Agricultural Extension and Imperfect Supervision in Contract Farming: Evidence from Madagascar

Bellemare, Marc F.
Duke University

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Marc F. Bellemare†

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Abstract

This article tests whether agricultural extension and imperfect supervision – conflated here into the number of visits by a technical assistant – increase productivity in a sample of contract farming arrangements between a processing firm and small agricultural producers in Madagascar. Production functions are estimated which treat the number of visits by a technical assistant as an input and which exploit the variation in the number of visits between the contracted crops grown on a given plot by a specific grower, thereby accounting for district-, grower-, and plot-level unobserved heterogeneity. Results indicate that the elasticity of yield with respect to the number of visits lies between 1.3 and 1.7.

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†Assistant Professor, Sanford School of Public Policy, Duke University, Box 90312, Durham, NC, 27708-0312, Telephone: +1 (919) 613-9382, Facsimile: +1 (919) 681-8288, Email: `marc.bellemare@duke.edu`.

Introduction

How effective are the processor's investments in agricultural extension and imperfect supervision in grower-processor contracts? And if they are effective, what is their marginal impact on grower yields? This article tests whether these investments increase yields in a sample of the contract farming arrangements signed between a processing firm and its growers in Madagascar. Within these contracts, the processor delegates its production of green vegetables – green beans, leeks, cucumbers, etc. – to growers by providing them with credit in the form of seeds, pesticides, and fertilizer. At harvest, this input advance is repaid in crop, and the firm purchases the remainder of the crop at a pre-agreed price, provided it satisfies certain quality requirements.

These contracts thus represent an important step away from spot markets and toward vertical integration in a country where the production of cash crops still remains marginal. Given that the markets for some of the inputs required to produce such crops often fail and that grower-processor contracts have the potential to resolve such market failures in developing countries (Grosh, 1994), the institution of contract farming allows producers to diversify their productive activities by helping them overcome non-convexities in the production of cash crops. In addition, small rural producers who lack the technical knowledge required to produce cash crops can often tap into such knowledge when the processor they contract with provides agricultural extension services as part of its supervision activities, as is the case in this article. This is especially important in Madagascar, where the adoption of technologies aimed at increasing staple crop (i.e., rice) yields has often been disappointing (Moser and Barrett, 2003 and 2006).

The contribution of this article is therefore to provide empirical evidence on the effects of agricultural extension and imperfect supervision in contract farming arrangements in Madagascar, where such contracts have been shown to be welfare-increasing (Minten et al., 2009). In light of the increased interest in contract farming in developing countries (Little and Watts, 1994; Grosh, 1994; Key and Runsten, 1999; Warning and Key, 2002; and Reardon and Timmer, 2005), knowing whether supervision increases productivity at the margin can provide a key insight to firms wishing to enter contract farming or expand their contract farming activities as well as to governments who may be considering contract farming as an instrument of industrial policy.

In the contracts studied in this article, the agricultural extension services provided by the processor and the imperfect supervision of growers by the processor are conflated into a single variable, i.e., the number of visits made by a technical assistant. These technical assistants ensure that growers follow a strict production schedule; that they apply the inputs provided by the processor in the right proportions; that they do not sell (or "leak") any of the contracted crop on the local market; and that they do not divert some of the inputs provided by the processor towards non-contracted crops. As such, while it is impossible to precisely disentangle the effects of agricultural extension and imperfect supervision, it is nonetheless possible to cleanly identify and estimate their combined marginal impact on grower productivity, which is of relevance to both the literature on extension in agricultural economics

(Feder et al., 1987; Birkhaeuser et al., 1991; Umali-Deininger, 1997; Anderson and Feder, 2004) and to the literature on imperfect supervision in development economics (Frisvold, 1994; Jacoby and Mansuri, 2009).[1]

This article therefore tests whether agricultural extension and imperfect supervision increase contracted crop yields by treating the number of visits made by a technical assistant as an input in the contracted crop production function. Given that the average producer grows several contracted crops on a given contracted plot and, more importantly, that the number of such visits varies at the crop rather than at the plot level, it is possible to control for unobserved heterogeneity at the district, grower household, and contracted plot levels. This setup provides clean identification of the effect of agricultural extension and imperfect supervision in these contracts and, as it turns out, a one percent increase in the number of visits increases yield by 1.3 percent on average, and by 1.7 percent when the number of visits is interacted with the grower's education so as to (crudely) tease out the agricultural extension and imperfect supervision aspects of these visits.

The remainder of the article is organized as follows. Section 2 offers a discussion of the contractual environment. In section 3, the data are presented alongside descriptive statistics. Section 4 discusses in turn the estimation strategy and the identification strategy. In section 5, the empirical results are presented and discussed. Section 6 concludes.

[1] Unfortunately, the survey includes no information as to how the supervisors choose who, when, and how to supervise, as only the growers were interviewed. Acquiring information on the supervision process itself would require a different survey altogether.

Contractual Environment

In a recent article using the same data to assess the technological spillovers from contract farming on rice production (i.e., the staple crop in Madagascar), Minten et al. (2009) offer an in-depth discussion of the contracts signed between Lecofruit, a processing firm who exports and sells the crops to supermarkets in the European Union (EU), and its growers. Lecofruit contracts with over 9,000 growers in the Antananarivo region. Each contract is written, and contracts are signed at the crop level given that growers can in principle grow more than one crop. The contract proceeds as follows:

1. The grower and the processor agree on an amount of cultivable area under contract and on a price at which the processor will buy the grower's output;
2. The processor provides the grower with seeds, pesticides, and fertilizer;
3. The grower undertakes production;
4. The technical assistant visits the grower;
5. Once the output is realized, the grower reimburses the processor in crop for the input advance and sells the remainder of his harvest to the processor at the price agreed upon in stage 1.

For the growers, the consequence of obvious shirking is non-renewal of the contract by the processor. This is discussed in greater detail toward the end of this section.

Given that this article seeks to determine whether extension and imperfect supervision have any effect on yields, it is important to take a closer look at the role of technical assistants in these contracts. The processor hires a total of 300 team leaders who each coordinate the work of five or six technical assistants who reside in the same village as the growers they are in charge of supervising.[2] Hiring these technical assistants locally allows the processor to exploit local knowledge about the growers it contracts with as well as to reduce the transactions costs of providing extensions services to and imperfectly supervising the growers.

The role of technical assistants is twofold. It consists first of the usual contract enforcement activities (i.e., preventing growers from shirking; from diverting the processor-provided inputs to non-contracted crops; from leaking contracted crops on the local market, etc.), but also of production management via agricultural extension services (i.e., ensuring that the growers adhere to the production schedule decided by the processor; that they apply seeds, pesticides, and fertilizers at the right time and in correct proportions; etc.), and of output quality assurance by making sure that the contracted crops conform to EU standards, whose phytosanitary requirements are much stricter than Madagascar's.

A legitimate concern in these contracts is that of side selling by the growers (or "leakage"; see Fafchamps, 2004), i.e., the sale of contracted output on the local market in the hope of fetching a higher price than the price

[2] Given that these data do not include unique identifiers for the supervisors, it is unfortunately impossible to control for the quality of supervision. The geographic indicators (i.e., district dummies) used below offer a crude way of controlling for heterogeneous supervision quality.

agreed upon at the contracting stage. To counter such opportunistic behavior, Lecofruit paid a much higher price for green vegetables than the local market price, a practice similar to that of paying an efficiency wage (Shapiro and Stiglitz, 1984). Minten et al. (2009) report that 61 percent of growers believe that the contract price is higher than the price on the local market and discuss how some growers even went so far as to sell vegetables from non-contracted plots to the processor given the high price paid by the processor. In addition, 59 percent of growers report never having leaked, 24.5 percent report only rarely having done so, and only 1.5 percent report regularly doing so.[3] Although these figures are subject to reporting bias, there is little to no evidence – statistical or anecdotal – of side selling in 2004, i.e., the contract year covered by the data.

The repayment rate of the growers as regards the input advance provided by the processor was about 98 percent. Even though contracts are written and the processor keeps a detailed database of its growers, it is unlikely that Lecofruit would have legal recourse if a grower chose not to repay. In Madagascar, resorting to the legal system to settle disputes involves a costly and inefficient process; institutions are weak; and agents tend to rely on repeated interactions as an enforcement mechanism (Platteau, 1994a, 1994b; Fafchamps and Minten, 2001; Fafchamps, 2004). Non-renewal of contracts is thus the main threat used by Lecofruit in enforcing repayment, a mechanism validated by the fact that these contracts are almost unambiguously beneficial to the growers. Indeed, Minten et al. report that the farmers who contract

[3] The statistics for "never leaked" and "rarely leaked" are significant at the 1 percent significance level, whereas the statistic for "regularly leaked" was only significant at the 10 percent significance level.

with Lecofruit have higher, less variable incomes than others in the same region who do not contract with Lecofruit.

Data and Descriptive Statistics

The data were collected under a joint Cornell University–Katholieke Universiteit Leuven effort in four districts in Madagascar's Antananarivo province during the months of June and July 2004. Each of the 200 randomly selected households in the sample had entered a contract with Lecofruit, whose main activity is to export fresh produce to the EU. Each selected household was chosen based on the stratification criterion of owning at least two plots: (i) a plot on which rice was grown during the agricultural season and on which at least one contracted crop (e.g., green beans, cucumbers, leeks, etc.) was grown during the off-season; and (ii) a rice plot on which rice was grown during the agricultural season and on which a non-contracted crop was grown during the agricultural off-season. Given that almost all agricultural households in Madagascar grow rice as a staple, this sampling strategy entails no loss of generality regarding the households contracting with Lecofruit. Data were collected at the household, contract, plot, and crop levels, so that accounting for missing data, the end result is a sample of 315 contracted crops across 188 grower households, each with one contracted plot. Among the 188 growers, 89 grew only one contracted crop while 74 grew two, 22 grew three, and three grew four.

Table 1a presents descriptive statistics for these 315 contracted crops, for the plots on which they are grown, and for the individuals growing them.

The average yield for green vegetables was a little over 12 metric tons per hectare.[4] A little under two thirds of contracted crops were green beans, one third were cucumbers, and only 2 percent were leeks. The average contracted crop covered about 1.5 ares and required 165 person-hours of labor. At the crop level, the number of visits by a supervisor averaged about 11. At this point, it is important to note that respondents were asked how many times a supervisor visited them for each contracted crop on the contracted plot. In other words, supervision varies within each grower-plot – a unique feature of the data that allows controlling for grower-plot unobserved heterogeneity and which will be discussed in greater detail when presenting the identification strategy in section 4. Although there may be some concern as to whether supervisors make separate visits to supervise production on separate crops, crops are often grown sequentially in different, not-necessarily-overlapping "plantings" in these data, which explains where the within-grower, between-crop variation in the number of visits by a technical assistant comes from. At the time of the survey, respondents were asked to delimit the production cycle of each planting by giving the beginning and end months for the production of each planting. This allowed them to better circumscribe the number of visits, even for partially overlapping plantings. Planting times did not fully overlap for 20 percent of the growers who were growing more than one crop. Alternatively, plantings did not fully overlap for 21 percent of the plantings on plots which had within-plot crop variation.

The quantities of seeds, pesticides, and fertilizer used in production are not reported in table 1 given that they are applied in equal proportions

[4] One hectare covers 10,000m^2, so that one are covers 100m^2.

across plots by virtue of the contract terms, but the percentage of pesticides provided by Lecofruit to each grower-plot-crop is reported, since some growers choose to use some of their own pesticides so as to not have to reimburse these inputs in crop at the end of the season. Lecofruit thus provides nearly 100 percent of the seeds, 37 percent of the pesticides, and 56 percent of the fertilizer used in production. Moreover, in 100 percent of cases, the contracted crop had been grown by the grower in 2003, indicating that every grower in the data set had at least one year of experience producing the crops he had contracted for with Lecofruit.

Turning to the characteristics of the grower households, the average household was composed of a little under six individuals, less than half of whom were dependents.[5] Over a quarter of growers were female and, at 38 years of age, the average grower was relatively young, having completed six years of education and having contracted with Lecofruit for almost eight years.

Finally, given that the empirical application below relies extensively on the panel nature of the data to identify the effect of the number of visits by a technical assistant on yield, table 1b present panel descriptive statistics for the dependent variable, the variable of interest, the production inputs, as well as the variables that will be used as instruments to control for the potential endogeneity of the number of technical visits.

[5]A household's dependency ratio is equal in this case to the proportion of individuals under 15 or over 64 within the household. It is thus a proxy for the quality of the household's labor endowment.

Empirical Framework

This section first discusses the estimation strategy used to study the effect of agricultural extension and imperfect supervision on yield in the application at hand by presenting the equations to be estimated in section 5. It then discusses the strategy relied upon to ensure clean identification of the effect of the number of visits by a technical assistant and addresses the potential endogeneity of these visits with respect to yield.

Estimation Strategy

In order to test the effects of agricultural extension and imperfect supervision in the contracts discussed in section 2, a simple empirical strategy is adopted. The basic specification is that of a Cobb-Douglas production function in which the unit observation is the contracted crop; the yield of green vegetables is the dependent variable; and labor, cultivated area, and the number of visits by a technical assistant are the inputs.[6] Two basic specifications of this production function are estimated below. The first specification pools all observations into a cross-section and is such that

$$(1) \quad \ln y_{ijk\ell} = \alpha_1 + \beta_1 \ln x_{ijkl} + \gamma z_{k\ell} + \pi_1 z_{jk\ell} + \delta_1 d_\ell + \zeta_1 d_i + \epsilon_{ijk\ell},$$

where $y_{ijk\ell}$ is the yield of contracted crop i on plot j cultivated by grower k in district ℓ; x_i is a vector of production inputs; $z_{k\ell}$ is a vector of grower-

[6] Following MaCurdy and Pencavel (1986), 0.001 was added to each observation of every variable for which a logarithm was taken. This was done so as to not have to introduce non-randomness in the sample by dropping all ln(0) observations, while still preserving the order between observations.

specific covariates; $z_{jk\ell}$ is a vector of plot characteristics; d_ℓ is a vector of district dummies; d_i is a vector of crop dummies; and $\epsilon_{ijk\ell}$ is an iid error term that is distributed normally. Obviously, this specification neither accounts for grower- or plot-level unobserved heterogeneity, so that in order to do so, the second specification incorporates a district-grower-plot fixed effect and is such that

$$(2) \quad \ln y_{ijk\ell} = \alpha_2 + \beta_2 \ln x_{ijk\ell} + \delta_2 d_{jk\ell} + \zeta_2 d_i + \nu_{ijk\ell},$$

where, $y_{ijk\ell}$ is again the yield of green vegetables of contracted crop i on plot j cultivated by grower k in district ℓ; x_{ijkl} is a vector of production inputs; $d_{jk\ell}$ is a vector of district-plot-grower fixed effects;[7] d_i is a vector of crop dummies; and $\nu_{ijk\ell}$ is an iid error term that is distributed normally. This specification ensures that unobserved heterogeneity is controlled for at the district, grower, and plot levels.[8] Both specifications are estimated by ordinary least squares (OLS).

Because the variable of interest (i.e., the number of visits by a technical assistant) conflates the processor's investment in both agricultural extension and imperfect supervision, two sub-specifications of equations 1 and 2 are estimated: (i) a specification in which the number of visits by a technical assistant enters production as an input; and (ii) a specification in which the number of visits by a technical assistant and its interaction with the grower's education both enter production as inputs. Because the data do not include

[7]In this context, however, the grower and plot fixed effects are the same given that the data include only one contracted plot per grower household.

[8]If households are better at growing specific crops, however, the estimates would be biased even in the presence of fixed effects.

specific information on the nature of each visit by a technical assistant, the latter sub-specification is estimated so as to crudely tease out the effects of the imperfect supervision and agricultural extension aspects of these visits. Although technical assistants, by virtue of residing in the same village as the growers they are in charge of supervising, have a good idea of each grower's "type", this variable is both unobserved by the econometrician and captured by the household fixed effect, so that one must rely on a proxy to disentangle the effects of extension and supervision. The data include few grower-specific covariates, so education is unfortunately the best such proxy one can use. Consequently, if the coefficient on the interaction term is positive (negative), the advice dispensed by the technical assistants gets more (less) effective the more educated the grower.

Identification Strategy

Even though the number of visits by a technical assistant is in theory predetermined in equations 1 and 2 because these visits occur prior to the realization of output, it remains possible that the number of visits is endogenous to yield. While this concern is assuredly valid in equation 1, where unobserved heterogeneity between plots and between growers is unaccounted for, the remainder of this section argues that endogeneity of the number of visits by a technical assistant to yield is of little concern in equation 2, in which district-grower-plot fixed effects combined with crop dummies should eliminate most of the correlation between the number of visits and the error term.

If technical assistants form rational yield expectations, these expectations are for the most part driven by within-district growing conditions as well as by grower- and plot-specific characteristics. These, however, are taken care of by the district-grower-plot fixed effects. The remaining unobserved heterogeneity is between crops within each district-grower-plot. One can think of a scenario in which technical assistants consider the grower's experience with a given crop.

The fixed effects will also not purge the error term of its correlation with the explanatory variables if, say, farmers demand fewer visits for certain crops if technical help is available from friends or neighbors for specific crops, or if the processor provides fewer visits to certain crops because local government or other agencies are providing extension service for specific crops.

Unfortunately, the data do not include the exact number of years of experience each grower has with each contracted crop, whether growers get technical help from friends or neighbors, or whether local extension agencies provide extension services for contracted crops.[9] Recall from table 1, however, that each and every grower in the data has previously grown each of the contracted crop that he or she grew during the current season. One could thus argue that most of the unobserved heterogeneity is purged by the district-grower-plot fixed effect. A similar reasoning can be applied to cases where technical assistants choose to visit more intensively with growers whose plots are closer to the village; with growers of a certain "type" (e.g., ability, efficiency, talent, etc.); with growers whose plots exhibit certain

[9]The data set did include information on public extension services for rice agriculture, but even if one wanted to use this as a proxy for the public extension services one receives for contracted crops, this does not vary between crops within a grower. In other words, the fixed effects control for public extension services for the staple crop.

characteristics; etc.

Still, the data include three variables that (i) are likely causally correlated to the number of visits by a technical assistant; (ii) are potentially exogenous to yield; and (iii) vary between crops within each district-grower-plot. These three variables are the percentages of seeds, pesticides and fertilizer provided by the processor.

As regards the first requirement, the number of visits by a technical assistant will presumably be higher on the crops for which the processor provides a higher proportion of seeds, pesticides, and fertilizer since in such cases, the processor has more at stake by virtue of being owed a higher amount of crop as reimbursement for the input advance. That is, the greater the input advance to the grower, the more the processor will wish to reduce the diversion of inputs to potentially more lucrative non-contracted crops, and so the greater the number of visits by a technical assistant. In other words, the more inputs a processor has advanced to a grower, the greater the processor's loss in case of crop failure given that inputs are reimbursed in crop, and thus the more technical advice the processor will wish to provide the grower. Whether this requirement holds can be ascertained by looking at whether the percentages of seeds, pesticides, and fertilizer provided by the processor are significant in the first-stage instrumenting regression.

The second requirement is harder to establish. In this case, because seeds, pesticides, and fertilizer are applied in equal proportions across contracted plots, the amount per are of each input does not vary between plots, as per Lecofruit's technical requirements, and although the quantity of pesticides and fertilizer varies depending on the crop grown, this is controlled for using crop dummies. The mix of processor- and grower-provided seeds, pesticides, and fertilizer varies between crops and within each district-grower-plot. So unless there are significant quality differences between the seeds, pesticides, and fertilizer provided by Lecofruit and those provided by the growers, the proportion these outputs provided by the processor should not affect yield. In what follows, the identifying assumption is therefore that if such quality differences do exist, they are small enough so as not to affect significantly yield. This is justified by Lecofruit's strict production requirements: if there were significant quality differences between processor- and grower-provided seeds, pesticides, and fertilizer, Lecofruit would simply prohibit growers from using their own inputs, as it could easily bear the initial investment in full for each contracted crop.

Therefore, in order to determine whether the number of visits by a technical assistant is endogenous to yield on the basis of these instruments, two-stage least squares (2SLS) regressions are estimated in both the pooled cross-section and the fixed effects specifications, and their results are compared to the OLS case using Hausman tests.

Estimation Results

This section presents both specifications and the two sub-specifications of the Cobb-Douglas production function discussed in the previous section. Then, because missing observations for grower-specific covariates cause the sample size to differ between the pooled cross-section ($N = 297$) and fixed effects specifications ($N = 315$), the latter are reestimated on a sample that is identical to the former. In both the pooled cross-section and in the fixed effects specifications, a comparison is run between the OLS and 2SLS estimation results via Hausman tests. Finally, the estimated elasticities of yield with respect to the number of visits by a technical assistant – the main parameters of interest in this article – are presented and discussed.

OLS Estimation Results

Although the panel nature of the data allows controlling for unobserved heterogeneity at the district-grower-plot level, the data constitute an unbalanced panel because the number of crops grown on each contracted plot differs between growers and ranges from one to four. Consequently, while the growers who produce two or more contracted crops on their contracted plot are included in the fixed effects regressions estimated below, those who produce only one contracted crop are left out of these regressions. If, as one cannot rule out *ex ante*, the growers who grow only one contracted crop differ systematically from the growers who grow two or more contracted crops, then the estimation results will be biased due to the non-random nature of the sample. At the very least, they will not be generalizable to the whole sample, and will be subject to the *caveat* that they only apply to the grower households who grow two or more crops on their contracted plot.

Turning to the estimation results, tables 2a and 2b present estimated coefficients for the Cobb-Douglas production function in the OLS case for the specifications discussed in the previous section. The difference between tables 2a and 2b, however, is as follows. Table 2a drops the observations for which some variables (i.e., household size, dependency ratio, relationship length, and distance to plot from house) are missing, while table 2b keeps them by replacing each missing value with a zero and by defining, for each variable for which some values are missing, a new variable (not shown) equal to one if the value is missing for this particular observation and equal to zero otherwise. This method then allows keeping the information contained in the fact that some values are missing.[10]

Both tables 2a and 2b show the estimation results for the pooled cross-sectional specification both without the interaction between the number of visits made by a technical assistant and grower education (model 1) and with the interaction term (model 2) as well as for the fixed effects specification both without (model 3) and with the interaction term (model 4). In each model, the number of visits by a technical assistant has a positive effect on yield, but estimated elasticities are presented in table 3 below.

In models 1 and 2, labor has the expected positive marginal effect on yield, and there is evidence of an inverse plot size–productivity relationship (see Barrett, 1996 and Barrett et al., 2010 for studies of the inverse productivity relationship in Madagascar). Likewise, the greater the amount of available household labor (as proxied by household size), and the better the quality of available household labor (as proxied by the inverse of the dependency ratio), the higher the yield.

Although models 1 and 2 include both district- and crop-level dummies,

[10] I am grateful to the anonymous who suggested this method of keeping the missing observations.

they fail to take into account unobserved heterogeneity at the grower and plot levels. Models 3 and 4 control for district-grower-plot unobserved heterogeneity and also include crop dummies. Comparing their results to those of models 1 and 2 is telling about the importance of controlling for unobserved heterogeneity: in models 3 and 4, the apparent inverse relationship between plot size and productivity disappears; the marginal effect of labor is multiplied more than threefold; and the dummy for leeks becomes significant, so that yields are lower for leeks than they are for cucumbers, snow peas, and asparagus, i.e., the omitted categories.

2SLS Estimation Results

In order to help ascertain whether the number of visits by a technical assistant is endogenous to yield, tables 4a and 4b respectively present the first- and second-stage estimation results for 2SLS versions of models 1 and 3'. In both 2SLS specifications, only the percentage of processor-provided pesticides and fertilizer used in production are used as instruments for the number of visits by a technical assistant. The percentage of processor-provided seeds was dropped from the first-stage equations because the processor provided almost 100 percent of the seeds on average, as shown in table 1.

Table 4a shows that in the district-grower-plot fixed effects specifications, the percentage of pesticides provided by Lecofruit had a significant impact at the margin on the number of visits made by a technical assistant. And although the percentage of fertilizer provided by Lecofruit was not significant in the same equation, the Sargan test of overidentifying restrictions indicated that both instruments should be kept, and the F-statistic for the Cragg-Donaldson test of weak identification was above the threshold of 10 below which a set of instruments is considered as weak. Comparing the results of both specifications in table 4a highlights yet again the importance of controlling for unobserved heterogeneity, as the effect on the number of visits of the percentage of processor-provided pesticides and fertilizer – which should both be positive if the story told above is right – goes from negative to positive when fixed effects are included. Further, the percentage of processor-provided pesticides was significant at the 1 percent level in both cases.

Table 4b shows the estimation results for the second-stage equations of the 2SLS versions of models 1 and 3', and Hausman tests indicate that these estimation results do not differ systematically from the results obtained by OLS. Although these Hausman tests have low power because the bulk of the probability mass rests on not rejecting the OLS specification, the p-value of 0.99 in each case offers a certain amount of confidence in the test result.

Elasticities

Does the combination of agricultural extension and imperfect supervision embodied by the number of visits made by a technical assistant increase yields in these contracts? The answer is obvious when looking at the elasticities in table 3. In models 3 and 4, the estimated elasticities of yield with respect to the number of visits made by a technical assistant, which are significant at the 1 percent level, are respectively equal to 1.34 and 1.67, and these same estimated elasticities are not sensibly different in models 3' and 4'. More importantly, comparing models 1 and 2 with models 3 and 4 highlights yet again the crucial importance of controlling for district-grower-plot unobserved heterogeneity in this context, since failing to do so understates the elasticities by roughly one order of magnitude. Finally, reverting to models 4 and 4' in tables 2a and 2b, it appears that the agricultural extension aspect of the visits made by technical assistants gets less effective as grower education increases.[11]

Although the estimated elasticities may *a prima facie* seem high, recall that the visits by a technical assistant serve a dual purpose in the application at hand. So if these visits are particularly effective in helping detect instances of shirking, leakage, or input diversion, or if only slight departures from Lecofruit's strict production schedule cause considerable drops in yields, then these estimated elasticities are within the bounds of what one should expect.[12]

Conclusion

This article has tested whether a combination of agricultural extension and imperfect supervision can serve to increase productivity in a sample of the

[11] In order to more effectively tease out the effect of extension, a referee suggested interacting the number of visits by a technical assistant with a grower's experience contracting with Lecofruit instead of his education. Doing so (not shown) leads to an estimated elasticity equal to 1.75, which is comparable to the elasticities obtained when interacting the number of visits with education.

[12] Grosh (1994) also notes how the agricultural extension services provided by processing firms are usually much more effective than the same services provided by governments, if only because growers tend to trust the former much more than the latter in developing countries.

contract farming arrangements signed by Lecofruit, a processing firm operating in Madagascar's Antananarivo province. In this setting, agricultural extension and imperfect supervision are conflated in a single variable, i.e., the number of visits made to each grower by a technical assistant working for the processor. Given that the number of visits varies between crops within each district-grower-plot, however, production functions controlling for district-, grower-, and plot-level unobserved heterogeneity were estimated which respectively included (i) the number of visits as an input in production; and (ii) the number of visits as an input in production as well as the interaction between the number of visits and grower education so as to tease out the agricultural extension and imperfect supervision aspects of the number of visits.

The empirical results show that the number of visits has an effect on productivity that is both statistically and economically significant, with an elasticity of yield with respect to the number of visits that is between 1.34 and 1.67, depending on the specification considered. Moreover, the empirical results show that the agricultural extension aspect of the number of visits is more effective for growers who have completed fewer years of education, indicating that Lecofruit should require its technical assistants to visit these growers more often.

A few *caveats* are in order, however. First the size of the sample used in this article, at about 300 observations, is somewhat small. Second, the data did not include variation at the level of the processor, which is both a blessing – one need not worry about either endogenous matching (Ackerberg and

Botticini, 2002) or unobserved heterogeneity between processors – and a curse – the empirical findings are limited to Lecofruit's operations. Future data collection efforts should thus focus on collecting data on several processors as well as on households who chose not to participate in contract farming. Indeed, given that the contracts in this article have elsewhere been shown to be associated with higher and more stable incomes as well as with shorter lean seasons, being able to formulate policy recommendations at the industry rather than firm level would be of prime interest, as would understanding the determinants of participation in contract farming and the matching process between growers and processors. Finally, while the variations across different crops within the same plot have some advantage for the analysis in this article, it also introduces the potential problem of comparing apples and oranges. Indeed, including crop dummies do not automatically control for this, especially if crop choice is endogenous. A better empirical strategy would consist in comparing the yield of the same crop grown on the same plot (or very similar plots), with different numbers of visits from technical assistants. This is left for future research.

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Table 1a – Descriptive Statistics

Variable	Mean	(Std. Dev.)	Observations
Crop-Level Variables			
Yield (Kg/Are)	123.50	(64.97)	315
Labor (Person-Hours)	165.07	(53.83)	315
Cultivated Area (Ares)	1.51	(6.73)	315
Visits by a Technical Assistant	10.83	(11.31)	315
Green Beans Dummy	0.65	(0.48)	315
Leeks Dummy	0.02	(0.15)	315
Cucumbers Dummy	0.33	(0.47)	315
Processor-Provided Seeds (Percentage)	1.00	(0.03)	312
Processor-Provided Pesticides (Percentage)	0.37	(0.27)	315
Processor-Provided Fertilizer (Percentage)	0.56	(0.39)	315
Crop Grown Last Year Dummy	1.00	(0.06)	315
Plot-Level Variables			
Black Soil Dummy	0.56	(0.50)	315
Red Soil Dummy	0.04	(0.21)	315
Brown or White Soil Dummy	0.38	(0.49)	315
Sand Soil Dummy	0.13	(0.34)	315
Clay Soil Dummy	0.37	(0.48)	315
Loam Soil Dummy	0.49	(0.50)	315
Grower-Level Variables			
Grower Household Size (Individuals)	5.79	(2.53)	307
Grower Household Dependency Ratio	0.46	(0.21)	307
Grower Age	38.23	(10.45)	315
Grower Female Dummy	0.28	(0.45)	315
Grower Education (Completed Years)	6.41	(2.36)	315
Relationship Length	7.77	(4.11)	311
District-Level Variables			
District 1 Dummy	0.25	(0.43)	315
District 2 Dummy	0.24	(0.43)	315
District 3 Dummy	0.25	(0.43)	315
District 4 Dummy	0.25	(0.44)	315

Table 1b – Panel Descriptive Statistics

Variable		Mean	(Std. Dev.)	Observations
Dependent Variable				
Yield	Overall	123.50	(64.97)	315
	Between		(65.53)	
	Within		(25.24)	
Explanatory Variables				
Visits by a Technical Assistant	Overall	10.83	(11.31)	315
	Between		(9.63)	
	Within		(2.42)	
Labor	Overall	165.07	(53.83)	315
	Between		(52.22)	
	Within		(17.48)	
Cultivated Area	Overall	1.51	(6.73)	315
	Between		(4.38)	
	Within		(4.74)	
Instruments for Number of Visits				
Proportion of Pesticides Provided by the Processor	Overall	0.37	(0.27)	315
	Between		(0.29)	
	Within		(0.02)	
Proportion of Fertilizer Provided by the Processor	Overall	0.56	(0.38)	315
	Between		(0.40)	
	Within		(0.00)	
Proportion of Seeds Provided by the Processor	Overall	1.00	(0.03)	312
	Between		(0.02)	
	Within		(0.02)	

Table 2a – OLS Estimation Results Omitting Observation with Missing Values

	(1) Pooled Cross-Section		(2) Pooled Cross-Section with Interaction Term		(3) Grower-Plot Fixed Effects		(4) Grower-Plot Fixed Effects with Interaction Term	
Variable	**Coefficient**	**(Std. Err.)**	**Coefficient**	**(Std. Err.)**	**Coefficient**	**(Std. Err.)**	**Coefficient**	**(Std. Err.)**
	Dependent Variable: Yield of Green Vegetables (Kilograms/Are)							
Visits	0.157***	(0.065)	0.313*	(0.180)	1.336***	(0.233)	5.227***	(0.916)
Visits*Education	–	–	-0.023	(0.025)	–	–	-0.556***	(0.127)
Labor	0.498***	(0.159)	0.484***	(0.159)	1.802***	(0.418)	1.912***	(0.390)
Cultivated Area	-0.428**	(0.209)	-0.465**	(0.213)	0.211	(0.383)	-0.537	(0.395)
Relationship Length	0.017	(0.015)	0.017	(0.015)				
Age	-0.004	(0.037)	-0.002	(0.037)				
Age Squared	0.000	(0.000)	0.000	(0.000)				
Female Dummy	0.009	(0.120)	0.011	(0.120)				
Education	0.021	(0.024)	0.069	(0.058)				
Household Size	0.048*	(0.025)	0.048*	(0.025)				
Dependency Ratio	-0.960***	(0.284)	-0.945***	(0.285)				
Distance to Plot from House	-0.005	(0.004)	-0.005	(0.004)				
Red Soil Dummy	0.203	(0.266)	0.179	(0.267)				
Brown or White Soil Dummy	0.134	(0.134)	0.125	(0.134)				
Clay Soil Dummy	-0.058	(0.194)	-0.072	(0.195)				
Loam Soil Dummy	-0.079	(0.176)	-0.076	(0.177)				
Green Beans Dummy	1.393	(0.898)	1.395	(0.898)	0.109	(0.107)	0.157	(0.100)
Leeks Dummy	0.433	(0.947)	0.446	(0.948)	-0.901**	(0.392)	-0.797**	(0.365)
Cucumbers Dummy	1.285	(0.898)	1.286	(0.898)	(Dropped)		(Dropped)	
District 2	0.277	(0.170)	0.274	(0.170)				
District 3	0.025	(0.158)	0.017	(0.158)				
District 4	-0.168	(0.159)	-0.166	(0.159)				
Intercept	0.699	(1.385)	0.396	(1.414)	-7.163***	(2.094)	-8.355***	(1.967)
Number of Plots	297		297		297		297	
Number of Growers	–		–		176		176	
p-value (All Coefficients)	0.00		0.00		0.00		0.00	
p-value (District-Grower-Plot FEs)	–		–		0.00		0.00	
R^2	0.24		0.25		0.87		0.89	

Note: The symbols *, **, and *** denote significance at the 10, 5, and 1 percent levels, respectively. Variables of interest are highlighted.

Table 2b – OLS Estimation Results Including Observations with Missing Values

	(1') Pooled Cross-Section		(2') Pooled Cross-Section with Interaction Term		(3') Grower-Plot Fixed Effects		(4') Grower-Plot Fixed Effects with Interaction Term	
Variable	**Coefficient**	**(Std. Err.)**	**Coefficient**	**(Std. Err.)**	**Coefficient**	**(Std. Err.)**	**Coefficient**	**(Std. Err.)**
Dependent Variable: Yield of Green Vegetables (Kilograms/Are)								
Visits	0.160**	(0.063)	0.316*	(0.174)	1.341***	(0.227)	5.207***	(0.887)
Visits*Education	–	–	-0.023	(0.024)	–	–	-0.553***	(0.123)
Labor	0.490***	(0.150)	0.478***	(0.151)	1.775***	(0.400)	1.925***	(0.373)
Cultivated Area	-0.419**	(0.198)	-0.455**	(0.202)	0.182	(0.363)	-0.519	(0.372)
Relationship Length	0.017	(0.014)	0.017	(0.014)				
Age	-0.002	(0.035)	0.000	(0.035)				
Age Squared	0.000	(0.000)	0.000	(0.000)				
Female Dummy	-0.002	(0.116)	-0.001	(0.116)				
Education	0.020	(0.023)	0.068	(0.055)				
Household Size	0.044**	(0.023)	0.044**	(0.023)				
Dependency Ratio	-0.947***	(0.272)	-0.934***	(0.273)				
Distance to Plot from House	-0.004	(0.004)	-0.004	(0.004)				
Red Soil Dummy	0.214	(0.251)	0.192	(0.252)				
Brown or White Soil Dummy	0.143	(0.127)	0.135	(0.127)				
Clay Soil Dummy	-0.038	(0.179)	-0.048	(0.179)				
Loam Soil Dummy	-0.069	(0.162)	-0.063	(0.162)				
Green Beans Dummy	1.392	(0.873)	1.388	(0.873)	0.103	(0.103)	0.155	(0.096)
Leeks Dummy	0.420	(0.922)	0.428	(0.922)	-0.902**	(0.383)	-0.799**	(0.357)
Cucumbers Dummy	1.287	(0.874)	1.283	(0.874)	(Dropped)		(Dropped)	
District 2	0.280*	(0.158)	0.278*	(0.158)				
District 3	0.019	(0.149)	0.010	(0.149)				
District 4	-0.150	(0.151)	-0.149	(0.151)				
Intercept	0.692	(1.325)	0.400	(1.359)	-7.028***	(2.007)	-8.403***	(1.891)
Number of Plots	315		315		315		315	
Number of Growers	–		–		188		188	
p-value (All Coefficients)	0.00		0.00		0.00		0.00	
p-value (District-Grower-Plot FEs)	–		–		0.00		0.00	
R^2	0.24		0.25		0.87		0.89	

Note: The symbols *, **, and *** denote significance at the 10, 5, and 1 percent levels, respectively. Variables of interest are highlighted. Observations with missing values were preserved using the method described in the text of the article.

Table 3 – Supervision and Extension Elasticity of Yield of Green Vegetables

Specification	Elasticity	(Std. Err.)	*N*
(1) Pooled Cross-Section	0.157**	(0.065)	297
(2) Pooled Cross-Section with Interaction Term	0.167***	(0.006)	297
(3) Fixed Effects	1.336***	(0.233)	297
(4) Fixed Effects with Interaction Term	1.737***	(0.136)	297
(1') Pooled Cross-Section	0.160**	(0.063)	315
(2') Pooled Cross-Section with Interaction Term	0.169***	(0.006)	315
(3') Fixed Effects	1.341***	(0.227)	315
(4') Fixed Effects with Interaction Term	1.734***	(0.135)	315

Note: The symbols ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

Table 4a: 2SLS First-Stage Estimation Results

	(1) Pooled Cross-Section		(2) Grower-Plot Fixed Effects	
Variable	**Coefficient**	**(Std. Err.)**	**Coefficient**	**(Std. Err.)**
Dependent Variable: Number of Visits by a Technical Assistant				
Labor	0.401***	(0.151)	0.251	(0.153)
Cultivated Area	0.249	(0.191)	0.743***	(0.168)
Relationship Length	-0.004	(0.013)		
Age	0.030	(0.032)		
Age Squared	0.000	(0.000)		
Female Dummy	0.309***	(0.104)		
Education	-0.006	(0.022)		
Household Size	-0.006	(0.022)		
Dependency Ratio	0.575**	(0.261)		
Distance to Plot from House	0.005	(0.003)		
Red Soil Dummy	-0.519**	(0.239)		
Brown or White Soil Dummy	-0.268**	(0.126)		
Clay Soil Dummy	-0.068	(0.175)		
Loam Soil Dummy	0.061	(0.160)		
Green Beans Dummy	0.176	(0.785)	0.071*	(0.040)
Leeks Dummy	-0.075	(0.847)	-0.168	(0.178)
Cucumbers Dummy	0.178	(0.785)	(Dropped)	
District 2	-0.624***	(0.146)		
District 3	-0.353**	(0.138)		
District 4	-0.146	(0.140)		
Processor-Provided Pesticides	-0.093	(0.245)	5.769***	(1.150)
Processor-Provided Fertilizer	-0.862***	(0.172)	5.382	(6.840)
Processor-Provided Seeds	-1.779	(1.683)	(Dropped)	
Intercept	1.703	(1.910)	-4.385	(3.937)
Number of Plots	294		294	
Number of Growers	–		176	
p-value (All Coefficients)	0.00		0.00	
p-value (District-Grower-Plot FEs)	–		0.00	
p-value (Joint Significance of IVs)	0.00		0.00	
F-statistic (Test of Weak IVs)	12.73		13.17	
p-value (Sargan Overidentification Test)	0.00		0.23	
R^2	0.28		0.98	

Note: The symbols *, **, and *** denote significance at the 10, 5, and 1 percent levels, respectively. Instrumental variables are highlighted.

Table 4b: 2SLS Second-Stage Estimation Results

Variable	(1) Pooled Cross-Section Coefficient	(1) Pooled Cross-Section (Std. Err.)	(2) Grower-Plot Fixed Effects Coefficient	(2) Grower-Plot Fixed Effects (Std. Err.)
Dependent Variable: Yield of Green Vegetables (Kilograms/Are)				
Visits	0.418**	(0.191)	1.592***	(0.545)
Labor	0.449***	(0.167)	1.737***	(0.453)
Cultivated Area	-0.446**	(0.217)	0.154	(0.407)
Relationship Length	0.018	(0.016)		
Age	-0.017	(0.039)		
Age Squared	0.000	(0.000)		
Female Dummy	-0.063	(0.138)		
Education	0.027	(0.025)		
Household Size	0.051**	(0.026)		
Dependency Ratio	-1.002***	(0.298)		
Distance to Plot from House	-0.008*	(0.004)		
Red Soil Dummy	0.273	(0.279)		
Brown or White Soil Dummy	0.164	(0.140)		
Clay Soil Dummy	-0.013	(0.203)		
Loam Soil Dummy	-0.027	(0.186)		
Green Beans Dummy	1.401	(0.927)	0.081	(0.119)
Leeks Dummy	0.521	(1.001)	-0.973*	(0.522)
Cucumbers Dummy	1.280**	(0.927)	(Dropped)	
District 2	0.453	(0.212)		
District 3	0.128	(0.178)		
District 4	-0.125	(0.168)		
Intercept	0.492	(1.431)	-7.309***	(2.133)
Number of Plots	294		294	
Number of Growers	–		176	
p-value (All Coefficients)	0.00		0.00	
p-value (District-Grower-Plot FEs)	–		0.00	
p-value (Hausman Test)	0.99		0.99	
R^2	0.97		0.87	

Note: The symbols *, **, and *** denote significance at the 10, 5, and 1 percent levels, respectively. Variables of interest are highlighted.