi \middle| adopt\ from\ j\right)$ is written as:

$$\Pr\left(\Pi_{fijv} < \pi \middle| adopt\ from\ j\right) = \frac{1}{\lambda_{fijv}} \int_0^\pi \exp\left(-\left(\tilde{\Phi}_{fi0} + \tilde{\tilde{\Phi}}_{fijv}\right) s^{-\varepsilon}\right) \varepsilon T_{jv}\gamma_{fijv}\pi^{-\varepsilon-1} \exp\left(-T_{jv}\gamma_{fijv}s^{-\varepsilon}\right)$$

Factoring out $\frac{T_{jv}\gamma_{fijv}}{\tilde{\Phi}_{fi0}+\tilde{\Phi}_{fi}}$, and then noting that $\tilde{\Phi}_{fi0} + \tilde{\Phi}_{fi} = \tilde{\Phi}_{fi0} + \tilde{\tilde{\Phi}}_{fijv} + T_{jv}\gamma_{fijv}$, we have:

$$\Pr\left(\Pi_{fijv} < \pi \middle| adopt\ from\ j\right) = \frac{1}{\lambda_{fijv}} \frac{T_{jv}\gamma_{fijv}}{\tilde{\Phi}_{fi0} + \tilde{\Phi}_{fi}} \int_0^\pi \varepsilon \left(\tilde{\Phi}_{fi0} + \tilde{\Phi}_{fi}\right) \pi^{-\varepsilon-1} \exp\left(-\left(\tilde{\Phi}_{fi0} + \tilde{\Phi}_{fi}\right) s^{-\varepsilon}\right) ds$$

Since $\lambda_{fijv} = \frac{T_{jv}\gamma_{fijv}}{\tilde{\Phi}_{fi0}+\tilde{\Phi}_{fi}}$, we land at the final result:

$$\begin{aligned} \Pr\left(\Pi_{fijv} < \pi \middle| adopt\ from\ j\right) &= \int_0^\pi \varepsilon \left(\tilde{\Phi}_{fi0} + \tilde{\Phi}_{fi}\right) \pi^{-\varepsilon-1} \exp\left(-\left(\tilde{\Phi}_{fi0} + \tilde{\Phi}_{fi}\right) s^{-\varepsilon}\right) ds \\ &= \Pr\left(\Pi_{fi} < \pi\right) \end{aligned}$$

Thus, the distribution of profits adopting from j is the same as the distribution of profits adopting anywhere.

Mark-ups

As in the manuscript, we the expected fertilizer revenues for agrovet j in location v as:

$$\mathbb{E}\left[v_{jv}\right] = \sum_i N_i \lambda_{ijv|adopt} \sum_f \mathbb{E}\left[F_{fi}\right]$$

Log differentiating, we get:

$$\frac{d\mathbb{E}\left[v_{jv}\right]}{dr_{jv}} \frac{r_{jv}}{\mathbb{E}\left[v_{jv}\right]} = \sum s_{ijv} \left(\frac{d\lambda_{ijv|adopt}}{dr_{jv}} \frac{r_{jv}}{\lambda_{ijv|adopt}} + \sum_f w_{fi} \frac{d\mathbb{E}\left[F_{fi}\right]}{dr_{jv}} \frac{r_{jv}}{\mathbb{E}\left[_{fi}\right]}\right) \tag{59}$$

where $\omega_{fi} = \frac{\mathbb{E}\left[F_{fi}\right]}{\sum_{f'} \mathbb{E}\left[F_{f'i}\right]}$ and $s_{ijv} = \frac{N_i \lambda_{ijv|adopt} \mathbb{E}\left[F_{fi}\right]}{\sum_{i'} N_{i'} \lambda_{i'jv|adopt} \mathbb{E}\left[F_{fi'}\right]}$.

To simplify this equation, it is straightforward to derive the following results using the structure of the model:

$$\begin{aligned}
\frac{d\lambda_{ijv|adopt}}{dr_{jv}} \frac{r_{jv}}{\lambda_{ijv|adopt}} &= -\varepsilon_a \left(1 - \lambda_{ijv|adopt}\right) \\
\frac{d\mu_{fi}}{\mu_{fi}} &= \frac{d\Phi_i}{\Phi_i} \left(1 - \mu_{fi}\right) \\
\frac{d\mathbb{E}\left[F_{fi}\right]}{dr_{jv}} \frac{r_{jv}}{\mathbb{E}\left[_{fi}\right]} &= \left(1 - \frac{\varepsilon - 1}{\varepsilon} \mu_{fi}\right) \frac{d\Phi_i}{\Phi_i} \\
\frac{d\Phi_i}{dr_{jv}} \frac{r_{jv}}{\Phi_i} &= -\varepsilon_a \lambda_{ijv|adopt}
\end{aligned}$$

Substituting these relationships into the log-derivative of agrovet revenues:

$$\varepsilon_{jv} = -\varepsilon_a + \varepsilon_a \frac{\varepsilon - 1}{\varepsilon} \sum_i s_{ijv} \lambda_{ijv|adopt} \sum_f \omega_{fi} \mu_{fi} \tag{60}$$

For reference, note that if we assume that all farmers in a given village i have the same attributes (a representative farmer per village), the equation collapses to:

$$\varepsilon_v \equiv \frac{d\mathbb{E}\left[v_{jv}\right]}{dr_{jv}} \frac{r_{jv}}{\mathbb{E}\left[v_{jv}\right]} = -\varepsilon_a + \frac{\varepsilon - 1}{\varepsilon} \varepsilon_a \sum_i s_{ijv} \lambda_{ijv} \tag{61}$$

Appendix B: Counterfactual Appendix

Calibration of Fertilizer Expenditures

As discussed in section 5, expected expenditure measures are required for the market clearing conditions and for agrovet pricing. For farmers that adopt fertilizer, we have an unbiased estimate for the expected value of fertilizer expenditures conditional on adoption, which are the values from the survey. These are multiplied by predicted adoption probabilities to get the unconditional expected fertilizer expenditures for those farmers reporting fertilizer use.

For farmers who do not report adopting fertilizer, we must impute values for expected fertilizer using the structure of the model and underlying selection into adoption. Recall the equation for unconditional expenditures in (15):

$$\mathbf{E}[F_{fi}] = \kappa \Phi_i^{\frac{1}{\varepsilon}} \pi_i K_{fi}^{\frac{\alpha}{1-\beta}} \mu_{fi}^{\frac{\varepsilon-1}{\varepsilon}}$$

This can be arranged into an additive Poisson model with a village fixed effect, log land holdings, and log of the probability of adoption

$$\mathbf{E}[F_{fi}] = \exp\left(d_i + \frac{\alpha}{1-\beta} \log\left(K_{fi}\right) + \frac{\varepsilon - 1}{\varepsilon} \log\left(\mu_{fi}\right) \right)$$

We run this model in two ways. First, we estimate the Poisson model with village fixed effects, the log value of land, additional farmer controls (treated in the same way as land), and the log of the predicted value of adoption from the logit model that was used to calibrate adoption probabilities. However, given that the predicted adoption probabilities use similar data for estimation, we can simplify the model using an approximation. Specifically, we conjecture that the value of ε is high enough such that $\frac{\varepsilon-1}{\varepsilon} \approx 1$. Under this approximation, the model can be estimated as a Poisson model with the log adoption as an offset terms. The results from both approaches in Online Appendix Table B1. There is little practical difference in the estimation results, so for simplicity we use the model with offset to calibrate expected fertilizer expenditures for those who do not adopt fertilizer.

Estimation of Production function parameters

As described in the manuscript, production function parameters (when using fertilizer) are necessary to calculate ε relative to ε_a. To do this, we estimate a simple production function framework with different sets of fixed effects to study the possible values of ε that will be used in the mark-up equation. We will use the LSMS-ISA for Tanzania, which surveys all plots for farmers in multiple waves of surveys, to estimate these parameters. Defining observations by each plot p for farmer f in location i in time t, the log of the production function with fertilizer can be represented by:

$$\log\left(Y_{fipt}\right) = \alpha \log\left(K_{fipt}\right) + \beta\gamma \log\left(L_{fipt}\right) + \beta\left(1-\gamma\right)\log\left(X_{fipt}\right) + Fixed + u_{fipt}$$

The OLS estimates for this equation under a variety of fixed effects assumptions are presented in Table B3 of the Online Appendix. Here, the values for β, the exponent on variable factors in the production function, ranges between 0.43-0.80, with generally higher values when including farmer-by-year fixed effects (so identification is across plots within farmers). Values for γ range between 0.38-0.58. Ultimately, this leads to a fairly wide range in the ratio of ε to ε_a, from 0.4 to 2.6. Thus, to ensure that the main conclusions of the paper are not a result of noisy estimation of productivity parameters, we present the sensitivity of our results to these ratios, evaluated from the estimated value of $\varepsilon_a = 7.89$.

Appendix C: External Validity

In this appendix, we assess the external validity of our sample by comparing patterns from our data collection with external datasets for other countries in Africa. First, in Online Appendix Table C1, we compile some statistics on the state of road infrastructure in other countries in the East African region, and find that Tanzania is about average. The evidence therefore suggests that Northern Tanzania is not atypical of the region. In Tables C2 and C3 of the same appendix, we examine how price dispersion in Northern Tanzania compares to a set of 1,512 markets in 56 African countries. Using two approaches, we find that the degree of observed price dispersion in Northern Tanzania is comparable to other countries. Finally, in Table C4, we use data from World Bank LSMS-ISA panel surveys to study how remoteness affects fertilizer adoption in other African countries.[48] Using both measures of remoteness available in the dataset (distance to the main market, and distance to a population center), we find a negative association between remoteness and technology adoption. The details of these regressions are described below.

C1. Price Dispersion

To compare price dispersion in our study region to other parts of Africa, we bring in evidence from five secondary datasets of prices in 1,512 markets in 56 African countries[49] We compare this to a small dataset we assembled between March and April 2016 with 251 retailers of various sorts (shops, agrovets, and maize traders) in 82 markets in the Kilimanjaro region.[50] To

[48]The countries included here are Ethiopia, Niger, Nigeria, Malawi, Tanzania, and Uganda.

[49]We include the following datasets: (1) prices of 6 staple crops in 41 major market centers in 8 East African countries from 1997-2015, collected by RATIN; (2) prices of 25 commodities from 276 markets in 53 countries in from 2013-2015, collected by Africafoodprices.io; (3) prices of 4 major varieties of fertilizer (Urea, DAP, CAN, and NPK complex 17-17-17) in 129 markets in 7 East African countries collected by AMITSA; (4) prices of 5 major varieties of fertilizer (Urea, CAN, DAP, and NPK 17 17 17) in 18 countries from 2010-16 in Africafertilizer.org; and (5) prices of a number of commodities in 38 countries from 1992-2016 collected by the WFP.

[50]To enroll participants, we visited each market and selected several types of retailers for project inclusion, including fertilizer retailers ("agrovets"), maize sellers, and retail shops. Each respondent was called once per month and asked about current retail and wholesale prices for each item in a pre-selected list of standardized goods (e.g., 200 ml box of Azam

quantify price dispersion, we decompose variation in spatial prices by running the following regression:

$$\log(p_{mcjt}) = \gamma_c + \gamma_j + \gamma_t + \epsilon_{mjt} \tag{62}$$

where p_{mcjt} (log) prices in market m for product j at time t in country c, and the γ terms are country, product, and time fixed effects. We report the standard deviation of the resulting residual in Online Appendix Table C2. In the secondary datasets, the standard deviation is 0.45 for all products, 0.34 for maize, and 0.12 for fertilizer; in our Tanzania data, the figures are 0.22, 0.14, and 0.09. While price dispersion is lower in our data (perhaps because of reduced measurement error, or that prices vary less within the geographic concentrated area of Kilimanjaro), this simple exercise sugggests substantial price dispersion in Northern Tanzania.

We also follow the literature,[51] to run dyadic regressions to look at price gaps, as follows:

$$\log(\mid p_{mjt} - p_{m'jt} \mid) = \theta \log(c_{mm'}) + \gamma_m + \gamma_{m'} + \gamma_j + \epsilon_{mm'jt} \tag{63}$$

where $p_{mjt} - p_{m'jt}$ is the price gap between markets m and m' and $c_{mm'}$is the cost of transport between markets.[52]

Results are presented in Online Appendix Table C3. For each dyad, we regress the absolute difference in log prices on two measures of distance: (1) kilometers between locations in Columns 1, 4, and 7, and (2) driving time between locations in Columns 2, 5, and 8 (both calculated via Google Maps API), and we cluster standard errors by both the destination and origin market. In each of the secondary datasets, we find significant, positive coefficients, suggesting that price gaps are larger between more distant markets. The coefficients are economically meaningful: a doubling of travel costs would increase price gaps by about 1-3%

juice). Respondents were compensated for participation by mobile money transfer.

[51]See Engel and Rogers (1996). In addition, see papers on the effect of cell phones on price dispersion, for example Aker (2010), Aker and Fafchamps (2015), and Jensen (2007).

[52]These regressions are motivated by an assumption of free entry where an arbitrageur will enter if $\mid (p_m - p_{m'}) \mid \geq c_{mm'}$.

in the secondary datasets. In Tanzania, we find that doubling distances would increase price gaps by a similar amount. We can also use this data to provide some descriptive evidence on road upgrading. We conjecture that price gaps should respond to the time it takes to travel from point to point, and not the geographic distance (since the time and other costs of traveling to sell items should be what is important). To examine this, we regress price gaps on both distance and duration in Columns 3, 6, and 9. Consistent with priors, we find that duration is significant, whereas distance is not – which suggests that improving road quality would reduce these gaps.

C2. Fertilizer adoption

Finally, we use data assembled data from World Bank LSMS-ISA household panel surveys to study how remoteness affects fertilizer adoption in other African countries.[53] Using both measures of remoteness available in the dataset (distance to the main market, and distance to a population center), we find a negative association between remoteness and technology adoption. These results are presented in Online Appendix Table C4.

[53]The countries included here are Ethiopia, Niger, Nigeria, Malawi, Tanzania, and Uganda.

Appendix D: Remoteness and Maize Markets

The primary analysis in the paper focuses on input markets, since our surveys and data collection exercise were precisely geared toward this market. However, similar issues of remoteness may affect farmers on output markets, since trade costs and poor access to buyers will reduce the margins that farmers may enjoy in selling their output. In this appendix, we document analogous patterns to those from the input side that we present in Section 4 of the manuscript..

To begin, we define analogous travel cost adjusted prices for the output market:

$$p_v^{max} = \max_m \{p_m - c_{mv}\} \tag{64}$$

Here, p_m is the price of maize post-harvest for market m, and c_{mi} is the cost of traveling from village i to market m. We use a 120 kg bag for this calculation, and assume that the cost of transporting the bag is proportional to the weight. Thus, a trip to the market and back to sell 120kg of maize requires 3.7 trips (2 for the farmer and 1.7 for the bag). Finally, as in section four with input markets, we also calculate the price if farmers only transact at the nearest maize market.

$$p_v^{nearest} = p_{nearest} - c_{nearest,i} \tag{65}$$

We calculate these prices for every village-agrovet and village-market pair. Figure D1 plots CDFs of village-level best prices output, adjusting for travel costs, and shows tremendous heterogeneity in prices across villages. In Panel A, the difference of the travel cost-adjusted price for maize between the 90th and the 10th percentile is about 54% of the mean, while the standard deviation is about 23% of the mean. To give a sense of the variation in profitability in using fertilizer, Panel B of Figure D1 calculates the ratio of the best travel-cost-adjusted maize price (per kg) to the best travel-cost-adjusted urea price (per kg). The 90-10 gap is 88% of the mean and the standard deviation is 34% of the mean.

Access to output markets

In Table 3 of the primary manuscript, we regress outcome measures for inputs at either the village or farmer level on remoteness. Here, we perform a similar analysis, but on the output side. In Web Appendix Table D1, Panel A shows that more remote villages are less likely to have a market within 10 km, and the nearest market where maize is sold is located farther away. Panel B1 shows travel cost-adjusted prices for maize. Since there are large seasonal price fluctuations in rural Tanzania (as in much of rural Africa),[54] we use a price for the single point in time which is most relevant for farmers: immediately post-harvest (our surveys show that most farmers who sell do so shortly after harvest, and that agents buying output rarely operate after this period). We find that across both remoteness measures, travel cost-adjusted prices of output are lower in remote areas. As before, we decompose this into the retail price and the travel costs, finding that transport costs to their best maize market rise by $3 with each standard deviation in remoteness, overwhelming the retail the price of maize. In Panel B2, we repeat the analogous exercise from the input market to evaluate the impact of remoteness when farmers simply choose the *closest* weekly maize market to sell their harvest. By definition, average travel cost adjusted sales prices are lower, and empirically the magnitude is large (about 50%). As in Panel B1, we find that this price declines with remoteness, and in fact the point estimate is similar. However, the decomposition between the retail price and the travel cost is very different: for the nearest price, the retail price falls and the travel cost rises.

We also show one other measure of price, in this case measured at the village level. First, in Panel B3, we report coefficients from farmers' self-reported "going price" of maize after the last harvest, regressed on measures of remoteness. Consistent with the above, the going price in the village is decreasing in remoteness. This is intuitive if maize agents are traveling from the larger population centers (which are used to construct our remoteness measures), and offering lower selling prices to compensate for the higher costs of travel.

[54]Aggarwal, Francis and Robinson (2018) document an average price increase of about 46% over the season for the years 2006-16 in Kisumu market in neighboring Kenya; Bergquist, Burke, and Miguel (2019) document increases in the range of 15-30% for a sample of markets in the east African region.

Overall, whether searching for the best market, or selling locally, the returns from selling maize are clearly lower in more remote regions.

Farmer output decisions

The results so far show clear evidence of reduced market access in more remote areas for output, lower (travel cost-adjusted) prices for output, and lower "going" prices for output within the village. These results lead us to expect lower maize sales in more remote areas. We investigate this in Online Appendix Table D2, where we present results with and without a full set of farmer controls. In Panel A, we present strong evidence that sales are lower in remote areas, especially when using the simple weighted-average distance measure of remoteness. While the regression predicts that 44% of farmers will sell in the least remote areas, this declines to only 14% in the most remote areas. This is predominantly coming from a decline in sales to agents (since agents are by far the most common way to sell maize), but there are declines in sales at the market as well.

Consistent with this, Panel B shows buying behavior. Remote farmers are more likely to buy maize and to be net buyers of maize. Interestingly, we find a lot of heterogeneity in net buying behavior - 37% of farmers buy maize but sell none, 24% sell maize but buy none, and only 8% buy and sell maize (the other 30% do not transact at all).

Web Appendix Tables

Market Access, Trade Costs, and Technology Adoption: Evidence from Northern Tanzania

Shilpa Aggarwal, Brian Giera, Dahyeon Jeong, Jonathan Robinson and Alan Spearot

Web Appendix Table A1. Survey Compliance Rates

	(1) Survey Attempts	(2) Completed	(3) Compliance Rate
Farmer surveys 2016	583	573	0.98
Farmer surveys 2017	2535	2477	0.98
Agrovet surveys	585	532	0.91
Maize sellers at markets	445	438	0.98

Notes: See text of details of surveys.

Web Appendix Table A2. Calibrating Travel Costs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Main roads (Market centers to hub towns) (Transport Operator Surveys)			Rural roads (villages to market)					
				Enumerator's Trips			Transport Operator Surveys		
	Cost	Cost	Hours	Cost	Cost	Hours	Cost	Cost	Hours
Panel A. Costs from Markets									
Google maps: kilometers to destination	0.02***								
	(0.00)								
Google maps: hours to destination		1.26***	1.00***						
		(0.03)	(0.03)						
Number of markets	201	201	201						
Number of observations	900	900	893						
Panel B. Costs from villages									
Google maps: kilometers to destination				0.10***			0.08***		
				(0.01)			(0.01)		
Google maps: hours to destination					3.54***	0.72***		2.61***	0.84***
					(0.27)	(0.07)		(0.25)	(0.08)
Number of villages				1087	1036	1036	1085	1085	1027
Number of observations				1087	1036	1036	1085	1085	1027

Notes: Data is constructed from interviews with transportation operators, and from travel costs and times incurred by enumerators. There are 226 market centers in our sample. In both regions, transportation operators were asked about the 3 most important hubs (Moshi, Arusha, and Dar es Salaam); in Manyara, they were also asked about 3 additional hubs (Tanga, Dodoma, and Babati). The unit of observation is the market-hub level for Panel A, while it is the village-market pair level for Panel B. Cost is for one-way trip for a given route. Standard errors in parentheses (clustered by market in Panel A).
*, **, and *** indicate significance at 10%, 5%, and 1% respectively.

Web Appendix Table A3. Costs of transporting fertilizer and transporting farmer, by distance

	(1)	(2)	(3)	(4)
	Cost of transporting fertilizer from agrovet in destination village (standardized to 50 kg)		Cost of farmer traveling himself to agrovet	
Google maps: kilometers to destination	0.04*		0.05***	
	(0.02)		(0.01)	
Google maps: hours to destination		1.28*		1.83***
		(0.68)		(0.26)
Number of villages	73	73	119	119
Number of observations	341	341	988	988

Notes: Data is constructed from Farmer Surveys, conditional on making input purchases and/or selling output. Clustered standard errors (by village) are reported in parentheses.
*, **, and *** indicate significance at 10%, 5%, and 1% respectively.

Web Appendix Table A4. Locations of Input and Output Distributors

Panel A. Locations of Agro-Input Distributors

Locations	Share of Retailer Revenues	Cum. Share
Arusha Urban District	0.80	0.80
Kilimanjaro Moshi Urban District	0.14	0.94
Manyara Babati Urban District	0.02	0.96
Dar es Salaam Kinodoni District	0.01	0.97
Dar es Salaam Ilala District	0.01	0.98

Panel B. Locations of Output Distributors

B1. 2017 Maize Store Census

Locations	Share of Maize Purchase	Cum. Share
Arusha Urban District	0.61	0.61
Manyara Babati Rural District	0.35	0.97
Kilimanjaro Hai District	0.02	0.98
Manyara Babati Urban District	0.01	0.99
Arusha Rural District	0.01	1.00

B2. 2016 Maize Store Census

Locations	Share of Maize Purchase	Cum. Share
Kilimanjaro Moshi Rural District	0.74	0.74
Arusha Urban District	0.13	0.87
Manyara Babati Urban District	0.10	0.97
Manyara Babati Rural District	0.02	0.99

Notes: Locations of agro-input distributors are based on the surveys conducted on the universe of agro-input retailers. Locations of output distributors are based on the maize store censuses we conducted in both year 2016 and 2017.

Web Appendix Table A5. Summary Statistics of Market Access Proxies

	(1) Remoteness measured by distance
Remoteness measured by elasticity-adjusted travel costs to hubs	0.81***
	(0.02)
Dependent variable mean before standardization	304.19
Dependent variable sd before standardization	31.56
Independent variable mean before standardization	0.03
Independent variable sd before standardization	0.02
Observations	1,135
R-squared	0.66

Notes: The regression is run at the village level. In all reduced-form regressions in the paper, the Donaldson-Hornbeck remoteness proxy is multiplied by -1 for consistent interpretation with the results from standardized distance remoteness. The regression coefficient is standardized. Standard errors in parentheses. *, **, and *** indicate significance at 10%, 5%, and 1%.

Web Appendix Table A6. Remoteness and fertilizer retailer sales, prices, and markups

	(1)	(2)	(3)
	Mean	(Standardized) coefficient on remoteness measure based on (population-weighted):	
		Distance to hubs	Elasticity-adjusted travel costs to hubs
Panel A. Varieties (retailer level, N=509)			
Sells fertilizer	0.87	-0.03	-0.07***
	(0.34)	(0.02)	(0.02)
Number of varieties of fertilizer	1.67	-0.06	-0.11
	(1.54)	(0.09)	(0.09)
Quantity of fertilizer sold last year (kg)	5588	-250.26	-581.15
	(11642)	(707.66)	(755.20)
Sells seeds	0.72	0.03	0.07***
	(0.45)	(0.02)	(0.03)
Number of varieties of seeds	1.2	0.10	0.28***
	(1.26)	(0.07)	(0.07)
Quantity of seeds sold last year (kg)	2194	903.63	1,657.90***
	(8008)	(557.24)	(442.65)
Cost of transport from wholesaler (per 50 kg)	0.64	0.32***	0.34***
	(0.69)	(0.04)	(0.04)
Panel B. Prices and markups (retailer-variety level, N=938)			
Retail price for 50 kilograms	25.21	0.65***	0.54**
	(5.21)	(0.22)	(0.23)
Wholesale price for 50 kilograms	21.43	0.16*	0.20**
	(4.14)	(0.09)	(0.09)
Markup (percentage points)[1]	13.42	0.86	0.42
	(10.25)	(0.62)	(0.69)

Notes: In Column 1, standard deviations are in parentheses. Columns 2 and 3 show regression coefficients from separate regressions of the dependent variable on a measure of remoteness (equations 5 and 6 in the paper). See text for further discussion of these measures. Regressions in Panel B includes type and brand fixed effects.

*, **, and *** indicate significance at 10%, 5%, and 1%.

[1]Markup accounts for cost of transport to wholesaler.

Web Appendix Table A7. Remoteness, access to input markets and adoption (hybrid seeds)

	(1)	(2)	(3)	(4)	(5)
	Mean	(Standardized) coefficient on remoteness measure based on (population-weighted):			
		Distance to hubs		Elasticity-adjusted travel costs to hubs	
Panel A. Summary measures of access to input retailers					
Has at least 1 agrovet within 10 km of village	0.66	-0.10***		-0.08***	
which sells seeds		(0.01)		(0.01)	
Number of agrovets within 10 km of village	3.83	-0.98***		-1.28***	
which sells seeds	(4.31)	(0.11)		(0.13)	
Distance to nearest agrovet	14.60	2.88***		3.16***	
which sells seeds	(27.21)	(0.95)		(0.84)	
Distance to the second nearest village with an agrovet	26.62	1.32		3.18***	
which sells seeds	(40.09)	(1.26)		(1.19)	
Panel B: Input usage					
Used improved seeds in previous	0.66	-0.06***	-0.04*	-0.11***	-0.09***
long rains		(0.02)	(0.02)	(0.02)	(0.02)
Quantity of improved seeds used (kg)	6.19	-1.17***	-1.03**	-1.05***	-1.02**
	(8.13)	(0.35)	(0.42)	(0.31)	(0.42)
Controls for farmer and soil characteristics?		N	Y	N	Y

Notes: In Panel A, the unit of observation is the village. Data is from the universe of villages in Kilimanjaro and Manyara regions (N = 1,180). In Column 1, standard deviations are in parentheses. In Panel B, the unit of observations is farmer (N = 2,845 farmers in 246 villages). See text for sampling details. Standard deviations are in parentheses in Column 1. Columns 2-5 show regression coefficients from separate regressions of the dependent variable on a measure of remoteness (equations 5 and 6 in the paper). In Columns 2-5, standard errors in parentheses. Standard errors clustered at the village level in Panel B.
*, **, and *** indicate significance at 10%, 5%, and 1%.

[1]We assume farmers buy a 50 kg bag in one trip (enough for 1 acre), and must incur the cost of a round-trip for herself, plus the cost of carrying the bag of fertilizer, equivalent to 0.7 trips.

Web Appendix Table A8. Robustness of Travel-cost Adjusted Prices

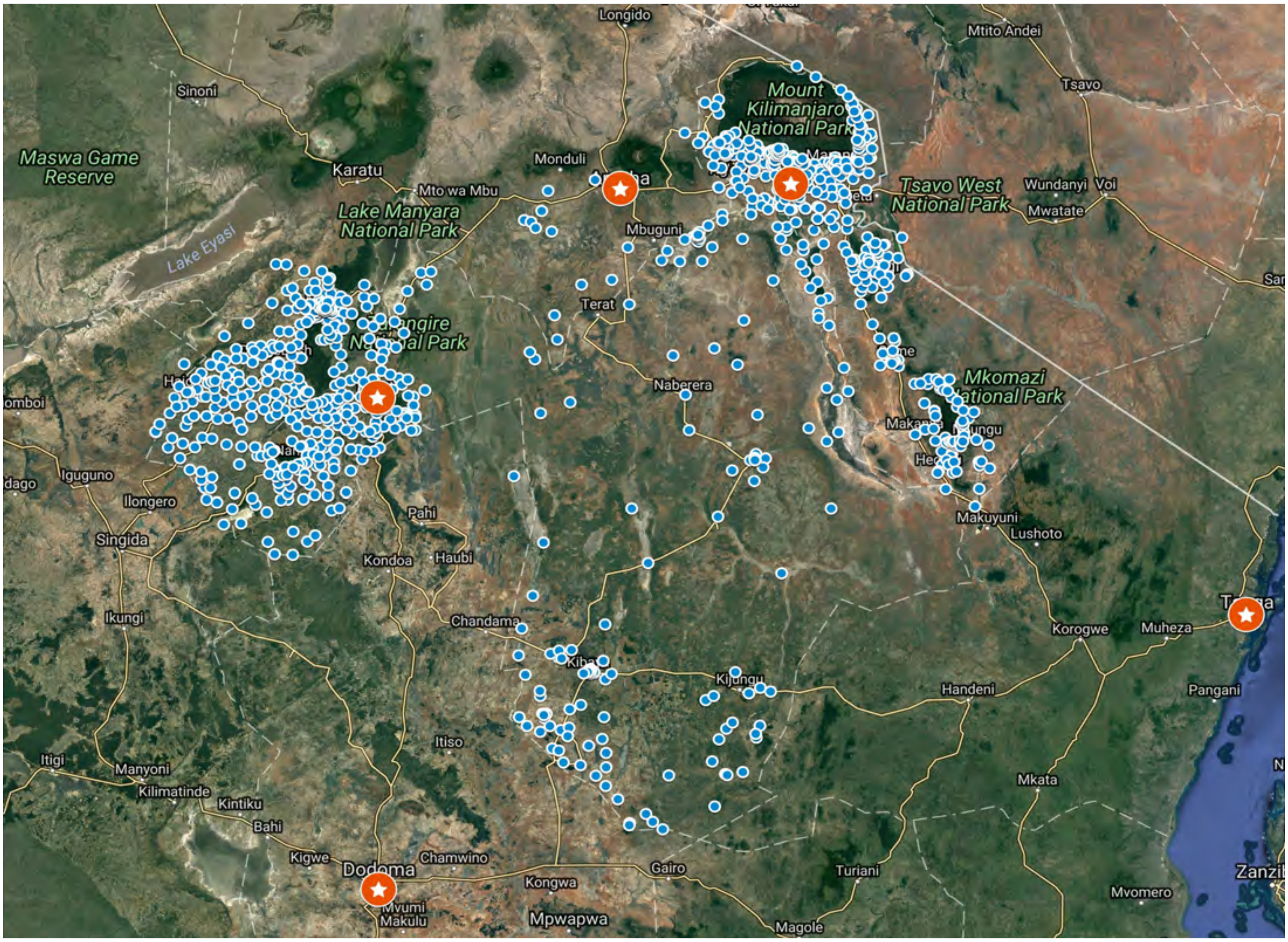
	(1)	(2)	(3)
	Mean	(Standardized) coefficient on remoteness measure based on (population-weighted):	
		Distance to hubs	Elasticity-adjusted travel costs to hubs
Panel A. Dropping Villages Within 10km of Regional Borders			
Minimum travel-cost adjusted price for 50 kg of Urea	23.83	2.51***	2.60***
	(4.88)	(0.18)	(0.14)
Decomposition of price between retail price and cost of transportation			
Retail price at the location with the lowest travel-cost adjusted price (USD)	19.75	1.33***	1.36***
	(2.64)	(0.08)	(0.06)
Cost of travel to obtain minimum travel-cost adjusted price (USD)	4.082	1.17***	1.24***
	(4.32)	(0.17)	(0.14)
Panel B. Bounding regression coefficients by assigning prices to missing retailers[1]			
Minimum travel-cost adjusted price for 50 kg of Urea	24.13	2.21***	2.33***
	(4.78)	(0.13)	(0.13)
Decomposition of price between retail price and cost of transportation			
Retail price at the location with the lowest travel-cost adjusted price (USD)	19.84	1.10***	1.24***
	(2.57)	(0.07)	(0.07)
Cost of travel to obtain minimum travel-cost adjusted price (USD)	4.29	1.12***	1.09***
	(4.44)	(0.13)	(0.13)
Panel C. Using the lower bound travel cost per km			
Minimum travel-cost adjusted price for 50 kg of Urea	24.23	1.88***	2.28***
	(5.33)	(0.17)	(0.14)
Decomposition of price between retail price and cost of transportation			
Retail price at the location with the lowest travel-cost adjusted price (USD)	19.80	0.92***	1.12***
	(2.59)	(0.07)	(0.06)
Cost of travel to obtain minimum travel-cost adjusted price (USD)	4.43	0.96***	1.17***
	(4.95)	(0.16)	(0.14)
Panel D. Using the upper bound travel cost per km			
Minimum travel-cost adjusted price for 50 kg of Urea	24.66	2.02***	2.41***
	(5.59)	(0.17)	(0.15)
Decomposition of price between retail price and cost of transportation			
Retail price at the location with the lowest travel-cost adjusted price (USD)	19.87	0.92***	1.13***
	(2.54)	(0.07)	(0.06)
Cost of travel to obtain minimum travel-cost adjusted price (USD)	4.79	1.10***	1.28***
	(5.14)	(0.17)	(0.14)

Notes: Data is from the near universe of villages in Kilimanjaro and Manyara region (N = 1,180). The unit of observation is the village. Travel costs imputed from transport surveys and Google maps. In Column 1, standard deviations are in parentheses. Columns 2 and 3 show regression coefficients from separate regressions of the dependent variable on a measure of remoteness (equations 5 and 6 in the paper). See text for further discussion of these measures.

*, **, and *** indicate significance at 10%, 5%, and 1%.

[1] In this calculation, we imputed prices to retailers with missing values. To do this, we estimated the distribution of prices within region. We then assigned high or low prices to the missing agrovet (defined as being at the 10th or 90th percentile of this price distribution) in a way that attenuated the regression coefficient. For example, a missing agrovet in a remote village was assigned a low price, causing a flattening of the regression.

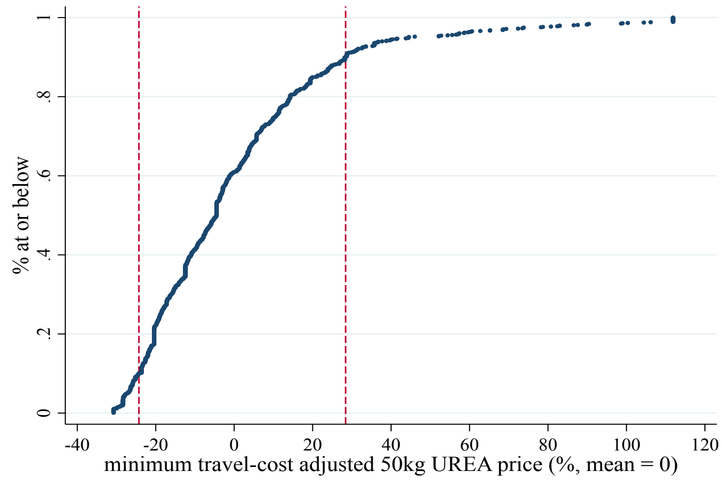
Web Apppendix Figure A1. Map of Survey Region and Villages



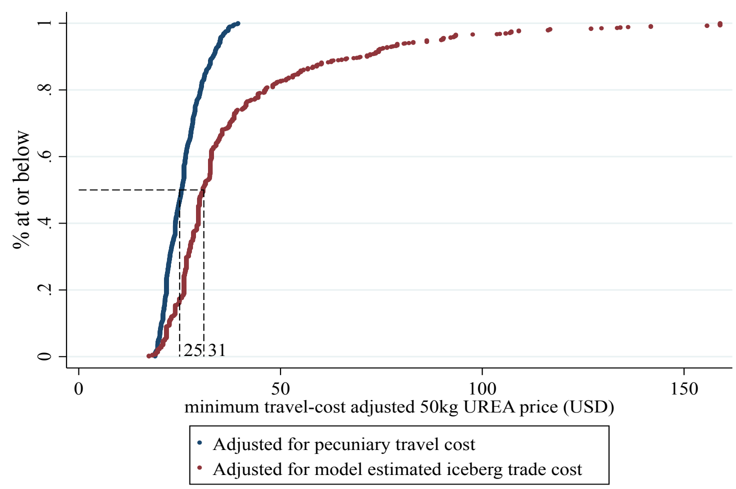
Notes: Blue dots represent all villages in the Kilimanjaro and Manyara Regions. The star signs represent the five major hubs that are used to construct our market access proxies in Section 4.1. They are Moshi, Arusha, Babati, Dodoma, and Tanga.

Web Appendix Figure A2. CDF of travel-cost adjusted prices at the nearest locations

Panel A. Pecuniary travel-cost adjusted fertilizer price

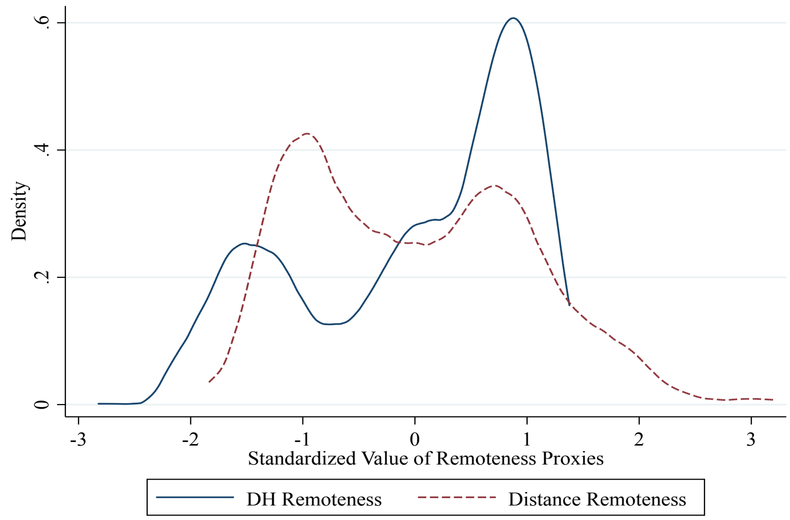


Panel B. Pecuniary vs iceberg trade cost



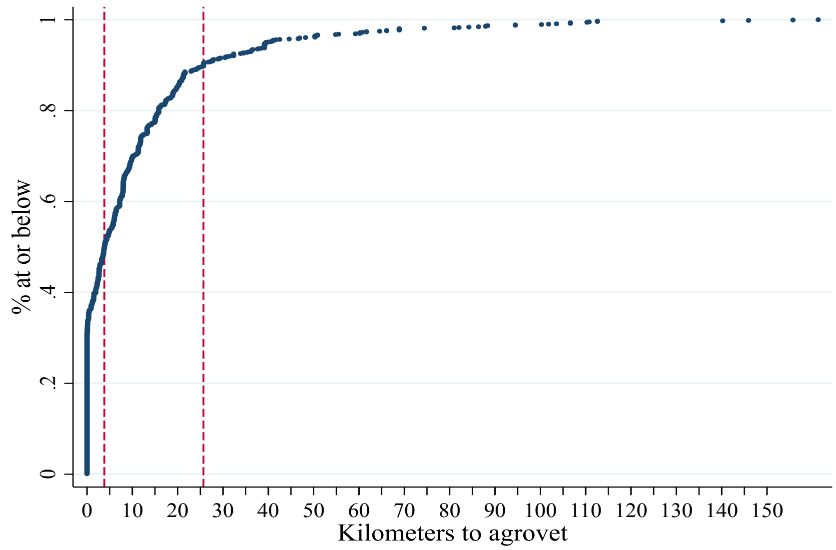
Notes: Each observation represents a village. Travel-cost adjusted prices are calculated through observed prices from a survey with fertilizer retailers and transport cost information collected from interviews with transport operators. In Panel A, the vertical dotted lines represent the 10th and 90th percentile. In Panel B, the vertical lines represent the median.

Web Appendix Figure A3. The Distribution of Remoteness Proxies



Notes: The distribution of remoteness proxies is depicted at the village level (N=1,180).

Web Appendix Figure A4. CDF of Distance Farmers Travel to Purchase Inputs



Notes: Each point represents a farmer. Purchase events include any kinds of agricultural inputs. Vertical dotted lines indicate distances corresponding to the the 50th and 90th percentile.

Web Appendix Table B1. Production Function Estimates with and without fertilizer

VARIABLES	(1) Used Fertilizer?	(2) Used Fertilizer?	(3) log(Fert. Expenditures)	(4) log(Fert. Expenditures)
log(Acres Land)	0.238***	0.167**	0.304***	0.312***
	(0.0787)	(0.0850)	(0.0108)	(0.0110)
log(Predicted Adoption) (column 2)				0.727***
				(0.0609)
Age		-0.00618	-0.000995	-0.00115
		(0.00520)	(0.000705)	(0.000705)
Female?		-0.0666	-0.0271	-0.0399**
		(0.146)	(0.0194)	(0.0197)
Married?		0.373**	0.0705***	0.0950***
		(0.173)	(0.0241)	(0.0248)
Years Education		0.0398*	-0.00960***	-0.00562*
		(0.0240)	(0.00287)	(0.00299)
Iron Roof?		0.595***	0.0920***	0.140***
		(0.217)	(0.0299)	(0.0317)
Mud Walls?		-0.0445	0.136***	0.139***
		(0.221)	(0.0337)	(0.0337)
Mud Floor?		-0.564***	-0.0675**	-0.118***
		(0.186)	(0.0292)	(0.0314)
Bank Account?		0.301	0.336***	0.348***
		(0.204)	(0.0226)	(0.0228)
Mobile Money?		0.306	0.342***	0.383***
		(0.203)	(0.0334)	(0.0347)
Household size		-0.0194	0.0220***	0.0214***
		(0.0336)	(0.00421)	(0.00420)
Mobile Phone?		0.195	-0.132***	-0.101**
		(0.262)	(0.0501)	(0.0505)
Value of Durables		-0.0293	0.00891***	0.0107***
		(0.0401)	(0.00320)	(0.00326)
Value of Livestock		0.0524	0.0368***	0.0456***
		(0.0732)	(0.00868)	(0.00890)
Has non-farming business?		0.0462	0.0808***	0.0800***
		(0.154)	(0.0195)	(0.0195)
Total non-farming income		4.03e-05	2.24e-05***	2.52e-05***
		(4.40e-05)	(2.78e-06)	(2.84e-06)

Notes: Village fixed effects used in all regressions. Columns (1) and (2) or estimated by conditional fixed effects logit, and columns (3) and (4) using PPML. Robust standard errors in parentheses. *, **, and *** indicate significance at 10%, 5%, and 1%.

Web Appendix Table B2: IV regressions of Quality Adjusted Prices

	(1)	(2)	(3)
		log(Eta) (from Calibration)	
log(Price)	-4.663***	-5.192***	-7.395*
	(0.989)	(1.588)	(4.360)
log(Experience)	0.912***	0.985***	0.942***
	(0.13)	(0.15)	(0.210)
	OLS	OLS	IV
First Stage F statistic			10.92
Observations	374	245	245

Notes: District fixed effects used in all regressions. In Column 3, the instrumental variable is lagged price at which fertilizer was bought from a distributor. Column 2 conditions on the lagged price being reported. ***, **, and * indicate significance at 1%, 5%, and 10%.

Web Appendix Table B3. Production Function Estimates for technology with fertilizer

	(1)	(2)	(3)	(4)	(5)
	Dependent variable: log(Harvest)				
log(land)	0.249***	0.152*	0.177*	0.201***	0.180
	(0.0463)	(0.0831)	(0.0984)	(0.0547)	(0.117)
log(labor)	0.299***	0.320***	0.250**	0.403***	0.295
	(0.0680)	(0.0949)	(0.115)	(0.106)	(0.316)
log(Fertilzer)	0.335***	0.261***	0.180*	0.395***	0.474**
	(0.0555)	(0.0800)	(0.0981)	(0.0755)	(0.212)
Observations	502	288	256	337	102
R-squared	0.793	0.842	0.875	0.844	0.959
Farmer Fixed	X				
Plot Fixed		X	X		X
Dist-Year Fixed	X	X			
Village-Year Fixed			X		
Farmer-Year Fixed				X	X
Beta	0.635	0.581	0.430	0.797	0.769
Gamma	0.472	0.551	0.581	0.505	0.383
Ratio (Epsilon/Epsilon_A)	1.089	1.606	3.164	0.515	0.487

Notes: Regressions use World Bank LSMS-ISA household panel surveys from Tanzania, and Uganda. ***, **, and * indicate significance at 1%, 5%, and 10%.

Web Appendix Table B4-1. Sensitivity Analysis for Counterfactuals

Effects of Shocks	Eps_a	Eps	Δlog(μ)		Δlog(Exp)		Δlog(Φ)		Δ(-log(1+μΔLog(Φ)))	
Primary estimates in gray			B0	R	B0	R	B0	R	B0	R
50% lower trade costs	4.7	2.3	1.172***	0.335***	1.441***	0.219***	1.785***	0.057**	-0.628***	0.272***
	4.7	2.3	(0.024)	(0.024)	(0.022)	(0.022)	(0.022)	(0.022)	(0.019)	(0.019)
	4.7	4.7	1.171***	0.335***	1.306***	0.276***	1.786***	0.055**	-0.629***	0.273***
	4.7	4.7	(0.024)	(0.024)	(0.023)	(0.023)	(0.022)	(0.022)	(0.019)	(0.019)
	4.7	9.3	1.171***	0.335***	1.239***	0.305***	1.786***	0.055**	-0.63***	0.273***
	4.7	9.3	(0.024)	(0.024)	(0.023)	(0.024)	(0.022)	(0.022)	(0.019)	(0.019)
	4.7	14.0	1.171***	0.335***	1.216***	0.315***	1.786***	0.055**	-0.63***	0.273***
	4.7	14.0	(0.024)	(0.024)	(0.024)	(0.024)	(0.022)	(0.022)	(0.019)	(0.019)
	5.6	2.8	1.26***	0.369***	1.517***	0.263***	1.96***	0.066***	-0.716***	0.294***
	5.6	2.8	(0.026)	(0.026)	(0.024)	(0.025)	(0.024)	(0.025)	(0.021)	(0.021)
	5.6	5.6	1.26***	0.368***	1.388***	0.315***	1.961***	0.065***	-0.717***	0.295***
	5.6	5.6	(0.026)	(0.026)	(0.025)	(0.025)	(0.024)	(0.025)	(0.021)	(0.021)
	5.6	11.1	1.259***	0.368***	1.324***	0.341***	1.962***	0.064***	-0.718***	0.295***
	5.6	11.1	(0.026)	(0.026)	(0.025)	(0.026)	(0.024)	(0.025)	(0.021)	(0.021)
	5.6	16.7	1.259***	0.368***	1.302***	0.35***	1.962***	0.064***	-0.718***	0.296***
	5.6	16.7	(0.026)	(0.026)	(0.026)	(0.026)	(0.024)	(0.025)	(0.021)	(0.021)
	7.4	3.7	1.385***	0.414***	1.618***	0.326***	2.229***	0.079***	-0.861***	0.324***
	7.4	3.7	(0.029)	(0.029)	(0.027)	(0.027)	(0.028)	(0.028)	(0.024)	(0.024)
	7.4	7.4	1.385***	0.414***	1.501***	0.37***	2.23***	0.078***	-0.863***	0.325***
	7.4	7.4	(0.029)	(0.029)	(0.028)	(0.028)	(0.028)	(0.028)	(0.024)	(0.024)
	7.4	14.8	1.384***	0.414***	1.443***	0.392***	2.231***	0.078***	-0.863***	0.325***
	7.4	14.8	(0.029)	(0.029)	(0.028)	(0.028)	(0.028)	(0.028)	(0.024)	(0.024)
	7.4	22.2	1.384***	0.414***	1.423***	0.399***	2.231***	0.078***	-0.864***	0.326***
	7.4	22.2	(0.029)	(0.029)	(0.028)	(0.028)	(0.028)	(0.028)	(0.024)	(0.024)
50% lower distribution costs	4.7	2.3	0.096***	0.037***	0.103***	0.036***	0.109***	0.037***	-0.017***	0.003***
	4.7	2.3	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
	4.7	4.7	0.095***	0.037***	0.099***	0.036***	0.109***	0.037***	-0.017***	0.003***
	4.7	4.7	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
	4.7	9.3	0.095***	0.037***	0.097***	0.037***	0.109***	0.037***	-0.017***	0.003***
	4.7	9.3	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
	4.7	14.0	0.095***	0.037***	0.097***	0.037***	0.109***	0.037***	-0.017***	0.003***
	4.7	14.0	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
	5.6	2.8	0.111***	0.043***	0.118***	0.042***	0.127***	0.043***	-0.02***	0.004***
	5.6	2.8	(0.003)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
	5.6	5.6	0.111***	0.043***	0.114***	0.042***	0.127***	0.043***	-0.02***	0.004***
	5.6	5.6	(0.003)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
	5.6	11.1	0.111***	0.043***	0.112***	0.043***	0.127***	0.043***	-0.02***	0.004***
	5.6	11.1	(0.003)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
	5.6	16.7	0.111***	0.043***	0.112***	0.043***	0.127***	0.043***	-0.02***	0.004***
	5.6	16.7	(0.003)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
	7.4	3.7	0.142***	0.055***	0.149***	0.054***	0.164***	0.056***	-0.026***	0.005***
	7.4	3.7	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.001)	(0.001)
	7.4	7.4	0.142***	0.055***	0.146***	0.055***	0.163***	0.056***	-0.026***	0.005***
	7.4	7.4	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.001)	(0.001)
	7.4	14.8	0.142***	0.055***	0.144***	0.055***	0.163***	0.055***	-0.026***	0.005***
	7.4	14.8	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.001)	(0.001)
	7.4	22.2	0.142***	0.055***	0.143***	0.055***	0.163***	0.055***	-0.026***	0.005***
	7.4	22.2	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.001)	(0.001)

Web Appendix Table B4-2. Sensitivity Analysis for Counterfactuals

Effects of Shocks	Eps_a	Eps	Δlog(μ)		Δlog(Exp)		Δlog(Φ)		Δ(-log(1+μΔLog(Φ)))	
Primary estimates in gray			B0	R	B0	R	B0	R	B0	R
50% lower main road trade costs	4.7	2.3	0.891***	0.29***	1.079***	0.198***	1.316***	0.064**	-0.44***	0.214***
	4.7	2.3	(0.024)	(0.025)	(0.025)	(0.025)	(0.025)	(0.026)	(0.016)	(0.016)
	4.7	4.7	0.892***	0.289***	0.986***	0.243***	1.319***	0.062**	-0.442***	0.215***
	4.7	4.7	(0.024)	(0.025)	(0.024)	(0.025)	(0.025)	(0.026)	(0.016)	(0.016)
	4.7	9.3	0.892***	0.289***	0.94***	0.266***	1.321***	0.062**	-0.443***	0.216***
	4.7	9.3	(0.024)	(0.025)	(0.024)	(0.025)	(0.025)	(0.026)	(0.016)	(0.016)
	4.7	14.0	0.892***	0.289***	0.924***	0.274***	1.321***	0.061**	-0.444***	0.216***
	4.7	14.0	(0.024)	(0.025)	(0.024)	(0.025)	(0.025)	(0.026)	(0.016)	(0.016)
	5.6	2.8	0.965***	0.316***	1.143***	0.233***	1.445***	0.071**	-0.496***	0.231***
	5.6	2.8	(0.026)	(0.026)	(0.026)	(0.027)	(0.027)	(0.028)	(0.017)	(0.018)
	5.6	5.6	0.966***	0.316***	1.055***	0.274***	1.448***	0.07**	-0.498***	0.232***
	5.6	5.6	(0.026)	(0.026)	(0.026)	(0.026)	(0.027)	(0.028)	(0.017)	(0.018)
	5.6	11.1	0.967***	0.316***	1.011***	0.295***	1.45***	0.069**	-0.499***	0.233***
	5.6	11.1	(0.026)	(0.026)	(0.026)	(0.026)	(0.027)	(0.028)	(0.018)	(0.018)
	5.6	16.7	0.967***	0.316***	0.997***	0.302***	1.451***	0.069**	-0.5***	0.233***
	5.6	16.7	(0.026)	(0.026)	(0.026)	(0.026)	(0.027)	(0.028)	(0.018)	(0.018)
	7.4	3.7	1.07***	0.352***	1.227***	0.283***	1.635***	0.081***	-0.583***	0.255***
	7.4	3.7	(0.028)	(0.028)	(0.028)	(0.028)	(0.030)	(0.030)	(0.020)	(0.020)
	7.4	7.4	1.071***	0.352***	1.15***	0.317***	1.639***	0.08***	-0.585***	0.256***
	7.4	7.4	(0.028)	(0.028)	(0.027)	(0.028)	(0.030)	(0.030)	(0.020)	(0.020)
	7.4	14.8	1.071***	0.352***	1.111***	0.334***	1.64***	0.079***	-0.586***	0.257***
	7.4	14.8	(0.028)	(0.028)	(0.027)	(0.028)	(0.030)	(0.030)	(0.020)	(0.020)
	7.4	22.2	1.071***	0.352***	1.098***	0.34***	1.641***	0.079***	-0.586***	0.257***
	7.4	22.2	(0.028)	(0.028)	(0.027)	(0.028)	(0.030)	(0.030)	(0.020)	(0.020)
50% lower rural road trade costs	4.7	2.3	0.621***	0.115***	0.728***	0.067***	0.863***	0.008	-0.248***	0.112***
	4.7	2.3	(0.012)	(0.012)	(0.011)	(0.011)	(0.010)	(0.010)	(0.009)	(0.009)
	4.7	4.7	0.619***	0.115***	0.672***	0.091***	0.861***	0.008	-0.247***	0.112***
	4.7	4.7	(0.012)	(0.012)	(0.012)	(0.012)	(0.010)	(0.010)	(0.009)	(0.009)
	4.7	9.3	0.618***	0.115***	0.645***	0.103***	0.859***	0.008	-0.246***	0.112***
	4.7	9.3	(0.012)	(0.012)	(0.012)	(0.012)	(0.010)	(0.010)	(0.009)	(0.009)
	4.7	14.0	0.618***	0.115***	0.636***	0.107***	0.859***	0.008	-0.246***	0.112***
	4.7	14.0	(0.012)	(0.012)	(0.012)	(0.012)	(0.010)	(0.010)	(0.009)	(0.009)
	5.6	2.8	0.635***	0.118***	0.727***	0.077***	0.884***	0.009	-0.255***	0.115***
	5.6	2.8	(0.013)	(0.013)	(0.012)	(0.012)	(0.011)	(0.011)	(0.009)	(0.009)
	5.6	5.6	0.634***	0.118***	0.679***	0.097***	0.882***	0.009	-0.254***	0.115***
	5.6	5.6	(0.013)	(0.013)	(0.012)	(0.012)	(0.011)	(0.011)	(0.009)	(0.009)
	5.6	11.1	0.633***	0.118***	0.655***	0.107***	0.881***	0.009	-0.254***	0.115***
	5.6	11.1	(0.013)	(0.013)	(0.012)	(0.012)	(0.011)	(0.011)	(0.009)	(0.009)
	5.6	16.7	0.632***	0.118***	0.648***	0.111***	0.88***	0.009	-0.254***	0.115***
	5.6	16.7	(0.013)	(0.013)	(0.013)	(0.012)	(0.011)	(0.011)	(0.009)	(0.009)
	7.4	3.7	0.653***	0.122***	0.725***	0.09***	0.911***	0.01	-0.264***	0.118***
	7.4	3.7	(0.013)	(0.013)	(0.012)	(0.012)	(0.011)	(0.011)	(0.010)	(0.010)
	7.4	7.4	0.652***	0.121***	0.687***	0.105***	0.909***	0.01	-0.264***	0.118***
	7.4	7.4	(0.013)	(0.013)	(0.013)	(0.013)	(0.011)	(0.011)	(0.010)	(0.010)
	7.4	14.8	0.651***	0.121***	0.669***	0.113***	0.908***	0.01	-0.263***	0.118***
	7.4	14.8	(0.013)	(0.013)	(0.013)	(0.013)	(0.011)	(0.011)	(0.010)	(0.010)
	7.4	22.2	0.651***	0.121***	0.663***	0.116***	0.908***	0.01	-0.263***	0.118***
	7.4	22.2	(0.013)	(0.013)	(0.013)	(0.013)	(0.011)	(0.011)	(0.010)	(0.010)

Web Appendix Table B5. Multinomial logit of agrovet choice, within Income Interaction

	Main Roads			Rural Roads	
	Bin	Bin x Income?		Coef	Bin x Income?
	(se)	(se)		(se)	(se)
between (0,5] km	0.764**	-0.881*	between (0,5] km	-2.705***	0.717
	(0.375)	(0.494)		(0.475)	(0.456)
between (5,10] km	-1.717***	-0.144	between (5,10] km	-1.437***	0.789
	(0.473)	(0.595)		(0.505)	(0.541)
between (10,15] km	-2.510***	-0.159	between (10,15] km	-2.447***	0.661
	(0.441)	(0.518)		(0.573)	(0.657)
between (15,20] km	-2.918***	-0.41	between (15,20] km	-3.509***	1.398
	(0.449)	(0.566)		(0.790)	(0.913)
between (20,30] km	-3.804***	-0.132	over 20 km	-3.632***	-1.02
	(0.405)	(0.485)		(0.998)	(1.218)
between (30,40] km	-7.262***	1.2			
	(1.086)	(1.241)			
between (40,50] km	-7.212***	1.320			
	(1.059)	(1.184)			
between (50,75] km	-7.097***	1.069			
	(0.592)	(0.653)			
over 75 km	-8.577***	0.237			
	(0.626)	(0.732)			

Notes: N = 515 farmers, 119 observed locations. Omitted group is agrovet located in respondent's village. Ad-valorem equivalent per kilometer is calculated at the upper bound of each bin, and assumes that the trade cost compounds each kilometer. Columns 1 and 3 are the estimates for trade costs bins for main and rural roads, respectively. Columns 2 and 4 interact these bins with an indicator of total income at the farmer level. Standard errors in parentheses. *, **, and *** indicate significance at 10%, 5%, and 1%.

Web Appendix Table B6. Counterfactuals with and without additional output market access

	$\Delta\log(\mu)$		$\Delta\log(Exp)$	
	B0	R	B0	R
50% lower trade costs	1.384***	0.414***	1.443***	0.392***
	(0.029)	(0.029)	(0.028)	(0.028)
50% lower trade costs	1.512***	0.465***	1.581***	0.444***
and 50% lower costs to maize market	(0.032)	(0.032)	(0.031)	(0.032)

Notes: This table compares the adoption and expenditure results from the main counterfactual with a joint counterfactual that reduces costs to agrovets by 50%, and also assumes that transport costs to the nearest agrovet fall by 50% to sell output at that location. Robust standard errors, clustered by village, in parentheses. *, **, and *** indicate significance at 10%, 5%, and 1%.

Web Appendix Table B7. Counterfactuals with different trimming assumptions

	$\Delta\log(\mu)$		$\Delta\log(Exp)$		$\Delta\log(\Phi)$		$\Delta(-\log(1+\mu\Delta Log(\Phi)))$	
	B_0	R	B_0	R	B_0	R	B_0	R
Panel A: Original Trimming Values								
All Roads	1.38***	0.424***	1.438***	0.403***	2.28***	0.065**	-0.911***	0.342***
	(0.029)	(0.030)	(0.029)	(0.029)	(0.030)	(0.031)	(0.026)	(0.026)
Rural Roads	0.648***	0.117***	0.664***	0.109***	0.903***	0.005	-0.262***	0.118***
	(0.013)	(0.013)	(0.013)	(0.013)	(0.011)	(0.011)	(0.010)	(0.010)
Main Roads	1.063***	0.365***	1.103***	0.347***	1.685***	0.063*	-0.632***	0.277***
	(0.028)	(0.030)	(0.028)	(0.030)	(0.031)	(0.033)	(0.021)	(0.021)
From Distributor	0.153***	0.062***	0.155***	0.062***	0.176***	0.063***	-0.028***	0.005***
	(0.004)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)	(0.001)	(0.001)
Panel B: Alternate Trimming Values								
All Roads	1.541***	0.506***	1.589***	0.478***	2.233***	0.077***	-0.71***	0.419***
	(0.035)	(0.035)	(0.034)	(0.034)	(0.028)	(0.028)	(0.026)	(0.026)
Rural Roads	0.675***	0.13***	0.691***	0.122***	0.909***	0.01	-0.239***	0.127***
	(0.014)	(0.014)	(0.014)	(0.014)	(0.011)	(0.011)	(0.010)	(0.010)
Main Roads	1.17***	0.417***	1.203***	0.395***	1.642***	0.078**	-0.489***	0.323***
	(0.032)	(0.033)	(0.031)	(0.032)	(0.030)	(0.030)	(0.021)	(0.021)
From Distributor	0.146***	0.057***	0.147***	0.057***	0.164***	0.056***	-0.022***	0.007***
	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.001)	(0.001)

Robust standard errors, clustered by village, in parentheses. Panel A uses original trimming values for village with no adoption (0.025) or full adoption (0.975). Panel B uses new trimming values for villages with no adoption (0.001) or full adoption (0.999).

Web Appendix Table C1. Road density in East Africa

	(1)	(2)
	Road Density (km per '00 sq km area)	Percentage Roads Paved
Burundi	44.28	12.17%
Democratic Republic of Congo	6.54	1.82%
Djibouti	13.21	40.00%
Eritrea	3.41	21.80%
Ethiopia	10.00	13.00%
Kenya	27.82	8.93%
Madagascar	11.18	11.60%
Malawi	13.04	26.37%
Mozambique	3.88	23.70%
Rwanda	17.84	25.68%
Somalia	3.47	11.80%
South Sudan	1.13	2.74%
Tanzania	9.13	8.20%
Uganda	8.52	20.72%
Zambia	12.15	22.00%
Zimbabwe	24.90	19.00%
Sub-Saharan Africa Average	13.70	22.63%

Notes: Data compiled from various World Bank and AfDB reports. Statistics correspond to years ranging between 2010 and 2016; DRC statistics are from 2001. We include all countries classified as Eastern African as per the United Nations Statistics Division scheme of geographic regions, except the island nations of Comoros, Mauritius and Seychelles, and the French Overseas Territories of Réunion and Mayotte. We also exclude Sudan because there is no data available for after it split from South Sudan.

Web Appendix Table C2. Input and output market price dispersion across countries

	(1) Secondary Datasets[1]	(2) Tanzania Data[2]
Residual standard deviation in log prices for:[3]		
All products	0.45	0.15
Maize only	0.34	0.10
Fertilizer only	0.12	0.09

Notes: [1]Secondary datasets include RATIN (prices of major crops across 41 major markets in 5 countries - Kenya, Tanzania, Uganda, Burundi, and Rwanda - over the 1997-2015 time period), Africafoodprices.io (25 products over 276 markets in 53 countries), AMITSA (the Regional Agricultural Input Market Information and Transparency System for East and Southern Africa, which includes information on 9 fertilizer varieties in 95 markets in 8 countries), prices of 5 major varieties of fertilizer (Urea, CAN, DAP, and NPK 17 17 17) in 18 countries from 2010-16 in Africafertilizer.org; and prices of a number of commodities in 38 countries from 1992-2016 collected by the WFP.

[2]Maize prices are from a survey of market sellers in 98 markets conducted in October 2017. Fertilizer prices are from surveys of agro-input retailers in 2017.

[3]Calculated from a regression of log prices on product, country, and time fixed effects. See text for details.

Web Appendix Table C3. Dyadic price dispersion

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Dependent variable: Absolute log price difference								
Panel A. Secondary Datasets									
Log (distance)	0.03***		0.000	0.03***		0.000	0.01***	0.000	0.010
	(0.002)		(0.010)	(0.002)		(0.015)	(0.002)	0.000	(0.014)
Log (travel time)		0.03***	0.03***		0.04***	0.04**		0.01***	0.000
		(0.002)	(0.011)		(0.003)	(0.017)		(0.002)	(0.016)
Products	All	All	All	Maize	Maize	Maize	Fertilizer	Fertilizer	Fertilizer
Dep. Var. mean	0.21	0.21	0.21	0.20	0.20	0.20	0.11	0.11	0.11
Dep. Var. SD	0.20	0.20	0.20	0.17	0.17	0.17	0.13	0.13	0.13
Observations	4,752,196	4,752,196	4,752,196	675,880	675,880	675,880	38,364	38,364	38,364
Number of locations	1335	1335	1335	1335	1335	1335	1335	1335	1335
Countries	49	49	49	43	43	43	18	18	18
Panel B. Northern Tanzania									
Log (distance)	0.01***		-0.030	0.03***		-0.10**	0.003*		0.007
	(0.003)		(0.020)	(0.011)		(0.050)	(0.002)		(0.017)
Log (travel time)		0.01***	0.04*		0.04***	0.16**		0.004	-0.004
		(0.004)	(0.025)		(0.016)	(0.069)		(0.002)	(0.019)
Products	All	All	All	Maize	Maize	Maize	Fertilizer	Fertilizer	Fertilizer
Dep. Var. mean	0.16	0.16	0.16	0.21	0.21	0.21	0.13	0.13	0.13
Dep. Var. SD	0.14	0.14	0.14	0.18	0.18	0.18	0.10	0.10	0.10
Observations	22,386	22,376	22,376	6,873	6,873	6,873	15,064	15,056	15,056
Number of locations	82	82	82	65	65	65	60	60	60

Notes: Regressions include product, month and year fixed effects. All regressions are within country. Travel time and distances calculated from Google maps. See Web Appendix Table A3 and text for discussion of datasets.
Two-way clustered standard errors in parentheses. ***, **, and * indicate significance at 1%, 5%, and 10%.

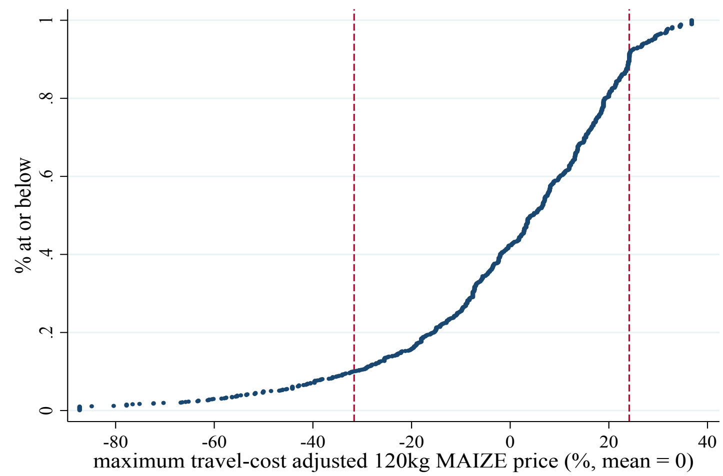
Web Appendix Table C4. Relationship betweten distance and fertilzier adoption in LSMS-ISA surveys

	(1)	(2)
	Dependent variable: used chemical fertilizer in last season	
Log of distance to nearest major market (km)	-0.027***	
	(0.005)	
Log of distance to nearest population center (km)		-0.019*
		(0.010)
Dependent variable mean	0.32	0.32
Independent variable mean	3.23	3.21
Independent variable sd	1.27	1.02
Observations	35,938	35,938
Individuals	26,653	26,653

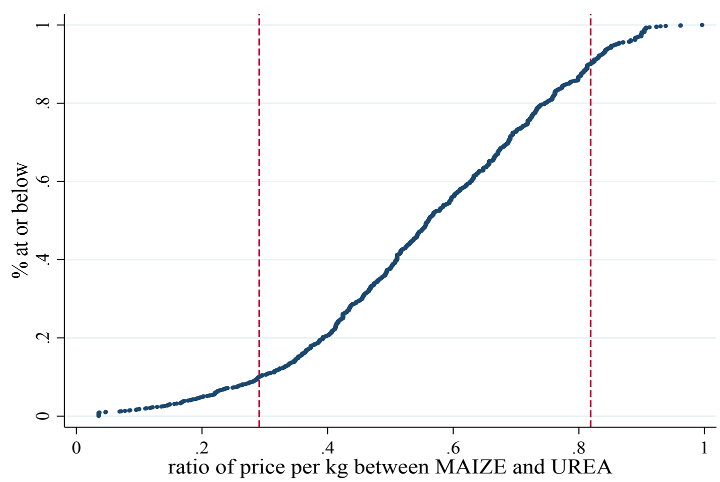
Notes: Regressions include World Bank LSMS-ISA household panel surveys in Ethiopia, Niger, Nigeria, Malawi, Tanzania, and Uganda. Standard errors clustered at the enumeration area level are in parentheses.
***, **, and * indicate significance at 1%, 5%, and 10%.

Web Appendix Figure D1. CDF of output price, and ratio of output and input price

A. CDF of Maize Price



B. CDF of Ratio of Maize Price to Fertilizer Price



Notes: Each observation represents a village. Travel-cost adjusted prices for maize are calculated from a maize price survey at markets and transport cost information collected from interviews with transport operators. The vertical dotted lines represent the 10th and 90th percentile.

Web Appendix Table D1. Remoteness, access to output markets and output price heterogeneity

	(1)	(2)	(3)
		(Standardized) coefficient on remoteness measure based on (population-weighted):	
	Mean	Distance to hubs	Elasticity-adjusted travel costs to hubs
Panel A. Summary measures of access to output markets			
Has at least 1 maize seller within 10 km of village	0.46	-0.12***	-0.10***
		(0.01)	(0.01)
Number of maize sellers within 10 km of village	1.13	-0.69***	-0.98***
	(2.12)	(0.06)	(0.09)
Distance to nearest output market with maize sellers (km)	22.72	7.11***	6.93***
	(33.90)	(0.96)	(0.91)
Panel B1. Maximum imputed travel-cost adjusted price if farmers were to sell in a local market			
Market survey: maximum travel-cost adjusted price immediately after 2017 harvest (USD)[1]	30.49	-3.12***	-3.39***
	(7.62)	(0.22)	(0.18)
Decomposition of price between retail price and cost of transportation			
Retail price at the location with the highest travel-cost adjusted price (USD)	40.07	0.11**	-0.51***
	(2.60)	(0.05)	(0.07)
Cost of travel to obtain the highest travel-cost adjusted price (USD)	9.58	3.23***	2.87***
	(7.41)	(0.22)	(0.19)
Panel B2. Travel-cost adjusted otput price at the nearest maize selling market			
Travel-cost unadjusted 120 kg bag of maize price immediately after 2017 harvest (USD)[1]	21.08	-3.28***	-3.64***
	(8.69)	(0.24)	(0.21)
Decomposition of price between retail price and cost of transportation			
Retail price at the nearest maize selling market (USD)	26.76	-1.34***	-1.77***
	(5.12)	(0.12)	(0.11)
Cost of travel to the nearest maize selling market (USD)	5.674	1.93***	1.87***
	(6.08)	(0.20)	(0.16)
Panel B3. Price available within village by maize-buying intermediaries immediately after last season's harvest			
Farmer surveys: average "going price" in local village immediately after previous harvest[2]	25.86	-1.31**	-2.60***
	(6.24)	(0.52)	(0.48)

Notes: The unit of observation is the village. Data is from the universe of villages in Kilimanjaro and Manyara regions (N = 1,180). Travel costs imputed from transport surveys and Google maps. In Column 1, standard deviations are in parentheses. Columns 2 and 3 show regression coefficients from separate regressions of the dependent variable on a measure of remoteness (equations 5 and 6 in the paper). See text for further discussion of these measures. In those columns, standard errors in parentheses, clustered at the village level.

*, **, and *** indicate significance at 10%, 5%, and 1%.

[1]We assume farmers sell a 120 kg maize bag in one trip, and must incur the cost of a round trip for herself and the cost of carrying the maize that is equivalent to 1.7 trips.

[2]Data is from the farmer surveys (2,171 farmers in 137 villages).

Web Appendix Table D2. Remoteness and output market access

	(1)	(2)	(3)	(4)	(5)
	Mean	(Standardized) coefficient on remoteness measure based on (population-weighted):			
		Distance to hubs		Elasticity-adjusted travel costs to hubs	
Panel A. Maize sales					
Sold maize after previous long rains	0.32	-0.09***	-0.05*	-0.07***	-0.04*
		(0.02)	(0.03)	(0.02)	(0.02)
Total quantity sold (kg)	374	-85.45**	-87.87*	-11.62	-21.74
	(1110)	(34.00)	(46.80)	(38.15)	(46.80)
Sales to agents at home					
Agent visited homestead	0.38	-0.12***	-0.07**	-0.11***	-0.06**
		(0.03)	(0.03)	(0.02)	(0.03)
Sold maize to agent after previous long rains	0.17	-0.06***	-0.04*	-0.05***	-0.02
		(0.02)	(0.02)	(0.01)	(0.02)
Quantity sold to agents (kg)	138	-41.97***	-30.74*	-15.10	2.82
	(423)	(13.27)	(17.88)	(11.96)	(18.63)
Sales at market					
Sold maize at market after previous long rains	0.06	-0.02***	-0.02**	-0.02***	-0.02**
		(0.01)	(0.01)	(0.01)	(0.01)
Quantity sold at market (kg)	34	-14.41***	-15.14**	-9.92*	-12.30*
	(198)	(5.22)	(7.51)	(5.72)	(7.18)
Panel B. Maize purchases					
Farmer ever buys maize	0.48	0.10***	0.07***	0.10***	0.08***
		(0.02)	(0.02)	(0.02)	(0.02)
Quantity purchased in typical year (kg)	155	72.11***	55.56***	85.95***	71.68***
	(323)	(16.13)	(17.84)	(15.28)	(14.50)
Net buying					
Farmer buys maize but sells none	0.38	0.11***	0.07***	0.10***	0.07***
		(0.02)	(0.02)	(0.02)	(0.02)
Farmer sells maize and buys none	0.23	-0.08***	-0.05**	-0.08***	-0.06***
		(0.02)	(0.02)	(0.01)	(0.02)
Farmer buys and sells maize	0.09	-0.01	0.00	0.00	0.02
		(0.01)	(0.01)	(0.01)	(0.01)
Net buyer (quantity bought > quantity sold)	0.44	0.10***	0.07**	0.10***	0.07***
		(0.02)	(0.03)	(0.02)	(0.03)
Net seller (quantity bought < quantity sold)	0.25	-0.08***	-0.05*	-0.07***	-0.05*
		(0.02)	(0.03)	(0.02)	(0.03)
Controls for farmer and soil characteristics?		N	Y	N	Y

Notes: N = 2,845 farmers in 246 villages. See text for sampling details. Standard deviations are in parentheses in Column 1. Columns 2-5 show regression coefficients from separate regressions of the dependent variable on a measure of remoteness (equations 5 and 6 in the paper). See text for further discussion of these measures. Standard errors in parentheses, clustered at the village level.

*, **, and *** indicate significance at 10%, 5%, and 1%.

Table XXX. Access to input markets, fertilizer retail price heterogeneity, and adoption

	(1)	(2)	(3)	(4)	(5)
	Mean	(Standardized) coefficient on remoteness measure based on (population-weighted):			
		Distance to hubs		Elasticity-adjusted travel costs to hubs	
Panel A. Summary measures of access to input retailers					
Has at least 1 agrovet within 10 km of village	0.62	-0.13***		-0.11***	
which sells fertilizer		(0.01)		(0.01)	
Number of agrovets within 10 km of village	4.14	-2.18***		-2.20***	
which sells fertilizer	(5.58)	(0.13)		(0.14)	
Distance to nearest agrovet	13.89	5.18***		3.83***	
which sells fertilizer	(29.71)	(1.09)		(0.93)	
Distance to the second nearest village with an agrovet	32.43	6.82***		3.57**	
which sells fertilizer	(49.08)	(1.72)		(1.61)	
Panel B1. Travel-cost adjusted prices faced by farmers					
Minimum travel-cost adjusted price	24.53	2.16***		2.27***	
for 50 kg of Urea (USD)[1]	(5.55)	(0.16)		(0.15)	
Decomposition of price between retail price and cost of transportation					
Retail price at the location with the lowest	19.75	1.11***		1.14***	
travel-cost adjusted price (USD)	(2.52)	(0.06)		(0.06)	
Cost of travel to obtain minimum travel-cost	4.786	1.05***		1.12***	
adjusted price (USD)	(5.07)	(0.16)		(0.14)	
Panel B2. Travel-cost adjusted prices at the nearest agro-input shop					
Travel-cost adjusted price at the nearest input seller	27.45	1.65***		1.96***	
for 50 kg of Urea (USD)[1]	(7.39)	(0.20)		(0.19)	
Decomposition of price between retail price and cost of transportation					
Retail price at the nearest input seller (USD)	23.49	0.67***		1.00***	
	(3.34)	(0.09)		(0.08)	
Cost of travel to the nearest input seller (USD)	3.97	0.98***		0.96***	
	(6.16)	(0.17)		(0.16)	
Panel C: Input usage					
Used chemical fertilizer in previous	0.39	-0.18***	-0.10***	-0.20***	-0.13***
long rains		(0.02)	(0.02)	(0.03)	(0.03)
Quantity of chemical fertilizer used (kg)	19.55	-11.99***	-6.18***	-14.12***	-9.04***
	(31.39)	(1.67)	(1.20)	(1.80)	(1.71)
Controls for farmer and soil characteristics?		N	Y	N	Y

Notes: For Panels A and B, the unit of observation is the village. Data is from the near universe of villages in Kilimanjaro and Manyara regions (N = 1,180). Only 3 villages are excluded because of missing GPS. Travel costs imputed from transport surveys and Google maps. For Panel C, the unit of observations is farmer (N = 2,845 farmers in 246 villages). See text for sampling details. Standard deviations are in parentheses in Column 1. Columns 2-5 show regression coefficients from separate regressions of the dependent variable on a measure of remoteness (equations 5 and 6 in the paper). See text for further discussion of these measures. In Columns 2-5, standard errors in parentheses; standard errors are clustered at the village level in Panel C.
*, **, and *** indicate significance at 10%, 5%, and 1%.

[1]We assume farmers buy a 50 kg bag in one trip (enough for 1 acre), and must incur the cost of a round-trip for herself, plus the cost of carrying the bag of fertilizer, equivalent to 0.7 trips.