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Supermarkets and agricultural labor demand in Kenya: A gendered perspective

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ABSTRACT

Many developing countries are experiencing a rapid expansion of supermarkets. New supermarket procurement systems could affect farming patterns and wider rural development. While previous studies have analyzed farm productivity and income effects, possible employment effects have received much less attention. Special supermarket requirements may entail intensified farm production and post-harvest handling, thus potentially increasing demand for hired labor. This could also have important gender implications, because female and male workers are often hired for distinct farm operations. Building on data from a recent survey of vegetable farmers in Kenya, a double-hurdle model of hired labor use is developed and estimated. Farmer participation in supermarket channels increases the likelihood of hiring labor by 20%, and demand for hired labor by 61%. A gender disaggregation shows that positive employment effects are especially pronounced for female laborers, who often belong to the most vulnerable population groups. Rural employment generation can be an important vehicle for poverty reduction.

Introduction

Developing countries are experiencing a food system revolution, spurred by rapid urbanization, rising incomes, and market liberalization (Mergenthaler et al., 2009; Reardon et al., 2009; Schipmann and Qaim, 2011; Reardon and Timmer, 2012). Supermarkets are quickly gaining in importance, with new opportunities for farmers to integrate into high-value markets (Reardon et al., 2003; Swinnen and Vandeplas, 2010; Rao et al., 2012). These trends may have important implications for agricultural and wider rural development. There may be direct gains in income that accrue to farm households participating in high-value markets. Additionally, there may be indirect effects to households not directly participating. Negative indirect effects may occur if smallholder farmers are excluded from emerging supply chains, which can lead to further marginalization (Balsevich et al., 2003). Yet there may also be positive indirect effects through innovation spillovers to traditional markets and employment generation (Neven et al., 2009; Schipmann and Qaim, 2010). Due to their labor-intensive nature, positive employment effects can be expected especially in horticultural crops (Barrientos et al., 2005; Weinberger and Lumpkin, 2007; Maertens and Swinnen, 2012).

The general importance of rural employment has been analyzed extensively (e.g., Maertens, 2009; Babatunde and Qaim, 2010). Overall, with increasing land and capital constraints, the role of off-farm income is increasing. While agricultural wage income constitutes a fairly small proportion of off-farm income in general, its relative role often increases with decreasing household incomes (Reardon, 1997; Kijima et al., 2006; Kristjanson et al., 2010). Hence, agricultural employment arising from the expansion of high-value markets could benefit the poorest segments of the rural population in particular.

Previous studies on employment effects of high-value supply chains have largely focused on non-traditional exports (Damiani, 2003; Dolan, 2004; Maertens and Swinnen, 2009). Yet, as Neven et al. (2009) suggest, increasing domestic demand for high-value products may entail new employment opportunities as well. Surprisingly, there are no studies that have attempted to estimate and quantify employment effects of the supermarket revolution in a systematic way.[1] Supermarkets often impose certain quality standards, which require intensified production and changes in traditional cultivation practices. Moreover, extra labor may be needed for additional post-harvest operations, such as cleaning and packaging of products ready for supermarket shelves (Neven et al., 2009).

The supermarket revolution may also have important gender implications. Women farmers tend to have limited access to productive resources such as land and capital (Udry, 1996; Quisumbing and Pandolfelli, 2010). Thus, they may be disadvantaged in terms of entering high-value markets as suppliers (Dolan, 2001; Fischer and Qaim, 2012). Labor market impacts, however,

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[1] Hernández et al. (2007) and Neven et al. (2009) compared supermarket and traditional farmers and found that supermarket farmers use more labor. However, they did not control for possible confounding factors, so that a causal relationship could not be established.

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may be more favorable for women. Maertens and Swinnen (2012) reported positive employment effects for female rural laborers in high-value export chains in Senegal. Similar effects may also occur in supermarket channels, when farmers supplying these channels hire more labor for operations where female workers are preferred. Women's participation in labor markets is often positively associated with women's well-being and economic independence (Quisumbing, 2003; Zhang et al., 2004; Quisumbing and McClafferty, 2006). Such gendered effects of the supermarket revolution have never been analyzed.

We contribute to the literature by estimating the impact of farmers' participation in supermarket channels on their demand for hired labor. To analyze gender implications, we differentiate between female and male hired labor. As farmers self-select into supermarket channels, we employ an instrumental variable approach and carry out different robustness checks to test and control for unobserved heterogeneity. We use a double-hurdle model, which accounts for the fact that not all farmers hire labor, and the general decision to hire may be separated from the decision of how much labor to hire.

The analysis is based on data from a survey of vegetable farmers in Kenya. The expansion of supermarkets in Sub-Saharan Africa is not yet as strong as in Asia and Latin America, but in Kenya supermarkets already account for about 6% of the national food retail sector, and 20% of food retailing in urban areas (Planet Retail, 2011). While the focus is largely on processed foods, supermarkets are also gaining ground in fresh product markets. Supermarket procurement strategies have started to influence the horticultural sector around Nairobi, and this phenomenon will likely spread to other parts of Kenya when the modern retail sector expands. Similar developments are also expected in other countries of Africa. Hence, a better understanding of rural labor market effects is important from a research and policy perspective.

Data and descriptive statistics

Farm survey

Data for this study were collected in 2008 through a survey of vegetable farmers in Kiambu district, Central Province of Kenya. Kiambu is relatively close to Nairobi and is traditionally known as one of the main vegetable-supplying regions for the capital city. Kiambu is also the district where the supermarket chains located in Nairobi source most of their vegetables. Based on information from the district agricultural office, four of the main vegetable-producing divisions in Kiambu were chosen. In these four divisions, 31 administrative locations were purposively selected, again using statistical information on vegetable production. Within these locations, we used stratified random sampling, differentiating between farmers supplying traditional channels and farmers supplying supermarkets. Since supermarket-supplying farmers are still the minority, we oversampled them using complete lists obtained from supermarkets and supermarket traders. In total, our sample comprises 402 farmers, including 269 traditional channels suppliers and 133 supermarket suppliers. The two sub-samples are representative of vegetable farmers in Kiambu.

A structured questionnaire was used to elicit data on vegetable production and marketing. Production information, including labor use and other input–output details, was collected at the plot level. Data on other farm and non-farm economic activities, as well as on household and contextual characteristics, were also collected. Farmers in Kiambu mainly grow vegetables in addition to maize, bananas, and several other cash crops. The main vegetables produced are leafy types, including exotic ones such as spinach and kale, and indigenous ones such as *amaranthus* and black nightshade, among others.

Traditional vegetable marketing channels consist of direct spot market trading and sales to middlemen at the farm gate. They mostly involve non-contract transactions with neither promise for repeated transactions nor prior agreements on product delivery and/or price. Some farmers in traditional channels have regular transactions with middlemen, but still without any binding agreement. In contrast, supermarkets do have agreements with vegetable farmers regarding product quality, hygiene, and consistency and regularity in supply (Ngugi et al., 2007; Rao and Qaim, 2011). As a higher effort in farming and post-harvest handling can contribute to meeting these requirements, we hypothesize that participation in supermarket channels increases demand for hired labor. Agreements on quantities to be delivered and prices are also made before delivery, resulting in market assurance and more stable and predictable prices. Similar reductions in price risk were also observed in other studies on supermarket supply chains (Michelson et al., 2011; Neven et al., 2009). Agreements between supermarkets and farmers are mostly verbal with no written contract. Some farmers also supply supermarkets through specialized traders, who use the same type of verbal agreements. Verbal agreements are quite common in contract farming with smallholders, also in other countries (Schipmann and Qaim, 2011).

Descriptive analysis

Table 1 shows descriptive statistics for the whole sample and for the two sub-samples of supermarket and traditional channel farmers. Average farm sizes are small. Farmers in supermarket channels own somewhat bigger land areas and also cultivate more vegetables than traditional channel farmers. There are also significant differences in terms of farmer age, education, occupational characteristics, and irrigation. While women play an important role in farming in Kenya, the majority of the vegetable farmers in our sample are male. The proportion of male farmers is even slightly higher in supermarket channels. While women are often responsible for food crop production, male household members tend to control cash crop production (Quisumbing, 2003; Weinberger et al., 2011). Increasing degrees of commercialization may further exacerbate the role of women within farming households (von Braun and Kennedy, 1994; Fischer and Qaim, 2012).

The lower part of Table 1 shows details of vegetable production and marketing. More farmers in traditional channels grow exotic vegetables. In other words, the proportion of farmers growing indigenous vegetables is higher in supermarket channels.[2] Supermarket suppliers receive significantly higher prices for both exotic and indigenous vegetables. These prices are expressed per bundle, which may vary in size. Since this is the way prices are expressed by farmers, we do not have exact price information per kilogram. In spite of this inaccuracy, higher mean prices in supermarket channels are consistent with higher quality requirements, as was also reported in other studies (Reardon and Timmer, 2012; Rao et al., 2012). A larger proportion of supermarket farmers employ hired labor for vegetable production. Likewise, the quantity of hired labor per plot is higher among supermarket suppliers.[3] These patterns are similar to findings by Hernández et al. (2007) and Neven et al. (2009). They support our hypothesis of increased hired labor demand through participation in supermarket channels. Strikingly, when disaggregating hired labor use by gender of the laborers, a significant difference between supermarket and traditional channels can only be observed

[2] Recently, African indigenous vegetables have received renewed attention from upper and middle income consumers (Ngugi et al., 2007).

[3] While plots are not equal in size, the difference in mean plot size between marketing channels is small. In the regression analysis, we will control for plot size.

Table 1
Socioeconomic and farm characteristics for the whole sample and by market channel.

	Whole sample (n = 402)	Supermarket (n = 133)	Traditional (n = 269)
Farm and household characteristics			
Total area owned (acres)	2.1 (3.8)	2.7** (5.6)	1.9 (2.5)
Area cultivated with vegetables (acres)	0.8 (1.2)	1.2*** (1.5)	0.7 (0.9)
Size of main vegetable plot (acres)	0.08 (0.09)	0.09* (0.09)	0.08 (0.09)
Length of vegetable cropping cycle (months)	5.32 (2.75)	5.51 (3.18)	5.23 (2.52)
Household size (adult equivalents)	4.0 (0.2)	4.0 (0.2)	4.0 (0.2)
Gender of operator (male dummy)	0.90 (0.30)	0.93* (0.25)	0.88 (0.32)
Age of operator (years)	49 (14)	47* (13)	49 (15)
Education of operator (years)	9.2 (3.8)	10.3*** (3.1)	8.7 (4.1)
Main occupation			
Working on own farm (dummy)	0.84 (0.37)	0.79** (0.41)	0.86 (0.35)
Agricultural employment (dummy)	0.01 (0.09)	0.01 (0.09)	0.01 (0.09)
Non-agricultural employment (dummy)	0.05 (0.22)	0.08** (0.26)	0.04 (0.19)
Self-employed outside farm (dummy)	0.10 (0.31)	0.13 (0.34)	0.09 (0.29)
Use of irrigation (dummy)	0.77 (0.42)	0.88*** (0.33)	0.71 (0.45)
Access to credit (dummy)	0.10 (0.30)	0.11 (0.31)	0.10 (0.30)
Vegetable production and labor use			
Farmers growing exotic vegetables (%)	84 (37)	76*** (43)	88 (32)
Price for exotic vegetables (Ksh/bundle)	9 (10)	15*** (15)	7 (5)
Price for indigenous vegetables (Ksh/bundle)	8 (4)	10*** (3)	7 (5)
Wage rate (Ksh/day)	147 (37)	142** (41)	149 (35)
Farmers using hired labor (%)	75 (43)	84*** (37)	70 (46)
Farmers using female hired labor (%)	48 (59)	55** (59)	44 (50)
Farmers using male hired labor (%)	60 (49)	69*** (46)	55 (50)
Hired labor use (labor days/plot)	12.6 (20.1)	16.0*** (23.2)	11.0 (18.2)
Hired female labor use (labor days/plot)	7.2 (14.6)	9.8*** (18.4)	5.9 (12.1)
Hired male labor use (labor days/plot)	5.5 (11.6)	6.2 (11.2)	5.1 (11.8)

Note: Mean values are shown with standard deviations in parentheses.
* Variables show significant differences between market channels at the 10% level.
** Variables show significant differences between market channels at the 5% level.
*** Variables show significant differences between market channels at the 1% level.

for female workers. Supermarket farmers use significantly more female labor than their traditional channel colleagues. This is in line with studies on horticultural export chains (World Bank/FAO/IFAD, 2009; Maertens and Swinnen, 2012; Maertens et al., 2012). In Kiambu, according to our data women tend to receive slightly lower daily wages (141 Ksh) than men (149 Ksh).

Table 2 shows a breakdown of hired labor use by farm operation and gender. The upper part of Table 2 shows that more female than male labor is hired for vegetable production in total. Moreover, there is a notable partition between women's and men's tasks. Female labor is more important for weeding and harvesting, which are labor-intensive operations. For land preparation, irrigation, and pesticide application, male labor dominates. A similar gendered labor division was also reported by von Braun and Kennedy (1994) and Fischer and Qaim (2012).

The lower part of Table 2 further differentiates between marketing channels. While for many of the operations higher labor use can be observed in supermarket channels, the differences are especially pronounced for weeding and harvesting, which are dominated by female workers. Regular weeding and more effort in harvesting contribute to higher product quantity, quality, and cleanliness. Interestingly, supermarket farmers also employ significantly more female labor for irrigation, although this is a male-dominated operation in traditional channels. The same holds true for packing vegetables into bundles. In traditional channels, vegetables are often simply stuffed into bags, which is not very labor-intensive. This is different in supermarket channels. As there is no further processing on the way to supermarket shelves, on-farm cleaning and sorting is required. The numbers in Table 2 suggest that female labor is preferred for such sensitive operations. Collins (1993) also showed that farmers in high-value vegetable chains have a relative preference for women labor in appreciation of their better skills in careful handling.

For fertilizer and manure application, differences in labor use between channels can be explained by the fact that supermarket farmers use significantly more farmyard manure. According to farmers' own statements, manure helps to speed up plant and leave regeneration after harvest. This is more important in supermarket channels, because vegetables have to be supplied on a regular basis (Rao and Qaim, 2011). While the application of chemical fertilizer is mostly a male activity, organic manure is primarily applied by female laborers. These patterns suggest that a gender disaggregation is important.

Empirical strategy

Modeling supermarket impacts on labor demand

Observed demand for hired labor can be expressed as a two-stage decision, involving first the decision to hire labor followed by the decision on the exact quantity of labor to hire. The binary decision to hire is represented as:

$$d_i^* = \alpha x_i + u_i; \quad u_i \sim N(0,1) \quad \text{and} \quad d_i = \begin{cases} 1 \ \textit{if} \ d_i^* > 0 \\ 0 \ \textit{otherwise} \end{cases} \tag{1}$$

where the subscript i refers to the main vegetable plot of the ith farm. d_i^* is a latent variable for d_i. When $d_i = 1$, the farm hires labor on its main vegetable plot, while $d_i = 0$ indicates no hired labor use. The decision on how much hired labor to use is represented as:

$$y_i^* = \beta z_i + v_i; \quad v_i \sim N(0,\sigma^2) \quad \text{and} \quad y_i = \begin{cases} y_i^* \ \textit{if} \ y_i^* > 0 \text{ and } d_i = 1 \\ 0 \ \textit{otherwise} \end{cases} \tag{2}$$

Table 2
Differences in hired labor use by gender of laborers and market channel (in labor days per plot).

	Male hired labor (402)	Female hired labor (402)
Total hired labor	5.46** (11.58)	7.19 (14.60)
Land preparation	1.29*** (2.98)	0.25 (1.67)
Planting	0.58 (1.73)	0.68 (2.59)
Gap filling	0.05 (0.52)	0.03 (0.21)
Weeding	1.42*** (4.24)	3.98 (9.85)
Irrigation	0.66** (4.75)	0.15 (2.99)
Pesticide application	0.21*** (1.17)	0.01 (0.12)
Application of fertilizer and manure	0.22* (1.88)	0.08 (0.91)
Harvesting	0.94*** (3.53)	1.93 (6.27)
Packing	0.10 (1.11)	0.07 (0.86)

	Male hired labor		Female hired labor	
	Supermarket (133)	Traditional (269)	Supermarket (133)	Traditional (269)
Total hired labor	6.24 (11.19)	5.08 (11.77)	9.76*** (18.40)	5.91 (12.14)
Land preparation	1.59* (4.30)	1.14 (2.03)	0.20 (0.65)	0.28 (1.99)
Planting	0.65 (1.81)	0.55 (1.69)	0.56 (1.12)	0.73 (3.07)
Gap filling	0.02 (0.16)	0.06 (0.63)	0.05* (0.25)	0.02 (0.19)
Weeding	1.82* (4.60)	1.22 (0.25)	5.32** (13.17)	3.32 (7.65)
Irrigation	0.35 (0.14)	0.81 (5.69)	0.45* (5.20)	0.01 (0.10)
Pesticide application	0.25 (1.18)	0.18 (1.17)	0.01 (0.08)	0.01 (0.14)
Application of fertilizer and manure	0.25 (1.38)	0.21 (2.09)	0.24*** (1.58)	0.00 (0.03)
Harvesting	1.13 (3.61)	0.84 (3.50)	2.73** (8.21)	1.53 (5.02)
Packing	0.16 (1.14)	0.07 (1.10)	0.20** (1.48)	0.01 (0.08)

Note: Mean values are shown with standard deviations in parentheses.
* Variables show significant differences, first between gender of hired labor and second between market channels, at the 10% level.
** Variables show significant differences, first between gender of hired labor and second between market channels, at the 5% level.
*** Variables show significant differences, first between gender of hired labor and second between market channels, at the 1% level.

where y_i refers to the observed quantity of hired labor on the farm's main vegetable plot, and y_i^* represents the latent variable for y_i, x_i and z_i are vectors of explanatory variables, which may or may not contain the same variables. Our main explanatory variable of interest is participation in supermarket channels, which is represented as a dummy and included in both x_i and z_i. Positive and significant coefficients for this dummy would indicate that supermarket participation increases the probability of hiring labor and hired labor intensity.

Control variables

The choice of control variables builds on the literature of agricultural household models that outline various regimes of household participation in labor markets (Eswaran and Kotwal, 1986; Sadoulet et al., 1998). Farm households are differently endowed with land, human capital, and other fixed assets that influence their labor supply and demand (Lovo, 2012). Moreover, access to markets and technologies can play an important role (Jayasuriya and Shand, 1986; Brosig et al., 2007). We capture such aspects using land ownership, education, age, gender, access to credit, irrigation, and participation in off-farm employment. Regional dummies are included to control for possible geographical effects. Moreover, farm-gate prices for inputs such as fertilizer, manure, and pesticide, as well as individual wage rates paid are included (when no hired labor was employed, the mean wage rate in the same location was used). Transaction costs in the labor market create a wedge between effective wages received when selling labor and effective wages paid when hiring labor leading to idiosyncratic price bands, which may affect labor demand considerably (Sadoulet et al., 1998). We also control for the type of vegetables grown (exotic or indigenous), as different types may have different labor requirements (Weinberger and Lumpkin, 2007). Finally, we include scale variables such as plot size and length of cropping cycle. This is important to make results comparable, because the dependent variable, hired labor quantity, is measured per plot and cropping cycle.

Potential endogeneity bias

One problem is that the treatment variable (supermarket participation) may potentially be endogenous, because farmers self-select into the group of supermarket suppliers. We test for endogeneity using a control function approach, as described by Rivers and Vuong (1988) and Smith and Blundell (1986). This approach involves predicting residuals from a reduced-form model of farmer participation in supermarket channels, and including these predicted residuals as an additional covariate in both decision stages of the labor demand model. A significant coefficient of this residual term indicates endogeneity; at the same time it controls for the resulting bias (Wooldridge, 2002).

The reduced-form model is estimated using a Probit estimator and requires an appropriate instrument. We use the dummy "availability of public transport in the village", meaning that there is a regular minibus or similar transport service reaching the village. Most farmers in our sample are located in villages that have some form of rural feeder roads, but not all these roads are served with public transport. Timely and consistent delivery of products is one of the requirements imposed by supermarkets. As many farmers do not own a car or pickup truck themselves, access to regular means of transport is important. Availability of public transport is exogenous and a significant determinant of participation in supermarket channels (Table A1 in the Appendix shows the reduced-form model).[4] It may potentially also affect labor demand through its influence on the wage rate or the price of agricultural inputs. Yet, we control for wage and other input prices in the model. There is no significant correlation between availability of public transportation and hired labor demand (correlation coefficient −0.076; $p > 0.1$), so we conclude that this is a valid instrument. Further tests for potential endogeneity bias are explained below.

[4] Ownership of a car/pickup could also be a potential instrument, which we tested with the same general conclusions. However, ownership of a car/pickup may be endogenous itself. Income gains through supermarket participation may induce purchase of an own vehicle.

A double-hurdle model

After discussing the general modeling framework, we now need to identify the best estimator for Eqs. (1) and (2). A Heckman selection approach may seem appropriate, because a certain proportion of all vegetable farmers report zero use of hired labor. However, the Heckman approach is designed for incidental truncation where the zeros are unobserved values (Jones, 1989; Wooldridge, 2002). In our case, a corner solution model seems more appropriate than a selection model, because the zero values are actually observed. It can be assumed that farmers who decide not to hire labor do so deliberately, so that the observed values represent rational choices (deliberate zeros) rather than censored zeros.[5] This situation is similar to the models of fertilizer demand that were recently estimated by Xu et al. (2009) and Ricker-Gilbert et al. (2011).

The Tobit estimator is a common approach to estimate corner solution models. However, the Tobit estimator is restrictive, as it assumes that the decisions to hire labor and how much labor to hire are determined by the same process. A more flexible approach is the double-hurdle (DH) model proposed by Cragg (1971), which accounts for the possibility that the two decisions (hurdles) are determined by different processes. DH specifications were recently used to model input demand and agricultural technology adoption (Langyintuo and Mungoma, 2008; Ricker-Gilbert et al., 2011; Shiferaw et al., 2008; Xu et al., 2009; Noltze et al., 2012). Following the specification in Eqs. (1) and (2) and assuming independent error terms, the likelihood function for the DH model can be expressed as follows (Jones, 1989):

$$L(y_i|x_i,\theta) = \prod_{y_i=0}[1-\Phi(x_i\alpha/\sigma_u)]\Phi(z_i\beta/\sigma_v)^*\prod_{y_i>0}\Phi(x_i\alpha/\sigma_u)\Phi(z_i\beta/\sigma_v) \times \frac{\phi[(y_i-z_i\beta)/\sigma_v]}{\sigma_v\Phi(z_i\beta/\sigma_v)} \quad (3)$$

where ϕ and Φ are the probability density and cumulative distribution function of the normal distribution, σ_u is standard deviation of u_i, and σ_v is the standard deviation of v_i. The term $[1/\Phi(z_i\beta/\sigma_v)]$ ensures that the density integrates to unity over $y_i > 0$. Eq. (3) can be solved for α, β, and σ^2 through maximum likelihood estimation.

Since the Tobit model is nested in the DH model, we can choose which of the two is preferred based on a likelihood ratio test. With independent error terms, the log-likelihood of the DH model is equivalent to the sum of the log-likelihoods of the Probit and the truncated regressions. A likelihood ratio test of the Tobit restriction can therefore be carried out as follows (Greene, 2008):

$$LR-statistics = -2[\ln L_T - (\ln L_P + \ln L_{TR})] \quad (4)$$

where L_T is the likelihood for the Tobit model, L_p is the likelihood for the Probit model, and L_{TR} is the likelihood for the truncated regression model.

We estimate three DH models, one for total hired labor use, one for female hired labor use, and the third for male hired labor use. The descriptive statistics suggested that supermarket participation may have differential impacts on the demand for female and male hired labor. It should be noted that the majority of farmers that hire labor use both female and male hired workers, depending on the particular operation to be performed. Hence, the separate models for female and male labor demand build on a disaggregation of the dependent variable rather than a split up of the sample into two smaller sub-samples. For all estimations, we apply a weighting procedure to account for the fact that supermarket farmers were oversampled. Each observation is weighted by the reciprocal of the sampling probability, using information on the share of vegetable farmers supplying supermarkets, as provided by the district agricultural office.

The treatment and most of the control variables are included in both hurdles, as we expect that they affect the general decision to hire and also labor quantity. Yet for a few variables we differentiate between the two hurdles. While we include an irrigation dummy in the first hurdle, we use a continuous variable "share of vegetable area under irrigation" in the second hurdle. Plot size, length of cropping cycle, and type of vegetable grown are only included in the second hurdle, as these are plot-specific variables that are expected to influence hired labor quantity, but not the more general decision whether or not to hire at all.

Estimating marginal effects

Using the DH model, one can estimate marginal effects of the explanatory variables on the probability of hiring labor and on the quantity of hired labor use. At first, we estimate the probability of hiring labor for each individual observation i as:

$$P(d_i^* > 0|x_i) = \Phi(x_i\alpha) \quad (5)$$

The conditional expected quantity of hired labor can then be estimated as:

$$E(y_i|y_i > 0, z_i) = z_i\beta + \sigma \times \lambda(z_i\beta/\sigma) \quad (6)$$

Similarly, the unconditional expected quantity of hired labor can be estimated as:

$$E(y_i|x_i, z_i) = \Phi(x_i\alpha)[z_i\beta + \sigma \times \lambda(z_i\beta/\sigma)] \quad (7)$$

The term $\lambda(z_i\beta/\sigma)$ in Eqs. (6) and (7) is the inverse Mills ratio:

$$\lambda(z_i\beta/\sigma) = \phi(z_i\beta/\sigma)/\Phi(z_i\beta/\sigma) \quad (8)$$

The marginal effect of each independent variable can be estimated following procedures outlined in Burke (2009). The average effects are obtained by averaging over all i observations. In addition to the first stage marginal effects, which are based on the first hurdle estimates, it is differentiated between the conditional average partial effect (CAPE) and the unconditional average partial effect (UAPE). While the CAPE expresses the second hurdle effect, conditional on the first hurdle being passed, the UAPE expresses the combined effect of both hurdles. For binary regressors, such as the supermarket participation dummy, the UAPE is calculated as explained in the online support for Burke (2009).

Estimation results

In this section, we discuss results of the DH models for total hired labor demand, and separately for female and male hired labor demand. We start with the discussion of model specification tests. Then, we focus on the results of the total hired labor model, followed by a robustness check of the estimated treatment effects. Only after this robustness check we turn to the gender-differentiated analysis. Unconditional average partial effects for all three models are presented at the end of this section, together with a discussion of the result's wider implications.

Specification tests

As outlined above, the Tobit model is nested in the DH model, so that we can use a likelihood ratio test (Eq. (4)) to determine the appropriate specification. Test results for all three models are shown in the upper part of Table 3. In all three cases, the Tobit restriction is rejected in favor of the DH specification.

[5] We tested for sample selection by running a two-step Heckman model. The inverse Mills ratio, generated from the first step probit, was not significant in the second step ($p = 0.15$), so we conclude that there is no selection bias.

Table 3
Specification tests for the DH models.

	χ – Statistics	Critical $\chi^2_{0.05.20}$	Conclusion
Test against the Tobit specification			
Total hired labor	220.62	31.41	DH preferred
Female hired labor	89.17	31.41	DH preferred
Male hired labor	237.85	31.41	DH preferred
		p-Value	
Test for endogeneity of supermarket participation			
Total hired labor	Hurdle 1	0.810	Exogenous
	Hurdle 2	0.195	Exogenous
Female hired labor	Hurdle 1	0.948	Exogenous
	Hurdle 2	0.769	Exogenous
Male hired labor	Hurdle 1	0.532	Exogenous
	Hurdle 2	0.773	Exogenous

We also test for endogeneity of the treatment variable, supermarket participation, using the control function approach. The reduced-form model, from which the residuals are derived, is shown in Table A1 in the Appendix. Test results are reported in the lower part of Table 3. The *p*-values indicate that the residual term is not significant in both hurdles of all three DH models. Hence, the null hypothesis of no correlation between supermarket participation and the respective error terms cannot be rejected. We therefore proceed without including the residual terms.

DH model results for total hired labor

Results of the DH model for total hired labor demand are presented in the first two columns of Table 4 (the other columns of Table 4 are discussed further below). Labor quantity is measured per plot. The estimates show that supermarket farmers are more likely to hire labor than their counterparts in traditional channels (first hurdle). The quantity of hired labor is also increased significantly (second hurdle). These findings confirm our hypothesis that participation in supermarket channels increases the demand for hired labor.

Based on these estimation results, Table 5 shows marginal effects, which are easier to interpret in terms of magnitude than the model coefficients. Supermarket participation increases the likelihood of hiring labor by 14 percentage points. Relative to a 70% mean likelihood of farmers in traditional channels hiring labor, this represents a 20% increase in the likelihood of hiring labor. The CAPE indicates that – conditional on hiring labor – supermarket participation increases the demand for hired labor by 4.8 labor days. Relative to the expected conditional demand for hired labor of 14 labor days by traditional channel suppliers, this represents a 34% increase. This is a relatively large effect, which can be explained by higher labor requirements to meet the supermarket standards in terms of product quality and regularity, as was already discussed above. Moreover, higher prices and returns for farmers in supermarket channels (Rao and Qaim, 2011) increase the incentive and ability to intensify vegetable production. Increased demand for agricultural labor can benefit land-scarce rural households in particular (Miyuki et al., 2008).

Looking at the marginal effects of the control variables in Table 5, the gender dummy indicates that male farmers use significantly more hired labor than female farmers. The CAPE implies that among those employing labor, male farmers hire 12.5 more labor days on their vegetable plot than female farmers. This may potentially be related to cultural factors. Farmers who are themselves employed as agricultural wage laborers are more likely to hire labor for their own farm, even though the quantity of labor hired is significantly lower than that of the reference group consisting of farmers with non-agricultural employment. The latter may be related to opportunity costs of own time resources; since non-agricultural employment is often more lucrative, it can make sense to substitute cheaper hired labor for more expensive own labor in the vegetable enterprise. Mduma and Wobst (2005) have shown such labor substitution effects in rural Tanzania.

Input prices are mostly not significant determinants of hired labor demand, except for fertilizer. Higher fertilizer prices entail lower demand for hired labor, indicating a complementary relationship between these two inputs. The plot level controls, which are only included in the second hurdle, are all significant. As one would expect, plot size, length of cropping cycle, and irrigation lead to higher labor demand. When exotic vegetables are grown, hired labor use is 11.4 days lower than when indigenous types are grown. Indigenous vegetables are more labor-intensive due to higher cropping density on the plot. Moreover, they are usually planted in finer seed beds, which require more labor for land preparation. Indigenous vegetables are also mostly harvested by uprooting the whole plant. Hence, cleaning and bundling is also more time-consuming than for exotic leafy vegetables, which are often harvested by simply plucking the leaves.

Robustness checks

Before turning to the separate models for female and male hired labor, some further reflection is given to the potential endogeneity of the treatment variable. As described above, we used the control function approach to test for endogeneity of supermarket participation and found that the exogeneity hypothesis could not be rejected. However, endogeneity tests always depend on the quality of the instrument used in the reduced-form regression. While "availability of public transport in the village" seems to be a valid instrument, the assumption that this fully addresses potential issues of unobserved heterogeneity could still be questioned. Hence, we carried out further robustness checks of the estimated treatment effects.

Unobserved factors that may potentially bias the treatment effects (because of jointly influencing supermarket participation and hired labor demand) could be individual farmer characteristics such as personal motivation, ability, access to relevant information, and intellectual flexibility. As these are difficult to measure, we looked for variables that are likely correlated with such unobserved factors. Three such variables, for which we have data, are: (i) being member of a group, such as a farmer association or church group, which is an indicator of a farmer's openness and social network; (ii) participation in programs of locally active NGOs that try to link farmers to high-value markets through institutional support and training[6]; and (iii) ownership of a car or pickup truck. All three may be endogenous themselves, but we can still use them for the following test. If unobserved heterogeneity would bias the original results significantly, inclusion of these correlated variables into the model should substantially change the estimated impact of supermarket participation on hired labor demand. Treatment effects resulting from such auxiliary regressions are shown in Table A2 in the Appendix. Each additional variable was entered in both hurdles of the DH model. While the treatment effects are influenced to some extent, the changes are small, and all of the effects remain significant. Hence, we conclude that the results are robust to unobserved heterogeneity.

[6] For instance, the NGO Farm Concern International (FCI) tries to link farmers to supermarkets in Kiambu (Rao and Qaim, 2011).

Table 4
Maximum likelihood estimates for DH models.

	Total hired labor		Female hired labor		Male hired labor	
	Decision to hire	Labor quantity	Decision to hire	Labor quantity	Decision to hire	Labor quantity
Supermarket participation (dummy)	0.530**	22.707**	0.580***	45.264*	0.374*	−1.816
	(0.232)	(10.944)	(0.224)	(24.254)	(0.205)	(5.100)
Total area owned (acres)	0.12	−0.729	0.072	−0.501	0.104*	−1.758
	(0.085)	(2.631)	(0.051)	(3.902)	(0.054)	(1.116)
Household size (adult equivalents)	−0.499	51.648**	0.831	−30.363	−0.353	24.209***
	(0.614)	(24.051)	(0.682)	(34.249)	(0.636)	(7.874)
Gender of operator (male dummy)	1.028**	93.359	−0.314	133.676	1.790***	53.871**
	(0.496)	(64.813)	(0.483)	(91.667)	(0.544)	(27.205)
Age of operator (years)	−0.015	1.390**	0.015	2.340**	−0.018	−0.189
	(0.015)	(0.684)	(0.012)	(1.168)	(0.014)	(0.22)
Education of operator (years)	−0.046	−3.001*	−0.003	−5.081**	−0.073	−0.426
	(0.045)	(1.674)	(0.042)	(2.548)	(0.045)	(0.820)
Self-employed outside farm[a] (dummy)	−0.579	81.489*	0.092	79.519	−1.119**	55.575***
	(0.592)	(41.958)	(0.524)	(48.829)	(0.548)	(20.857)
Working on own farm[a] (dummy)	0.324	46.141	0.320	30.591	−0.264	35.873**
	(0.504)	(38.096)	(0.432)	(46.031)	(0.455)	(16.930)
Agricultural wage employment[a] (dummy)	1.834**	−154.219**	2.557***	−595.635***	0.866	−23.982
	(0.842)	(71.250)	(0.741)	(213.685)	(0.755)	(23.524)
Use of irrigation (dummy)	0.550		−0.111		−0.043	
	(0.389)		(0.369)		(0.362)	
Access to credit (dummy)	0.931**	26.513	0.391	57.858**	0.791*	−23.474
	(0.465)	(19.519)	(0.379)	(28.359)	(0.407)	(16.640)
Wage rate (Ksh/day)	−0.004	0.176	0.002	−0.440	0.000	0.136*
	(0.003)	(0.188)	(0.004)	(0.342)	(0.003)	(0.081)
Price of fertilizer (Ksh/kg)	−0.003	−0.387**	−0.001	−0.375	−0.004	−0.155*
	(0.005)	(0.191)	(0.004)	(0.261)	(0.004)	(0.081)
Price of pesticide (Ksh/ml)	0.011	0.125	0.058	1.560	0.035	−2.443**
	(0.036)	(1.595)	(0.039)	(1.991)	(0.032)	(1.134)
Price of purchased manure (Ksh/kg)	−0.114	−5.339	−0.018	1.473	−0.133	−8.323***
	(0.192)	(6.669)	(0.147)	(9.332)	(0.158)	(3.097)
Limuru region[b]	−0.692	11.573	−1.222**	−62.414*	2.254***	54.714***
	(0.467)	(20.050)	(0.505)	(34.309)	(0.487)	(20.539)
Githunguri/Lower Lari region[b]	−1.620***	−36.614	−1.625***	−142.180**	1.280**	43.021**
	(0.564)	(30.167	(0.570)	(56.564)	(0.620)	(20.452)
Kikuyu/Westland region[b]	−0.614	−43.048	−1.652***	−112.307**	2.239***	36.798*
	(0.503)	(27.874)	(0.434)	(51.111)	(0.496)	(19.062)
Exotic vegetables (dummy)		−39.504***		−39.903*		−28.559***
		(13.305)		(22.962)		(7.612)
Plot size (acres)		188.191***		87.618		126.790***
		(54.105)		(90.266)		(27.443)
Length of cropping cycle (months)		5.410***		6.182**		3.465***
		(1.858)		(2.654)		(0.99)
Share of land area under vegetable	−0.049	54.456**	0.736*	46.584	0.085	7.325
	(0.617)	(23.990)	(0.443)	(34.098)	(0.489)	(15.760)
Share of vegetable area under irrigation		10.343**		8.889		4.379**
		(3.774)		(5.590)		(1.743)
Constant	3.743	−459.076***	−3.656	−71.944	0.071	−219.412***
	(2.918)	(150.717)	(2.96)	(175.130)	(2.962)	(62.166)
Sigma		27.170***		28.416***		12.142***
		(4.378)		(4.999)		(1.978)
Number of observations	400		400		400	
Log pseudo-likelihood	−22791.04		−17183.86		−16231.14	
Wald χ^2 (41)[c]	143.04***		94.73***		142.52***	

Note: Standard errors are shown in parentheses.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.
[a] The reference occupation is non-agricultural employment.
[b] The reference region is Lari.
[c] The Wald chi[2] test for model significance accounts for the fact that sampling weights were applied during estimation.

DH model results for female and male hired labor

Estimation results of the separate DH models for female and male hired labor are shown in the right-hand part of Table 4. We first discuss the results for the female labor model, for which marginal effects are given in Table 6. Supermarket participation increases the likelihood of hiring female labor by 23 percentage points, which is a much stronger effect than for total hired labor. This represents a 52% increase relative to the mean likelihood of traditional channel farmers hiring female labor. The conditional increase in the demand for female hired labor as a result of supermarket participation is also positive and significant, and much higher than for total hired labor. An additional quantity of 7.9 labor days represents a 72% increase relative to the expected conditional demand for female hired labor by traditional channel farmers.

Results for the control variables show that – conditional on hiring labor – male farmers tend to hire significantly more female labor than female farmers. The effects of agricultural wage

Table 5
Marginal effects for DH model (total hired labor).

	Hurdle 1 decision to hire labor		Hurdle 2 quantity of labor used	
	Marginal effects	SE	CAPE	SE
Supermarket participation	0.141**	0.062	4.828**	2.234
Total area owned	0.025	0.018	−0.180	0.639
Household size	−0.104	0.128	12.783**	6.365
Gender of operator	0.314**	0.152	12.482***	3.475
Age of operator	−0.003	0.003	0.344**	0.142
Education of operator	−0.010	0.009	−0.743*	0.419
Self-employed outside farm [a]	−0.150	0.154	32.994	25.433
Working on own farm [a]	0.075	0.116	9.822	6.972
Agricultural wage employment [a]	0.128**	0.059	−14.179***	1.582
Use of irrigation	0.142	0.100		
Access to credit	0.124**	0.062	7.604	6.075
Wage rate	−0.001	0.001	0.044	0.047
Price of fertilizer	−0.001	0.001	−0.096**	0.044
Price of pesticide	0.002	0.008	0.031	0.395
Price of purchased manure	−0.024	0.040	−1.321	1.738
Limuru region [b]	−0.193	0.131	3.087	5.998
Githunguri/Lower Lari region [b]	−0.439***	0.153	−8.598	6.733
Kikuyu/Westland region [b]	−0.119	0.097	−11.865	7.726
Share of land area under vegetable	−0.010	0.128	13.478***	5.098
Share of vegetable area under irrigation			2.560***	0.780
Plot size			46.577***	14.970
Length of cropping cycle			1.339***	0.437
Exotic vegetables			−11.408**	4.699
Number of observations	400		299	

* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.
[a] The reference occupation is non-agricultural employment.
[b] The reference region is Lari.

employment are similar but somewhat stronger than in the total hired labor model. Interestingly, the regional dummies are all significant, while most of them were insignificant in the total hired labor model. This is potentially related to regional differences in labor market conditions and different employment opportunities for male and female laborers in non-agricultural sectors.

Marginal effects for the male labor model are shown in Table 7. Participation in supermarket channels increases the likelihood of hiring male labor by 14 percentage points. However, the effect on hired labor quantity is insignificant, suggesting that the positive employment effects of supermarkets are much stronger for female than for male laborers.

Unconditional effects and implications

In addition to the conditional marginal effects discussed so far, we calculated unconditional marginal effects, which are combined effects of both hurdles. These are usually more relevant for policy-making purposes. UAPEs of the supermarket treatment variable are shown in Table 8 for the three models. Supermarket participation increases the demand for total hired labor by 6 labor days. Compared to the unconditional expected demand for total hired labor, this implies an increase of 61%. The unconditional effect for male labor demand is small and statistically insignificant. Yet, consistent with the results discussed already, the increase in the demand for female hired labor is bigger than the total effect. Around 7.2 additional labor days for female workers means an increase of 121%. The labor days refer to one single vegetable plot (average size of 0.09 acres) and one cropping cycle of approximately 6 months. With two cropping cycles per year and 1.2 acres of vegetables that the average supermarket supplier has, the annual increase in female employment amounts to 192 additional labor days per farm. Given the average daily wage rate of 141 Ksh for female workers, each supermarket farmer provides additional female employment worth more than 27,000 Ksh (327 US$). A recent study showed that this is the average annual income that a rural labor household derives from agricultural wage employment in Kenya (Iiyama et al., 2008). This underlines the economic significance of the labor market impacts.

These results underline that the supermarket revolution provides new agricultural employment opportunities in the Kenyan vegetable sector, especially for women. While similar trends have been reported for horticultural export channels (Dolan, 2004; Maertens and Swinnen, 2009; World Bank/FAO/IFAD, 2009; Maertens et al., 2012), they have not been analyzed previously in a supermarket context. Hoddinott and Haddad (1995) and Quisumbing (2003) showed that female-controlled income is often more beneficial for child nutrition and household welfare than male-controlled income. Women with agricultural employment may not be able to fully control their wage income. But women's empowerment and control over income resources is strongly determined by their access to labor markets and paid employment (Quisumbing and McClafferty, 2006; Maertens and Swinnen, 2012).

The labor market effects are also welcome from a broader equity perspective. Agricultural employment is often a more important source of income for poorer than for richer households. Fig. 1 shows a simple breakdown of the structure of off-farm income among different income segments in our sample of vegetable farmers. As can be seen, agricultural wage employment plays the biggest role for the poorest income tercile. Our sample of vegetable farmers is not representative of all rural households in the region. For households that are not engaged in own commercial vegetable production, agricultural wage employment often plays a much bigger role. Based on other data from Kenya, Miyuki et al. (2008) and Kristjanson et al. (2010) showed that the role of agricultural employment is considerably bigger for low-income households. Hence, the poor could benefit overproportionally from the positive rural employment effects. Again, similar effects were shown for horticultural export sectors (Maertens et al., 2012), but not yet for domestic supermarket supply chains.

Table 6
Marginal effects for DH model (female hired labor).

	Hurdle 1 decision to hire labor		Hurdle 2 quantity of labor used	
	Marginal effects	SE	CAPE	SE
Supermarket participation	0.227***	0.087	7.931***	2.708
Total area owned	0.028	0.020	−0.121	0.937
Household size	0.328	0.269	−7.323	7.881
Gender of operator	−0.120	0.185	14.134***	3.127
Age of operator	0.006	0.005	0.564**	0.247
Education of operator	−0.001	0.017	−1.225**	0.543
Self-employed outside farm [a]	0.036	0.206	29.127	23.568
Working on own farm [a]	0.127	0.171	6.649	8.787
Agricultural wage employment [a]	0.446***	0.129	−16.468***	1.572
Use of irrigation	−0.044	0.145		
Access to credit	0.148	0.144	18.460*	9.836
Wage rate	0.001	0.001	−0.106	0.073
Price of fertilizer	−0.001	0.002	−0.091	0.062
Price of pesticide	0.023	0.016	0.376	0.473
Price of purchased manure	−0.007	0.058	0.355	2.253
Limuru region [b]	−0.428**	0.177	−10.909***	3.651
Githunguri/Lower Lari region [b]	−0.578***	0.202	−34.548***	12.307
Kikuyu/Westland region [b]	−0.567***	0.149	−33.665**	15.370
Share of land area under vegetable	0.291*	0.175	11.235	6.848
Share of vegetable area under irrigation			2.144*	1.173
Plot size			21.131	22.726
Length of cropping cycle			1.491**	0.614
Exotic vegetables			−11.036*	6.588
Number of observations	400		190	

* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.
[a] The reference occupation is non-agricultural employment.
[b] The reference region is Lari.

Table 7
Marginal effects for DH model (male hired labor).

	Hurdle 1 decision to hire labor		Hurdle 2 quantity of labor used	
	Marginal effects	SE	CAPE	SE
Supermarket participation	0.137*	0.075	−0.498	1.409
Total area owned	0.035*	0.018	−0.468	0.285
Household size	−0.119	0.215	6.438***	2.159
Gender of operator	0.620***	0.189	6.148***	1.018
Age of operator	−0.006	0.005	−0.050	0.059
Education of operator	−0.025	0.015	−0.113	0.220
Self-employed outside farm [a]	−0.419**	0.205	29.123**	14.229
Working on own farm [a]	−0.085	0.147	6.971***	2.614
Agricultural wage employment [a]	0.209	0.182	−4.186*	2.212
Use of irrigation	−0.014	0.121		
Access to credit	0.212*	0.109	−4.522**	2.056
Wage rate	0.000	0.001	0.036*	0.021
Price of fertilizer	−0.001	0.001	−0.041**	0.020
Price of pesticide	0.012	0.011	−0.650**	0.280
Price of purchased manure	−0.045	0.053	−2.213***	0.760
Limuru region [b]	0.325***	0.070	29.473**	13.760
Githunguri/Lower Lari region [b]	0.358**	0.173	17.752*	10.204
Kikuyu/Westland region [b]	0.712***	0.158	8.995**	4.238
Share of land area under vegetable	0.029	0.165	1.424	4.199
Share of vegetable area under irrigation			1.165***	0.445
Plot size			33.718***	5.200
Length of cropping cycle			0.922***	0.205
Exotic vegetables			−9.680***	2.321
Number of observations	400		240	

* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.
[a] The reference occupation is non-agricultural employment.
[b] The reference region is Lari.

Table 8
Unconditional marginal effects of supermarket participation on labor demand.

	Unconditional expected demand for labor in traditional channels	UAPE [a]	% Increase
Total hired labor	10	6.146* (3.398)	61
Female hired labor	6	7.238* (4.119)	121
Male hired labor	5	0.639 (1.311)	13

** Significant at the 5% level.
*** Significant at the 1% level.
* Significant at the 10% level.
[a] Computed as explained in the online support of Burke (2009), taking into account that supermarket participation is a binary regressor. Bootstrapped standard errors are shown in parentheses.

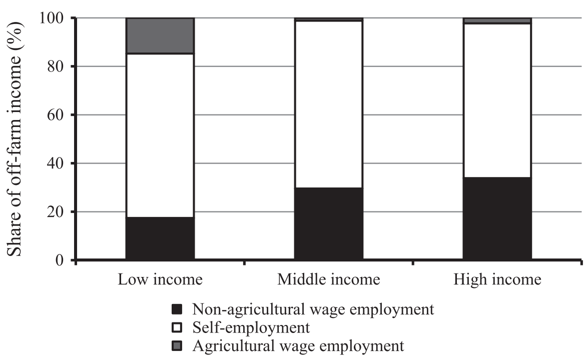

Fig. 1. Relative importance of different off-farm income sources among vegetable farmers in Kiambu (by income tercile).

Conclusion

The supermarket revolution has raised concerns about the implications for the rural poor. Recent research examined determinants of access to supermarket channels, as well as productivity and income effects for participating farm households. Possible employment effects have received much less attention. We have addressed this research gap by analyzing the impact of supermarket participation on farmers' demand for hired labor, using a survey of vegetable farmers in central Kenya. In addition to analyzing demand for total hired labor, we have studied gender implications by disaggregating between female and male hired labor.

Results show that farmer participation in supermarket channels increases the likelihood of hiring labor by 20%, and demand for hired labor by 61%. Hence, the expansion of supermarkets is associated with positive employment effects. Since agricultural wage employment is often more important for the lower income segments, the rural poor may benefit overproportionally. Positive employment effects are especially pronounced for female laborers. Participation in supermarket channels increases farmers' demand for female hired labor by 121%. This is a welcome finding from a gender equity perspective. Women's access to paid employment tends to increase their economic independence and control over income (Hoddinott and Quisumbing and McClafferty, 2006). Hence, when assessing rural development effects of the supermarket revolution, it is not enough to focus only on the impacts on farmers that directly participate in supermarket channels. Labor market effects must also be considered. This was also observed for horticultural export chains (Maertens et al., 2012). But horticultural export production is often a niche activity in certain regions of a country, whereas the supermarket expansion may gradually affect farm production more widely.

Nonetheless, when the focus is on gender issues, it should be mentioned that the role of women may be weakened in farm households that participate in supermarket channels as suppliers. Due to their limited access to productive resources, women farmers find it more difficult to enter high-value markets themselves (Udry, 1996; Quisumbing and Pandolfelli, 2010). And with increasing degrees of commercialization, men often take over control of agricultural resources and income (von Braun and Kennedy, 1994; Fischer and Qaim, 2012). Also within the labor market, more female employment may not always be a sufficient condition for positive welfare effects. In their studies on agricultural export chains, Barrientos et al. (2003) and Dolan (2004) showed that positive employment effects may be undermined by a gender bias in terms of wage discrimination or unfair labor practices. Such aspects were not analyzed here but deserve further scrutiny in follow-up research.

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Appendix A

See Tables A1 and A2.

Table A1
Determinants of farmer participation in supermarket channels (reduced-form model).

	Coefficient	SE
Availability of public transport in village (dummy)	0.110*	0.063
Total area owned (acres)	0.027*	0.016
Share of land area under vegetable	0.135*	0.081
Household size (adult equivalent)	−0.216	0.139
Gender of operator (male dummy)	0.077	0.085
Age of operator (years)	0.024**	0.012
Age of operator squared (years)	−0.000**	0.000
Education of operator (years)	0.019**	0.008
Self-employed outside farm[a] (dummy)	0.037	0.131
Working on own farm[a] (dummy)	0.015	0.105
Agricultural employment[a] (dummy)	−0.109	0.226
Use of irrigation (dummy)	0.049	0.070
Access to credit (dummy)	−0.028	0.077
Wage rate	−0.000	0.001
Price of fertilizer (Ksh/kg)	−0.002**	0.001
Price of pesticide (Ksh/ml)	−0.008	0.007
Price of purchased manure (Ksh/kg)	0.049*	0.030
Limuru region[b]	−0.182	0.142
Githunguri/Lower Lari region[b]	0.425**	0.187
Kikuyu/Westland region[b]	0.291*	0.152
Exotic vegetables (dummy)	−0.058	0.066
Share of vegetable area under irrigation	0.020	0.026
Plot size (acres)	−0.190	0.300
Length of cropping cycle (months)	0.016*	0.009
Log-likelihood	−189.767	
Number of observations	400	

* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.
[a] The reference occupation is non-agricultural employment.
[b] The reference region is Lari.

Table A2
Robustness checks of the treatment effects to potential endogeneity.

		Treatment effect (marginal effect)
Original model	Hurdle 1	0.141**
	Hurdle 2	4.828**
Group membership	Hurdle 1	0.141**
	Hurdle 2	5.906***
Participation in NGO linkage	Hurdle 1	0.155**
	Hurdle 2	4.157*
Own car/pickup truck	Hurdle 1	0.132**
	Hurdle 2	4.194*

Note: The original model results refer to the treatment effects of supermarket participation as shown in Table 5 for total hired labor. For the robustness checks, the additional variables group membership, participation in NGO linkage, and own car/pickup truck were separately included into the original model.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

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