

Impacts of prices and transactions costs on input usage in a liberalizing economy: evidence from Tanzanian coffee growers

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Abstract

Despite improvements in production incentives, agricultural output in Africa remained sluggish through the 1990s. Low use of purchased inputs may be part of the cause of persistently low productivity in African agriculture. This article analyzes the roles of relative prices and transactions costs in explaining low use of chemical inputs among Tanzanian coffee growers. A sample selection model indicates that output prices exert great influence on input purchases and that both fixed and variable transactions costs affect input use decisions. Travel costs in input and output markets have distinct effects on input usage, implying distinct avenues for interventions to promote more intensive use of agricultural inputs.

JEL classification: O1, Q1

Keywords: Agricultural inputs; Fertilizer; Coffee; Liberalization; Transactions costs

1. Introduction

Over the last two decades currency devaluations and commodity market liberalization have been widely implemented in Africa in order to stimulate export production. The results of these reforms have been mixed, but they appear to have had more success in improving output prices than in improving actual output (Kherallah et al., 2000). This tendency has been especially pronounced among traditional agricultural exports such as coffee, tea, and cocoa, which remain the mainstay of many African economies. Despite market reforms and some recent increases in export values, Africa's share in the world trade of these products has fallen steadily from 25% in 1980 to 17% in 1990 and less than 15% in 2000 (UNFAO, 2002).

Part of this muted production response may be explained by the failure of policy reforms to adequately address the provision of inputs like agrochemicals, extension advice, and finance. Indeed, commodity market liberalization may have simultaneously reduced the costs of marketing output and increased the costs of providing inputs. Competition among new, private traders seems to have reduced the costs of exchanging many export crops, but the presence of multiple marketers can make completion of other exchanges in the marketing chains more

costly (Dorward et al., 1998). Quality control of intermediate inputs, for example, should be easier to provide in a system with a single official dealer than in an open system with many distributors. Similarly, crop-secured lending offers the potential to provide seasonal finance at low monitoring and enforcement costs when there is a monopsonistic buyer, but it can be costly or impossible to enforce in the presence of multiple output buyers. Because monitoring costs for crop-secured credit can be reduced further if loans are distributed in the form of inputs, rather than cash, monopsonists in agricultural output markets often distribute inputs at all points where production is collected. In the absence of crop-secured lending, the spatial distribution of inputs suppliers may contract relative to the distribution of output markets, raising the travel costs that farmers face when buying inputs. That fertilizer use has declined in many African settings despite improvements in output prices suggests the possibility that transactions costs in quality assurance, seasonal finance, or travel may be stifling output response. The trend in inputs usage, however, might also be explained by increasing inputs prices.

It has been well-established that transactions costs in output markets influence crop choice and marketed supply response (Goetz, 1992; Jayne, 1994; Key et al., 2000; Omamo, 1998). Inputs markets may be subject to costs that differ from those in product markets, and thus transactions costs in those markets may impose a separate constraint on intensification. For

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example, inputs distributors may be concentrated in larger towns while product buyers are present in villages, implying different travel costs for inputs and outputs. Similarly, the costs of finance that farmers face may affect the costs of acquiring inputs, but not the costs of selling output.

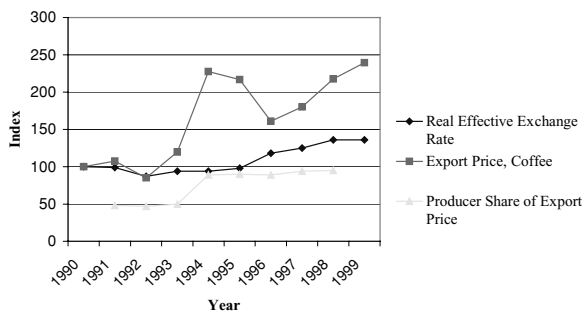
To better understand the constraints on African export crop production, this article examines the influences of prices and transactions costs on the markets for inputs and outputs among a sample of 250 coffee growers in Tanzania. The transactions costs considered are the travel costs in output marketing and costs relating to input use. Because prices for coffee vary both across villages and through the extended harvest season, the output price data used here show considerable farm-level variability. Relative to a frequent situation in which prices vary only at the village or regional level, these data allow greater opportunity to measure the relative impacts of prices and transactions costs.

As in Jha and Hojjati (1993), Saha et al. (1994), and Minot et al. (2000), this article uses a selection model to assess the impact of various factors on the separate decisions of whether or not to use an input and the amount of the input to use. In contrast to other work on the subject, this article interprets results by distinguishing between fixed transactions costs, which should influence only the first decision, and variable transactions costs, which can influence both decisions. This distinction serves to improve the estimation procedure and yields insights into the effectiveness of specific mechanisms for reducing transactions costs. Also, to better assess the degree to which liquidity constrains inputs use, the research uses two-stage least squares to address potential endogeneity of income.

2. Trends in agricultural inputs use

Between 1990 and 1999, coffee growers in Tanzania saw incentives rise through (1) macroeconomic reforms that produced a 50% depreciation of the real exchange rate (World Bank, 2001); (2) domestic market liberalization, which led to the share of the world price transmitted to farmers rising from 50 to 90% (Market Development Bureau, 2000; Winter-Nelson and Temu, 2002); and (3) world market prices that steadily climbed from 1.40 to 3.00 US\$ per kg (UNFAO, 2002). Despite these remarkable improvements in producer incentives (shown in Fig. 1), coffee output and agricultural production, in general, remained flat (Fig. 2). While lack of an output response may be partly attributable to the lag between planting coffee seedlings and harvesting from mature plants, the low yields experienced by Tanzanian farmers imply considerable room for increased output from existing mature trees. Coffee yields in Tanzania over the 1990s averaged 70% of the level achieved in similar ecological situations in Kenya.

There is evidence of a general decline in the use of intermediate inputs during the 1990s. According to the UNFAO, fertilizer consumption in Tanzania fell from 46,800 MT in 1990 to 21,000 MT in 1999 (Fig. 2). Meanwhile, the value of pesticide imports dropped from 18 million US\$ (mUS\$)

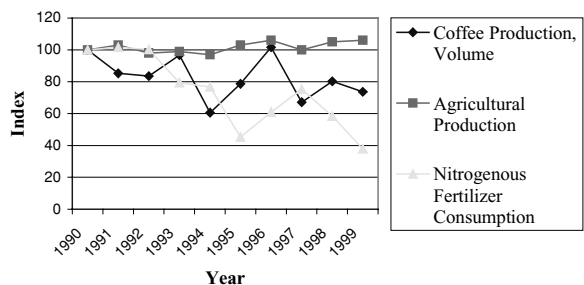


Source: Real effective exchange rate data are from World Bank (2001); export price data are from UNFAO (2002); and producer share of export price data are from Market Development Bureau (2000).

Fig. 1. Agricultural incentives, Tanzania.

in 1990 to 14 mUS\$ in 1995 and 10 mUS\$ in 1999. Household data collected for this research suggest a similar trend. Sixty-five percent of 250 coffee growers surveyed in 2001 reported that they had used agrochemicals in each of the 5 years up to liberalization in 1995, but only 37% of them indicated that they had continued to use purchased inputs regularly since 1995.

Reduced inputs usage could reflect a number of developments. First, it may be a response to changes in the relative prices of inputs and outputs. Through the 1990s, devaluation of the Tanzanian shilling (Tsh) followed by currency market liberalization brought substantial increases in the local price of imported fertilizer and chemical inputs. At the same time, trade liberalization increased the range of chemicals being imported, resulting in increased costs to the governmental regulatory system and a new tax on agrochemicals. Meanwhile, changes in market structure may have brought even greater increases in the input prices perceived by farmers. Prior to coffee market liberalization in 1995, growers received inputs from cooperative societies on credit, with the costs deducted from final receipts. This financing system could be maintained at low enforcement and monitoring costs because all smallholder coffee was marketed via the cooperative system. Through automatic deductions, farmers paid for inputs and other cooperative services in proportion to their coffee deliveries. Because the costs



Source: UNFAO (2002).

Fig. 2. Agricultural performance, Tanzania.

of inputs were bundled with other cooperative expenses, many growers believed that the inputs were provided at little or no charge by the central government. For these growers, the perceived price increase in 1996 was from a base of near zero. Furthermore, since those who did not use inputs still paid for them through a deduction from sales revenues, nonusers subsidized users prior to 1996. Another implicit subsidy had been provided to input users through low interest rates that were charged on the provided inputs. At the same time that these real or perceived inputs subsidies were removed, output prices initially rose, as marketing margins fell and international prices rose, and then fell precipitously in 2000 and 2001 because of a collapse in international market prices.

Aside from affecting relative prices, liberalization may have raised transaction costs in input markets. First, by opening up multiple channels for output marketing, liberalization complicated the provision of crop-secured loans, causing farmers' costs of seasonal finance to rise. Prior to liberalization, all coffee growers had access to inputs on credit through cooperatives. With the emergence of competitive coffee trade, enforcement of crop-secured loans became unmanageable and the credit system disintegrated. While all growers had access to seasonal credit under the controlled system, most growers have had to self-finance input purchases since 1996.

Beyond affecting the costs of seasonal finance, liberalization had implications for the spatial distribution of input markets. Prior to liberalization, inputs were distributed through village-level cooperative societies where coffee production was also purchased. Since liberalization, most farmers have continued to sell output at local villages, but inputs are usually purchased in towns that can be reached only at greater distance. Many coffee buyers do provide inputs at villages during the peak coffee marketing season. Street vendors may also provide coffee inputs for sale in villages at other times of the year. Nonetheless, most surveyed coffee growers chose to buy inputs at distant markets rather than in their local villages. On average, surveyed growers traveled less than 3 km to sell output, but went about 15 km to buy inputs in 2001.

The tendency to buy inputs in towns rather than in villages may be explained by liquidity constraints and efforts to gain quality assurance. Although inputs are often available from coffee buyers during the peak sales period, liquidity-constrained growers might prefer to delay input purchases until closer to the time of application. Street vendors offer inputs in some villages in a more timely manner, but there have been numerous reported cases of paint, solvents, or diluted agrochemical solutions being sold as pesticides by such vendors. The risk of purchasing poor-quality inputs may be addressed by use of larger shops that have longer records and observable sunk investments to enhance their reputations. Reliance on such shops implies increased travel costs.

Since the primary cooperative societies were, in fact, often unable to provide adequate supplies in a timely manner, it may not be the case that transactions costs rose after liberalization. In the absence of time series data, this article will not test whether transactions costs have changed because of marketing

reforms. Rather, it aims to measure how prices and transactions costs in inputs and output markets currently affect input use decisions.

3. Surveyed coffee growers

The data for this analysis come from a stratified random sample of 250 coffee growers in Northern Tanzania surveyed between August and December 2001, with selected revisits in April 2002. Farmers were questioned concerning farm operations, sources of finance, social networks, and marketing behavior. Some descriptive statistics from the sample are provided in Table 1. Reflecting out-migration of young men, the average age of household heads in the sample was high, 55 years. All respondents had grown coffee throughout their adult lives and all had knowledge of recommended inputs. Fewer than 7% of them had never used purchased inputs. Hence, this study is not an analysis of the adoption of a new technology, but of the use of a known one. Scale of production ranged from a low of 20 trees to a high of 15,000, with farms ranging from 0.25 to 21 acres in size.¹ Household income and wealth (measured as an index of various assets) showed similar ranges. Yields varied widely across the sample, with many farmers harvesting no coffee and a high of about 5 kg per tree. Comparison of mean and median values indicates a skewness in the distribution of yields, sales, and total income. Logarithmic transformation of the data achieves normality for the purposes of later estimations. Prices received in 2001 ranged from Tsh 250 to Tsh 1,000 per kg, depending on timing of sale, location, and the intermediary chosen. Falling prices during the marketing season are the primary cause of intra-village price variation. Product quality is difficult to discern at the point of sale and does not appear to have influenced the product prices within villages.

Expenditures on chemical inputs averaged Tsh 7,500, compared with average coffee revenues of over Tsh 100,000. In contrast to output prices, input prices were almost constant across the sample, reflecting reliance on distributors whose prices are set in contracts with wholesalers. Average distance to input markets was five times greater than distance to output markets (14.5 km compared to 2.69), and a large share (36%) of users relied on buses or cars to transport inputs while 40% transported inputs on foot. In contrast, 72% of growers delivered their output on foot and only 11% used vehicles. Among the input users, the average volume of pesticides purchased was less than 10 kg.

Partly to offset the costs of travel, many of the surveyed growers organize themselves into groups for joint sales or purchases. Twenty percent of those surveyed had bought inputs jointly with other growers, while over 47% had sold jointly with others. Because of the potential for social networks to affect farmer decisions and costs, the survey solicited information

¹ Producers at either extreme of the range in tree count could be considered outliers. However, results of statistical analyses were not affected by the exclusion of those who had fewer than 60 or more than 6,000 trees. Model results shown in this article include the full range of farm scale.

Table 1
Descriptive statistics

	<i>N</i>	Minimum	Maximum	Mean	Std. dev.	Median
Age of household head (years)	248	26	90	55	12.97	54
Education of household head (years)	248	0.00	20	6.38	3.44	7
Household size (headcount)	247	1.00	7.00	4.00	1.51	4
Female-headed household (0/1)	250	0.00	1.00	0.09	0.29	0
Tree count	247	20	15,000	857	118,914	615
Average age of trees (years)	243	2.00	100	31.50	16.82	30
Wealth index	249	0.00	14.45	2.24	1.98	1.72
Total household income (Tsh), 2000	247	0.00	3,550,000	328,686	485,220	140,000
Income per household member (Tsh)	245	0.00	626,667	83,075	115,354	36,000
% of income from nonfarm source, 2000	247	0.00	100	14.25	28.94	0.00
Yield (Kg/tree), 2000	247	0.00	5.00	0.41	0.65	0.23
Yield (Kg/tree), 2001	247	0.00	4.50	0.20	0.42	0.14
Price (Tsh/kg), 2000	223	350	1,500	660	225.84	650
Price (Tsh/kg), 2001	186	250	1,000	533	130.04	500
Total sales (kg), 2000	246	0.00	5,000	246	412.56	120
Total sales (kg), 2001	247	0.00	4,000	185	405.22	50
Chemical inputs used (Tsh), 2001	250	0.00	125,000	7,510	18,259	0.00
Repeated inputs use since, 1995 (0/1)	250	0.00	1.00	0.43	0.49	0.00
Travel time to market (min)	241	0.00	120	31	23.75	30
Distance to inputs source (km)	198	0.05	57.00	14.51	17.78	7.00
Distance to coffee buyer (km)	219	0.00	125.00	2.69	10.69	1.00
Joint purchases (0/1)	250	0.00	1.00	0.20	0.40	0.00
Joint sales (0/1)	250	0.00	1.00	0.47	0.50	0.00
Associational activity (0/1)	249	0.00	1.00	0.16	0.37	0.00
Purchased bad inputs (0/1)	249	0.00	1.00	0.41	0.49	0.00
No access to credit (0/1)	250	0.00	1.00	0.60	0.49	1.00

Source: Survey results.

on formal and informal associations. The data reveal a subset of farmers, 17%, who were especially active in formal associations such as churches/mosques, cooperatives, and self-help groups.

Concerning input quality, 40% of the growers surveyed reported that they had bought inputs that proved to be ineffective or harmful in the past. While many farmers had suffered losses through purchase of poor-quality inputs, almost all growers reported that purchasing from reputable dealers would ensure the quality of agrochemicals. Growers reported that such dealers were not necessarily more expensive than other sources, but that they could be reached only by traveling “a long way” relative to other suppliers.

Chemical inputs expenditures in 2001 ranged from 0 to Tsh 125,000 with the majority of growers buying none. Recommended practices call for use of chemical fertilizer and repeated application of copper-based fungicides to control leaf rust, other fungicides to address coffee berry disease, and insecticides. Failure to use these inputs results in lower yields and lower quality coffee selling at a discount in international markets.² Of the surveyed farmers, only 60% used any of the recommended

inputs in 2000, and only 35% applied one or more of them in 2001. Less than 10% used all the recommended inputs in either year. Among the users, applications rates averaged about 60% of the recommended rate (Table 2). Although most farmers did not use chemical inputs in 2001, fewer than 20% considered the products to be ineffective and less than 5% reported that they were unavailable. However, relatively large percentages attributed their low use of inputs either to a lack of cash for purchases (70%), to a lack of credit for purchases (30%), to a lack of household labor time (35%), or to a lack of funds to hire workers (72%). Over 60% of the growers reported that they had no access to credit from formal or informal sources to finance input usage.

Table 2
Surveyed coffee growers' use of purchased inputs (*n* = 250)

	Share of growers applying input (%)		Median rate per 1,000 trees (kg) (2000/2001) ^a	Recommended application rates (kg)
	1999/2000	2000/2001		
Fertilizer	8.6	6.5	62	100
Red copper	19.8	9.1	8.4	14
Blue copper	55.6	31.5	7.0	10
Any of the above	60.8	35.3		

Source: Survey results.

^aMedian rate over those applying the inputs only.

² If this coffee could be certified as organic, the discount would become a premium. However, organic certification is not likely for smallholder-grown Tanzanian coffee since neither mechanisms for identity preservation from farm through factory and auction, nor monitoring systems to ensure farm-level compliance, are in place.

4. Conceptual model

This article seeks to build on existing work on transactions costs in agricultural markets (Key et al., 2000) by assessing the impact of transactions costs on input usage. Such analysis is relevant because inputs may be subject to different sources of transactions costs than outputs and because input usage may be affected by transactions costs in output markets. To focus on this theme, the analysis is based on a simple static model of an agricultural household in which utility is a function of net revenue, such that the household objective is to

$$\text{MAX}(U) = U(PQ - C_i I_i),$$

s.t.: $g(Q, I_i; \mathbf{Z}) = 0$, production function.

Here, P is the output price, Q is the volume of output, I_i and C_i reflect the quantity and unit cost of input i , and \mathbf{Z} is a vector of household characteristics. Output is described by a production function in which $\partial Q/\partial I_i > 0$, $\partial^2 Q/\partial I_i < 0$. To include variable transactions costs (vtc) explicitly, define $C_i = (p_i + \text{vtc}_i)$, where p_i is the unit price of input i and vtc_i is the transaction cost per unit of input i . Similarly, the effect of variable transactions costs in output marketing (vtc_o) can be included through a downward adjustment in output price. Given the low volumes of inputs used in this study area, travel costs to buy them are probably invariant to marginal increases in use rates. To accommodate such fixed transactions costs (ftc) of input usage, expand the objective function as in Key et al. (2000) to

$$\text{MAX}(U) = U((P - \text{vtc}_o)Q - (p_i + \text{vtc}_i)I_i - \text{ftc}_i(\tau_i)),$$

$$\tau_i = 1 \quad \text{if } I_i > 0$$

$$\tau_i = 0 \quad \text{if } I_i = 0.$$

While this objective function could be expanded to reflect factor market failures, risk aversion, nonrevenue goals, time and income constraints, etc., first-order conditions will yield a reduced form demand for input j of

$$I_j = f(P, \text{vtc}_o, p_i, \text{vtc}_i; \mathbf{Z}) \quad \text{if } \tau_j = 1,$$

implying that for those who use inputs, the amount used is unaffected by the fixed transaction costs. Once the cost of participating in the market is paid, fixed transaction costs do not affect the use rate. Participation in the market is determined by discrete comparison of expected utility given $\tau_i = 1$ and $\tau_i = 0$, and will therefore be affected by the fixed and variable transactions costs.

The above static model could be made dynamic by including past input use, as suggested by Besley and Case (1993). A dynamic model would be appropriate if learning or sunk costs affected costs or benefits from use of a technology over time. In the current application, the technology in question is not new. Learning effects are therefore not likely to be significant and the static model is applied.

5. Empirical analysis of inputs usage

Cross-sectional analyses of fertilizer or agrochemical use in developing countries usually take one of three approaches. In many cases (Green and Ng'ong'ola, 1993; Kaliba et al., 2000) a probit or logit model is specified to explain whether or not farmers use a given input without considering intensity of use. Alternatively, a tobit model can be applied if the same process determines both whether a product is used and the intensity of use (Nkonya et al., 1997). A few studies have applied double-hurdle models in which the decision to use the input and the decision of how much to use may be affected by different factors (Coady, 1995). Because fixed transactions costs could be expected to affect the decision to participate in a market, but not the intensity of participation, variants of the double-hurdle model are appropriate when such transactions costs may be large. Assuming that the decision to use or not must be made before the use-intensity decision, a double-hurdle approach can be applied, using Heckman's sample selection method (Jha and Hojjati, 1993; Minot et al., 2000). In this case, a probit model is used to describe the participation decision and to generate the inverse Mills' ratio, which is used in a separate regression to explain the intensity of use among users.³ (Heckman, 1976)

The first element of the selection model is the probit equation to predict participation in inputs markets:

$$\text{Prob}(\text{INPUT USE} = 1) = 1 - F(-\alpha\mathbf{X}) + u, \quad u \sim N(0, 1), \quad (1)$$

where INPUT USE takes the value of 1 if farmers used any red copper, blue copper, or chemical fertilizer on their 2001 crop, and is 0 otherwise; \mathbf{X} is a vector of explanatory variables; α is a vector of coefficients to be estimated and u is a random error.

The second equation is a regression explaining the intensity of input use (USE RATE) measured in total expenditures on the three chemical inputs per coffee tree in 2001:

$$\text{USE RATE} = \beta_1\mathbf{X} + \beta_2\lambda + \varepsilon, \quad \varepsilon \sim N(0, \sigma^2). \quad (2)$$

Here λ represents the inverse Mills' ratio calculated from Eq. (1) as $\varphi(\alpha'\mathbf{X})/\Phi(\alpha'\mathbf{X})$, where φ is the probability density function and Φ is the cumulative distribution function of the standard normal. Including λ in the OLS estimation of Eq. (2) avoids sample selection bias that would otherwise arise, while dropping at least one exogenous variable that is present in Eq. (1) from the estimation of Eq. (2) ensures identification (Madalla, 1983).

Explanatory variables in Eqs. (1) and (2) include measures of output price, transactions costs, factors mitigating transactions costs, environmental factors affecting input responsiveness, and farm and farmer characteristics influencing the costs or impacts of input use. Price effects are measured with the coffee price

³ The Heckman approach may also be implemented, using a maximum likelihood technique (StataCorp). Applying this approach to our data yielded qualitatively similar results.

in the 2000 crop year. Because input prices showed almost no variation across users, the output price reflects the relative price of output to inputs and is expected to be positively correlated with participation in the market and with the rate of use.

Because inputs markets are not as widely distributed as output and food markets, farmers face different travel costs when they sell their output than when they purchase inputs. Both these costs can affect input use. Distance to commodity markets effectively reduces the returns to coffee production and therefore is expected to negatively effect both participation in input markets and the intensity of use. Because the volumes of inputs purchases are low and the location of shops can be inconvenient, the cost of traveling to purchase inputs is probably fixed over the quantities transacted. Thus, the distance to an input source is expected to affect participation, but not the intensity of use. Travel costs associated with input purchases were measured by the distance in kilometers that farmers traveled to buy inputs (inputs distance). For growers who had not purchased inputs in the last 2 years, the average distance reported in their village was used. Travel costs in product markets were measured by the time required to reach the nearest cooperative office or commercial center (remoteness).

Previous experience of using poor-quality inputs is expected to have a residual impact on farmers' use decisions. A dichotomous variable (used bad inputs) taking the value of 1 if farmers reported purchasing poor-quality agrochemicals in the past and 0 otherwise is therefore included in the estimation. This variable is expected to be negatively correlated with participation in Eq. (1), because of mistrust in the value of inputs that can only be overcome by incurring some cost. Since this cost of quality assurance is not related to the quantity of inputs used, prior use of bad inputs is not expected to affect the use rate decision.

Poorly developed and high-cost financial institutions may result in liquidity constraints that limit input usage at zero or some other point below the desired rate. Thus we expect liquidity to be positively correlated with participation in the input market and the rate of use. Survey data revealed that only 8% of farmers felt they could borrow money from a formal financial institution, and only 1 farmer of the 250 sampled had purchased inputs on credit in the previous year. In the absence of widespread access to credit, liquidity is closely related to wealth, which is measured here by a weighted average of the number of cars, bicycles, dairy cows, oxen, donkeys, sheep and goats, and radios owned by residents of the household. The weights used in the analysis were based roughly on market values, using a dairy cow as the base. Models were estimated, using a range of weights, with little impact on results. Because these assets are not fully divisible, relatively high levels of this wealth index may not address liquidity constraints, and its insignificance in the regression does not necessarily imply the absence of a financial constraint.

Given the difficulties involved in measuring wealth in developing countries, household income is commonly used as a measure of liquidity (Coady, 1995; Kaliba et al., 2000). A problem with this measure is that it may not be exogenous to input

usage; farmers who regularly use more inputs are expected to have greater farm cash revenues. To address this potential endogeneity, farm income in the year 2000 is regressed against a set of exogenous variables including those in Eq. (1), and predicted values from that regression are used as an instrument for actual farm income in the selection model.⁴ Nonfarm income from 2000 is included as a separate exogenous variable in the model. It includes salary, business income, remittances, and gifts received in 2000. Aside from being less subject to endogeneity, nonfarm income may have a distinct impact on input use because it represents finance that is not linked to the agricultural calendar. Income in 2000 is used because chemical applications for the 2001 coffee harvest would be made in late calendar year 2000 or early 2001.

Social capital is increasingly recognized as a resource that can influence production decisions and economic outcomes (Grootaert, 2001; Narayan and Pritchett, 1999). In this analysis, social capital is measured through a dichotomous variable (associations) taking the value of 1 if a household head belongs to at least four of the following associations: church or mosque, primary cooperative society, self-help group, farmers' cooperative, or financial association. These associations were available throughout the areas surveyed. The threshold of four was selected in an effort to ensure real activity as opposed to purely nominal participation. Social interaction in any of these associations may diminish the effects of fixed transactions costs, by reducing costs of learning about input efficacy, market conditions, and dealer reputations, or by facilitating group buying to divide the fixed costs of travel. Through reputation or monitoring, social networks might also allow greater access to finance and reduce the potential for a liquidity constraint to affect either the decision to use an input or the decision on the rate of use. If associational activity affects only the fixed transactions costs, but not liquidity constraints, it will be positive and significant in the participation model, but not the use intensity model.

The impact of fixed transactions costs on the decision to participate could be mitigated by scale. Tree count, the number of mature coffee trees on land controlled by the grower, is therefore expected to be positively correlated with participation in input markets. The well-documented tendency for management intensity to decline with scale in tropical Africa (Feder, 1985) suggests that tree count will be negatively correlated with the intensity of input use.

Environmental factors included in the model are the average age of mature coffee trees (tree age) and a dummy variable for Monduli district, the most environmentally distinct of the four districts represented in the survey. Input use intensity is expected to rise with age (and size) of trees. Monduli district receives less rainfall than the other regions surveyed, and has fewer rivers and streams (United Republic of Tanzania, 1998).

⁴ In their Heckman sample selection model of fertilizer adoption, Jha and Hojjati (1993) apply a similar instrumental variables approach to address endogeneity in area cropped and variety planted. Newey (1987) provides a theoretical justification for this method.

Lower and less reliable rainfall reduces the return on pesticide use, while reduced access to water generally makes pesticide application more difficult. Thus, being in Monduli is expected to negatively affect the participation decision and to lead to lower use rates among those who do use inputs. Farmer characteristics include age (in years), education (in years of formal schooling), and gender (1 = female). Since the technology under study here is not new, experience and education are not expected to have strong effects. The number of residents (residents count) and the share of residents over 65 or under 15 years of age (dependency ratio) were included to assess the impact of household labor availability. Finally, past use of inputs was measured through a dummy variable taking the value of 1 if a farmer reported having used chemical inputs repeatedly in the last 5 years. This variable was included to capture unmeasured farm and farmer characteristics that increase the likelihood of using inputs. All data that are not categorical were converted into log form for estimation. Because of the frequency of zeros in the data, 1 (one) was added to all observations before converting into log form.

6. Results

Prior to estimating the selection model, an instrument for farm income was calculated, using OLS. Exogenous variables in this estimation included all those described earlier in this article plus dummy variables representing two of the four districts surveyed (Hai and Moshi) and participation in group selling arrangements. As shown in the first column of Table 3, statistically significant variables have the expected signs. Farm income is positively correlated with coffee price received, number and maturity of trees, and the past use of chemical inputs. The coefficient on wealth is positive, but statistically insignificant, a result that may reflect the coarseness of the wealth index, the absence of a link between these assets and income, or the tendency for wealth to be more related to nonfarm than to farm income. Although most of the coefficients are statistically insignificant, the *F*-test indicates joint significance and confirms the relevance of the predicted values as an instrument for farm income.

The second column of Table 3 presents results from the probit model of participation in input markets. A Durbin–Wu–Hausman test failed to reject the hypothesis of endogeneity of farm income in this model and the models in Table 4, confirming the appropriateness of applying the instrument.⁵ In the probit model, the output price is a significant and large determinant of the decision to use inputs. In addition to price, transactions costs appear to play a role. The negative and significant coefficient on remoteness indicates that travel costs in the market for output diminish the probability of using purchased inputs. The

⁵ To test the endogeneity of farm income, the residual from the regression estimating farm income was included in the selection model along with actual farm income. A statistically significant coefficient on the residual in both stages of the selection model was taken as evidence of the endogeneity of farm income.

Table 3
Selection model for inputs (probit stage)

Dependent variable	Farm income (OLS)	Input use (ML probit)	
		Coefficient	Marginal effect (dF/dx)
Output price	0.808** (2.07)	0.894* (1.82)	0.300*
Remoteness	0.082 (0.45)	−0.316** (2.08)	−0.106**
Inputs distance	0.111 (0.77)	−0.283** (2.26)	−0.095**
Tree count	0.307** (2.26)	−0.059 (0.37)	−0.020
Tree age	0.732*** (3.54)	−0.135 (0.51)	−0.045
Farmer age	0.224 (0.39)	0.442 (0.80)	0.149
Farmer education	0.281 (1.23)	0.131 (0.71)	0.043
Female head	−0.511 (1.20)	0.786* (1.85)	—
Residents count	0.473 (1.05)	−0.913* (1.90)	−0.306*
Dependency ratio	−0.461 (0.71)	0.123 (0.19)	0.041
Predicted farm income	—	0.496 (1.59)	0.167
Nonfarm income	0.013 (0.51)	0.032 (1.48)	0.011
Wealth	0.258 (0.93)	−0.552* (1.69)	−0.185*
Associations	0.053 (0.15)	0.570* (1.63)	—
Repeated inputs use	0.861*** (2.68)	1.187*** (2.97)	—
Used bad inputs	−0.130 (0.49)	0.093 (0.33)	—
Monduli	0.103 (0.19)	−0.850 (1.32)	—
Hai	−0.871** (2.15)	—	—
Moshi	−1.055*** (2.65)	—	—
<i>R</i> ² (pseudo <i>R</i> ²)	0.33	(0.37)	—
<i>n</i>	193	193	—
<i>F</i>	6.47	—	—
Log likelihood	—	−80.50	—
Wald Chi ²	—	62.51	—
Outcomes correctly predicted	—	80.31%	—

Note: Robust Huber–White *t*-statistics in parentheses. In each regression, joint insignificance is rejected at 1%. Marginal effects are not reported for categorical variables.

*, **, *** represent significance at 10, 5, and 1%, respectively.

distance to an input source discourages input use to a similar degree. Since input markets are five times more distant than output markets, there may be a considerable potential to increase inputs use through expansion of the input distribution system.

The coefficients on farm and nonfarm income are positive, but significant only at 11 and 14%, respectively. A likelihood ratio

Table 4
Selection model for inputs use intensity (Second stage)

Dependent variable	Inputs usage per coffee tree		
	Model 1	Model 2	Model 3
Output price	1.516*** (2.27)	1.327*** (2.98)	1.244*** (3.19)
Remoteness	-0.376* (1.72)	-0.426** (2.29)	-0.387** (2.40)
Inputs distance	-0.167 (1.04)	—	—
Tree count	-0.707*** (4.60)	-0.706*** (4.68)	-0.705*** (5.12)
Tree age	0.115 (0.55)	0.156 (0.43)	0.137 (0.76)
Farmer age	0.150 (0.30)	0.138 (0.31)	—
Farmer education	0.113 (0.45)	0.091 (0.35)	—
Female head	0.980* (1.96)	0.811** (2.31)	0.773** (2.59)
Residents count	-1.350** (2.40)	-1.358*** (3.22)	-1.359*** (3.57)
Dependency ratio	0.729 (1.36)	0.656 (1.20)	0.673 (1.31)
Predicted farm income	0.636* (1.89)	0.593*** (2.61)	0.577*** (3.01)
Nonfarm income	0.013 (0.58)	-0.005 (0.30)	—
Wealth	-0.201 (0.46)	-0.094 (0.32)	—
Associations	0.523 (1.37)	0.392 (1.35)	0.335 (1.32)
Repeated inputs use	1.319 (1.37)	1.079* (1.64)	0.949* (1.67)
Monduli	0.875 (0.70)	—	—
λ (Mills' ratio)	1.366 (1.31)	1.209** (2.38)	1.091*** (2.69)
n	73	73	73
F	4.85	5.00	7.61
Adj. R^2	0.48	0.45	0.50
Ramsey omitted variable (F)	1.10	1.51	1.01

Note: Robust Huber–White t -statistics in parentheses. All variables except dummy variables have been converted into log form. In each regression, joint insignificance is rejected at 1%.

*, **, *** represent significance at 10, 5, and 1%, respectively.

test, however, indicated joint significance of farm and nonfarm income at 9%, $\chi^2(2) = 4.96$, suggesting the role of liquidity in the participation decision. A negative relationship between wealth and input use is contrary to expectations and probably reflects the crudeness of the wealth index as a measure of liquidity. The positive and significant coefficient on associations suggests that associational activity can reduce the fixed costs of using inputs. This result is consistent with observed pooling of transactions to lower fixed travel costs, and the opportunity that all associations provide for sharing and processing information about the use of chemicals, prices, and the reputation of distributors. Contrary to expectations, female-headed households

were more likely to use inputs than other farms, once differences in other variables are accounted for. Minot et al. (2000) find a similar result. In their case, as here, the small number of female-headed households in the sample may affect the outcome.

The experience of having purchased poor-quality inputs does not affect the probability of buying. Since the initial deregulation of the markets, buyers have developed ways to avoid poor-quality materials. Over 90% of the survey respondents indicated that the main method of avoiding poor-quality products was to not buy from street vendors. Apparently, the institutions to reduce risk of poor product quality have developed and transitional experiences with poor quality control are not exerting a persistent effect on use decisions. Aside from past use of chemical inputs and gender, variables capturing farmer characteristics (age, education) are insignificant individually and jointly, $\chi^2(2) = 0.80$. Because the technology in question is not new, the insignificance of age and education is not surprising. Tree age, tree count, and Monduli district were also individually and jointly insignificant, $\chi^2(3) = 2.11$.

Table 4 presents three specifications of the use intensity model. The dependent variable in these regressions is input expenditure per tree. The regressions were run, using iteratively reweighted least-squares to address heteroskedasticity (StataCorp, 1999). Because fixed costs should not influence the degree of input use, experience with poor-quality inputs was excluded from the intensity of use models. By the same reasoning, distance to an input dealer (inputs distance) should be excluded unless there is a variable component in the travel cost. Inputs distance is included in the first specification of the use intensity model to test whether or not it has an impact on use rate. Insignificance of the variable implies that distance presents a fixed cost only, making it appropriate to exclude it from the intensity regression. Dropping this variable has the added benefits of ensuring identification of the estimation and increasing degrees of freedom. Given its insignificance in the first specification and in the probit model, and out of consideration for the small sample size, the dummy variable for Monduli district is also dropped from the second specification. A more parsimonious specification is estimated in the third column. In each of the specifications the Ramsey test fails to reject the hypothesis of no omitted variables. Statistical significance of the Mills' ratio in models 2 and 3 implies that selection bias would arise if it were excluded.

Estimated coefficients and significance levels are similar across the estimations in Table 4. As in the probit stage, the output price has a highly significant influence on the intensity of input use. A 1% increase in output price is estimated to raise input expenditure by 1.25% or more. This suggests that by reducing marketing margins, liberalization encouraged increases in input use. At the same time, the dramatic declines in coffee prices since 1999 are likely to have stimulated dramatic declines in investment in coffee. Reflecting its fixed cost attributes, distance to input dealers does not affect the rate of application by users, but remoteness from the product markets does influence

input intensity. Since remoteness effectively reduces the output price and may increase the costs of complementary inputs, this result is consistent with expectations. Although wealth and nonfarm income are not statistically significant, some evidence that liquidity affects the intensity of use is given by predicted farm income which is significant and large in its impact. The negative and significant coefficient on tree count is consistent with expectations concerning the inverse relationship between scale and productivity. This inverse relationship could itself be attributed to a financial constraint, if farmers with more trees lack the liquidity to secure sufficient inputs or wage labor for their scale.

As in the probit model of participation, there is no evidence that household labor availability constrains input use. Indeed, the number of residents is negatively associated with use intensity. This result may reflect a preference for using hired labor for chemical application. The combination of the strenuousness of operating a pesticide sprayer and the need for timeliness in application remove children, teenagers attending school, older farmers, and most women from the pool of potential applicators. Lack of a sprayer or protective clothing and particularly sensitive skin were also reasons why household labor was not used for spraying. Other evidence that household demographic variables poorly represent the labor available for spraying may be seen in survey results showing that twice as many households felt that the availability of hired household labor time was a constraint. Repeated past use of inputs is associated with more intensive use of chemicals, which is consistent with expectations. Female household head is positively correlated with input intensity, but farmer age and education level, as well as tree age, are statistically insignificant.

The coefficient on associations is positive but statistically insignificant. The reduced statistical significance of associations between the probit and the intensity stages is partly a consequence of the reduced sample size. Nonetheless, the finding that associational activity encourages use of inputs but does not affect the intensity of use suggests that this social capital only influences fixed transactions costs. While associations could affect variable costs by providing lower cost finance or facilitating access to labor for chemical application, the results imply that they are not doing so effectively.

The marginal effects of variables in a selection model can be calculated in many ways. The marginal effects in Table 3 indicate the change in the probability of participating in the inputs market given a change in the exogenous variable. These values suggest that output price and remoteness, both of which reflect the relative price of output to inputs, have the largest impacts on the decision whether to use inputs. Distance to input markets also has an impact on the probability of using inputs, which is similar in magnitude to the effect of travel time to an output market.

The relationship between the exogenous variables and the rate of input use may be assessed either conditional on using inputs at the time of the survey, or unconditionally. Because the

double-log specification is used, the coefficients in Table 4 are elasticities conditional on participation. Again, output price and remoteness from output markets have relatively large impacts on use intensity, and liquidity, as reflected in predicted farm income, also has a substantial marginal effect.

Unconditional marginal effects capture the joint impact of a variable on the changes in the rate of market participation and in the intensity of use. As shown in Huang et al. (1991), the unconditional marginal effect of a change in an exogenous variable can be calculated as the corresponding change in the intensity of use weighted by the probability of participation plus the corresponding change in the probability of participation weighted by the predicted rate of input use. Table 5 presents the unconditional marginal effects calculated at the mean, and reports separately the effect on chemical input use through changes in participation and changes in intensity of use. Setting aside demographic variables (age and residents count) the largest marginal effect emerges from price, with an elasticity of 1.5. About two thirds of the impact is through increased participation in input markets and one third from increased intensity of input use. Travel costs are also significant, with a 1% reduction in the time required to reach output markets or the distance required to reach inputs markets, leading to increases in input use of 0.5 and 0.3%, respectively. Finally, the marginal effect of predicted income appears large, suggesting a potential for improved liquidity to increase inputs use.

The high estimated elasticity of input use with respect to output price reported from this cross-sectional data is consistent with the dramatic decline in inputs use between 1999 and 2001, when prices fell by 65% and participation declined from 60 to 35%. While these price effects are substantial, the elasticities with respect to farm income and distance to inputs markets suggests some possibility for promoting input usage, even under reduced prices. For example, making inputs available at all points of output sale would reduce the distance to input markets

Table 5
Unconditional marginal effects

Dependent variable	Full unconditional marginal effect	Marginal impact via participation	Marginal impact via intensity
Output price	1.51*	1.00*	0.51*
Remoteness	-0.52*	-0.36*	-0.16*
Inputs distance	-0.32*	-0.32*	—
Tree count	-0.34*	-0.07*	-0.27*
Tree age	-0.09	-0.15	0.06
Farmer age	0.55	0.49	0.05
Farmer education	0.18	0.14	0.03
Residents count	-1.55*	-1.03*	-0.52*
Dependancy ratio	0.39	0.14	0.25
Predicted farm income	0.79*	0.56*	0.23*
Wealth	-0.66	-0.62	-0.04
Nonfarm income	0.04	0.04	0.00

Note: Calculations based on data from model 2, Table 4, and probit result in Table 3. Marginal effects are not reported for categorical variables.

* indicates that the value is based on statistically significant coefficients.

by over 80%. Given the marginal effect of -0.32 on inputs distance in Table 5, this implies scope for expanded distribution to increase input usage.

7. Conclusions

In practice, Africa's agricultural liberalization programs in the 1990s focused on output markets and neglected other exchanges in production systems. Implicit in these programs was the assumption that exchanges would arise at reasonably low costs to support production and trade. By measuring the impact of nonprice factors on the use of purchased inputs, this article has attempted to test the appropriateness of that assumption. Findings show that coffee growers' use of inputs is highly sensitive to output price, but that transactions costs in travel also influence input use and consequently output. Results also provide some evidence that liquidity constraints restrict input use. At the same time, there is evidence that farmers are organizing to reduce some of these transactions costs.

In the case studied here, output price, transactions costs in output markets, and transactions costs in input markets each influence input use. Market liberalization in 1995 reduced marketing margins by about 30% of the average output price (Temu et al., 2001), which, based on these results, would lead to an increase in input use of 45%. Any contraction in the distribution of inputs or the availability of finance could reverse this effect. If farmers shifted from purchasing inputs at cooperative societies to the current distributors, average distance to input markets would have risen by over 400%. Based on the elasticities in Table 5, an increase in distance of 150% would have been sufficient to fully offset the effect of improved output prices on input use. Rising travel costs in input markets may therefore explain the low use of purchased inputs and limited output response following market reforms in the 1990s. Data suggest that reduced access to output buyers would have an even larger impact on input use, but there is little evidence that buying centers have become less accessible in the study area. The significance of farm income in the results implies that reduced access to seasonal finance could have exacerbated difficulties in securing inputs.

The cost of acquiring high-quality inputs could be reduced through cheaper public transportation, deeper penetration of reputable vendors, greater use of group buying by associations of farmers, or seasonal finance to facilitate purchase at the time of crop sales. That 20% of growers or 65% of input users do buy in groups suggests the significance of social capital in addressing transactions costs. The emergence of reputable coffee growers as local level input distributors would seem a natural progression from group buying, but this development may be hampered by lack of liquidity among potential farmer-dealers.

The small size of the sample used in this study suggests caution in generalizing the specific results of this analysis. Nonetheless, the findings that costs as well as prices influence input use

shed some light on Africa's mixed agricultural performance since liberalization. Moreover, it is reasonable to expect that producers, in general, face different sets of transactions costs for inputs and outputs, and that those costs require distinct interventions. Furthermore, the results provide evidence that institutions, such as group buying and use of reputable stockists are emerging to enhance the functioning of liberalized markets in Africa. Further institutional innovation in distribution systems and financial markets is needed to allow farmers and traders to take greater advantage of existing market opportunities.

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