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The impact of extension services in times of crisis: Côte d'Ivoire (1997-2000)

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Abstract

This paper revisits the contested issue of the impact of agricultural extension on farm productivity. Often studies in this field suffer from a bias either due to self-selection of the best farmers for the extension services or to endogenous placement of the programme. The panel dataset collected by ANADER and the nature of the extension programme put into operation in Côte d'Ivoire between 1997 and 2001, allow to control for such biases and to deliver more robust estimates. The results indicate a positive impact of extension on yields, after controlling for other factors of production and for time and location effects. While such effect is significant and of considerable magnitude for food crops, coffee and cocoa outputs seem to have behaved differently. The results seem to suggests a tendency for farmers involved in extension to reduce their efforts in coffee and cocoa production, a finding consistent with the recent experience in the country. Once we look at revenue the overall impact of extension disappears, indicating that the switch from cash to food crops, despite being the optimal choice during a period of deep crises for perennial crops in the international markets, did not increase the revenues of farmers.

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1 Introduction

Extension programmes improve productivity primarily through two mechanisms: innovation and training. They constitute the main link between agricultural research institutions and the farmers. In addition to diffusing new technology supplied by such institutions, they provide feedback from the farmers to the research centres themselves. Extension services also offer training in existing techniques. They improve the knowledge base of farmers through a variety of means, such as demonstrations, model plots, specific training, group meetings and so on.

The exposure to such activities is intended to increase the ability of farmers to use their resources efficiently and ultimately increase crops' yields. Given the potential of extension services, and the amount of resources invested over the years in such activities, it comes with no surprise that the literature on the impact of extension programmes is quite rich. In their 1991 paper Birkhaeuser, Evenson and Feder review several studies published between 1970 and 1989, and find 11 estimates of the impact of extension on yields being significant and positive, with coefficients indicating up to 27% elasticity of output to extension services. Evenson (forthcoming) reviews more than 60 studies which address the issue of the impact of extension and research in a number of different approaches, and finds that most of them report positive rates.

Even though the results of the impact of extension services on agricultural production seem homogeneously positive, several studies have recommended caution in interpreting the results. There are a number of problems connected to such analysis, three of which are recurrent:

1. Endogenous placement bias. Often the governments place programmes in regions which are likely to be more responsive to the dissemination of innovation and training provided by extension agents. Such deliberate placement creates a correlation

between the regressor and the error that leads to a bias in the coefficients.

2. Selection bias. Particularly skilled farmers have more experience or come from more knowledgeable households and are therefore more likely to seek extension agents advice and to be involved in their activities. In the same manner the agents themselves might prefer to work with such farmers, making them again more likely to be selected to be part of the agent's contact groups. If the model does not control for these characteristics and leaves some variables omitted from the model, the error term will incorporate them. Due to the higher probability for such individuals to be involved in extension services, this will imply that the error term can be correlated, once again, with the regressor. The result of selection bias will therefore be similar to the case of endogenous placement, i.e. inconsistent coefficients.

3. Simultaneity bias. If farmers call in the extension agents only in the moment of need, then the agents will visit regularly farmers which are having problems, introducing a bias in the sample of contacted farmers. This would cause the coefficient of extension to be negative.

While these biases are well known and recommendations for caution are frequent in the literature, very few studies are based on a dataset that allows to control for them. Cross sectional analysis is not ideal to answer the technology adoption and impact question, and coefficient estimated are difficult to interpret and, often, biased (Besley and Case 1993). The focus has mainly been on choosing an extension variable that is "exogenous to individual households and internalizes inter-farmer communications" (Brikhauser et al., 1991, p.613 as cited in Evenson and Mwabu, 1998). Unfortunately it is difficult to define a convincingly exogenous extension variable: even variables based on - for example - ratio of extension staff per farm, are indeed dependent on the number of farms in the sample cluster. This number, though, will naturally be the consequence of a decision process taken by farmers, and therefore endogenous.

(Evenson and Mwabu, 1998). This study tries to take a step forward in this direction drawing on a panel sample collected by ANADER between 1997 and 2000 in Côte d'Ivoire. The nature of the dataset allows to approach this problem from a different perspective: accepting the inevitable endogeneity of the extension variable, we control for farmers' unobservable characteristics (that are the source of the endogeneity) with individual fixed effects (for a similar approach see Owens et al. 2003).

2 Diffusion of agricultural technology in Côte d'Ivoire

ANADER is the coordinating agencies for extension services in Côte d'Ivoire. It acts as the intermediary between agricultural science research centres and the farmers. It does so through a network of offices distributed throughout the country and a workforce of agents and agronomists residing in villages, in charge of the creation and running of the contact groups and of the diffusion of innovation themes and techniques.

ANADER provides advice for all crops, both cash crops and food crops. Most of the advice is rather simple and straight forward, and it involves the preparation of the fields and the respect of optimal distances between the stems, fertilization techniques, pesticides treatment, creation of plant nurseries. Of course the advice is plant specific and involves more complex issues related to each specific crop, such as protection and treatment of parasites diseases. Table 1 gives a summary of the main training carried out by ANADER in 2000.

Cash crops, coffee and cocoa, tend to carry slightly better results in terms of adoption of the techniques diffused by the agents. Nevertheless, it seems that the practices disseminated for coffee and cocoa are more likely to be already established among the farmers, therefore not likely to have a decisive impact on the yields. This result is in line with the recent experience of the ANADER agents, that report an increase in the diffusion of techniques for food crops and a decrease in the flow of innovations regarding coffee and cocoa. This is consistent with the usual diminishing returns argument for the effectiveness of extension services: indeed given the stage of the rural sector in the country, and the relatively long history of extension services, it is likely that most of the quite large and permanent innovations have already been diffused among the coffee and cocoa growers (Evenson, forthcoming; Deaton and Benjamin, 1988). The most significant advice given to farmers during the years of analysis concerns replanting, part of the innovation theme that goes under the name of "Soil preparation and distancing between plants". It is remarkable how relatively few farmers (none for cocoa and 28.1% for coffee) applied in some ways the advice received. This doesn't come as a surprise given the low profitability of these crops during years of low prices, making unlikely a further investment in the crop. Replanting, it is important to underline, has a long term impact, as both cocoa and coffee trees do not bear fruits for the first 3-5 years after being planted (Carr, 1993).

Coffee and cocoa markets experienced a recession from 1997 to 2000 due mainly to excessive capacity. Prices have been extraordinarily low, especially coffee prices that have plummeted after the boom of the mid-1990s (see figure 1). In the survey starting year (1997), 37% of the revenue of the farming activities for the households in the sample used for the analysis came from the production of coffee and cocoa (at the aggregate level coffee and cocoa account for 18% of GDP and more than 45% of total exports) (World Bank, 1999). It is evident that a drop in the prices of these commodities, in the absence of a minimum price scheme, can have a deep impact on the investment and production decisions of the farmers. Figure 2 and figure 3 give an indication of the overall quantities of food crops and cash crops produced in the country over the period in analysis. Cocoa overall exports are stable, while coffee exports decrease significantly. Interestingly overall revenues from the exports of these two crops drop drastically because of decreasing international prices. Food crops production seems to increase slightly over the years in analysis (IMF, 2000)

The country recently liberalized both the coffee and cocoa markets. The marketing board, that insured a minimum price for all farmers, was gradually dismantled allowing private actors to enter the market and to provide all the services necessary to deliver the commodities from the farmers to the exporters. The 1999/2000 season was the first in a fully liberalized context (McIntire and Varangis, 1999)

The impact of this austere period in the international market of coffee and cocoa was amplified in Côte d'Ivoire by the progressive deterioration of the political situation. Starting at the end of 1997 Côte d'Ivoire went through the worst crisis since its independence in 1960. The subsequent recession brought the economy virtually to a halt, with devastating consequences for the population. Most of donor assistance was suspended and the sudden and frequent change of leadership was not conducive to the implementation of any development programme.

3 The Model

Farmers productivity can be augmented by the introduction of new techniques. Such techniques are both concerned with improved cultivation practices, and with the use of inputs, such as fertilizers and pesticides. Feder and Slade (1985) developed a model which includes the effect of both these innovations. They set up a production function augmented by a knowledge factor:

$$Y_{it} = g(K_{it}) * F[L_i, h(K_{it}) * N_{it}] \tag{1}$$

Where Y_{it} is total output of the farm belonging to farmer i at time t, K_{it} is his/her knowledge level, L is the quantity of fixed inputs (land) owned, N_{it} is the quantity of variable inputs utilized; $F(.)$ is a well behaved production function (with positive and decreasing marginal productivity) and $g(.)$ and $h(.)$ are - respectively - the general and input specific knowledge functions. As a farmer accumulates knowledge she/he can be expected to increase her or his efficiency, therefore produce more output for a given amount of inputs. As Feder and Slade notice, knowledge is not neatly divisible in the two categories: input specific and general. Indeed an extension agent's visit is likely to supply the farmer with information that combine general practices and use of specific inputs (and indeed it appears as K_{it} in both knowledge functions). While such distinction can lead to interesting specifications, the limitations of the dataset used for this study would not allow us to identify the impacts of knowledge separately for the two effects. We therefore opted for a simpler version of the model, as originally introduced by Kislev and Shchori-Bachrach (1973). The impact of knowledge on the production function can be seen as a shift in the production frontier. Starting from equation (1) as K increases, $g(.)$ converges to an upper limit g^* as the farmer's cumulative knowledge increases to its maximum. Farmers who do not receive extension are limited to K_0 and, consequently, to g_0^*, while farmers that receive extension can accumulate knowledge up to K_1 and reach $g_1^* > g_0^*$.

This version includes - among the determinants of the general knowledge function - a variable describing the farmer's "raw labour" and personal skills (interpreted as a shadow wage, w):

$$Y_{it} = g(K_{it}, w_{it}) * F[L_i, N_{it}] \tag{2}$$

The inclusion of this variable has an important implication: the overall impact of knowledge will depend upon the skills and quality of the farmers. If we take g such that $0 \leq g \leq 1$ (that implies $g = 1$ being the maximum impact of knowledge), then we can define the properties of the knowledge function as follows:

$$\frac{\delta g}{\delta w} \geq 0, \frac{\delta^2 g}{\delta w^2} \leq 0;$$

$$\frac{\delta g}{\delta K} > 0, \frac{\delta^2 g}{\delta K^2} < 0;$$

$$\lim_{K \to \infty} \frac{\delta g}{\delta K} = 0.$$

The marginal contribution of knowledge is non-negative and declining: as knowledge increases the knowledge function converges to 1, its marginal contribution declining to 0. Kislev and Shchori-Bachrach also postulate the existence of two classes of products, according to the potential that the combination of knowledge and personal skills can have on the efficiency of their production. We can summarize their point with the following expression:

$$g(w, \infty) \leq 1$$

If $g(w, \infty) = 1$ given infinite knowledge and whatever the unobservable quality of the farmer, the impact of knowledge on production of this class of products is already at its maximum. In other words the farmer's personal skills do not count. In the class of products characterized by $g(w, \infty) < 1$, instead, an individual effect exists and will determine the ultimate level of g. The distinction between these two cases does not need to be defined along the line of no technological innovation vs. high potential technological innovation in the product. In fact $g(w, \infty) < 1$ could be true even in a technologically static setting: some production techniques and methods will be more easily learnt and applied by more skilled farmers. This is likely in an agricultural setting in developing countries: even very low-technology innovations (such as plant distancing, pruning, proper use of pesticides, etc.) are not likely to be widespread. Together with the assumption that $\frac{\delta g}{\delta w} \geq 0$, the case $g(w, \infty) < 1$ implies that farmers with better education, coming from a wealthier background, with better access to inputs or simply more skilled, are likely to be adopting this class of products more quickly and successfully than average. This observation has an important implication: trying to carry out an empirical analysis on the basis of this model without an appropriate control for individual effects will lead to biased estimates.

4 The data

The data come from a panel data survey managed by ANADER on a sample of 2500 households evenly spread across the territory. The survey was collected between 1997 and 2000, and gathered information about production during the ending farming season (so data collected in 1999 pertain to the 1998-1999 farming season). This survey is collected among a sub-sample of a bigger survey (comprising more than 10,000 households) collected only once between 1996 and 1997 and containing additional information about the households. This data was also available for the analysis.

The cross sectional part of the survey depicts an agricultural system where land and labour are the major inputs. It is almost completely non-mechanized and very few households have access to animal traction or chemical fertilizers and pesticides, as indicated by the summary statistics reported in table 2. Farmers have medium size plots, quite far from the village, and tend to have small-medium size households. 75% of the farmers interviewed reporting having more than one crop on their land, while only 25% report having a single crop farm. Moreover multicrop farms had, on average, between 3 and 4 different crop types cultivated on their land. Table 3 reports some simple results derived from a cross sectional production function estimation based on the 1997 dataset. The table reports results for both quantities and values of production as a dependent variable. The resulting production function is useful as a benchmark for the results we will get later from the panel dataset. Land and labour seem to be the most important inputs for production; fertilizers and pesticides - in the rather unlikely case in which they are used - seem to have a positive effect on production and on total value of production. Female farmers tend to be disadvantaged for permanent crops, which reflects the gender discrimination in production of such crops in Côte d'Ivoire (Duflo and Udry 2003).

The panel data survey focused on farmers production capabilities, with precise information about single plots and crops for each household.

While this survey was first collected in 1997, unfortunately the data for that year is not usable, due to some mishandling of the questionnaires. The problem was subsequently solved, leaving three usable years in the panel: 1998, 1999 and 2000.

Tables 4 to 7 summarize the trends in average production per household, average total land surface per household, average crop density, and yields for some of the crops object of the analysis during the period 1998-2000.

The yields levels for cocoa seem to have deteriorated considerably from 1998 to 2000. Quite interestingly the average size of the cocoa yields tends to decrease substantially, especially from 1999 to 2000. This result is consistent with the more accurate analysis possible through panel data: in fact following the households from period to period we come to a similar conclusion. With the exception of some few farmers that increased cocoa cultivated areas extensively, on average there was a contraction in the size of cocoa plots. This is confirmed by the decrease in average output per households. Similar conclusions, regarding the size of the plots, can be drawn from the analysis of the coffee data. Again the reduction in output is quite drastic: for coffee, in particular, this decrease in not associated with a major reduction in yields, but is reflected in the statistics on the country aggregate production . This could be due to a reduction in the effort and land dedicated to coffee cultivation and harvesting during a period of low prices and consequent low profitability. Figure 1 reports the international and farmgate price level for coffee and cocoa over the years of analysis while figure 2 reports the export quantities and values.

The story for food crops seems to be much more linear: both in the case of rice and yam the values of average output, plot surface and yield do not seem to follow a specific pattern, nor they undergo any structural changes.

Table 8 illustrates the participation rates to the extension programme of the households in the sample. There is a slight increase in the participation rates between 1998 and 1999, which is contemporary to the period of expansion of ANADER activities in the country, and general restructuring of the extension programme. The variation of the status of the households, between one year and the next, constitutes the fundamental source of variation that we are testing in our model. Table 9 shows the movements in and out of the programmes of the households interviewed. It is clear from the numbers of the observations in the table that, as it often happens with panel data, only a small proportion of the total households in the sample were tracked down year after year, while many were not re-interviewed. There doesn't seem to be any special pattern or reason that explains the drop out rate.

5 The specification

We can consider the following production setting:

$$Y = F(x, f, s, k, q) \tag{3}$$

Where

Y = output

x = variable inputs

f = fixed inputs

l = land quantity

s = soil quality

k = knowledge on innovations

q = quality of the farmers.

There are several empirical options to identify the impact of innovations on output; the first step consists in identifying a meaningful proxy for k, the variable describing the knowledge on the innovation. This analysis will use membership in the contact groups of the extension agency to represent exposure to knowledge. This choice might not be ideal: it does not give us any information on the *amount* of knowledge of the farmer on the innovation and it doesn't qualify the *kind* of innovation object of the visits. Still the data constrain the choice to this indicator, which is anyway in line with the literature (Evenson, forthcoming). Fixed inputs (except land), soil quality and the quality of farmers (f, s and q) can be considered time-invariant given the short time span available for analysis. Variable inputs (mainly fertilizers/pesticides and hired labour) were not explicitly included among the information collected by the survey. This limitation in the data availability may not prove to be undesirable. As we noticed earlier the danger of endogeneity of variable inputs is particularly severe: it is likely that the choices regarding the adoption and usage of inputs such as fertilizers and pesticides are strongly influenced by the advice of extension agents, by the weather conditions or by the change in the market prices. Of course other factors contribute to such choices, typically location effects or income and credit constraints. Using information from the 1997 cross sectional survey, though, it is clear that both fertilizers and pesticides are not a major input in the production function for the farmers in the sample. In 1997 4.5% of the plots included in the survey were fertilized while pesticides were used in only 7% of the plots. Still we will proxy usage of modern inputs with dummy variables on the quality of the material planted and the layout of the fields; this is a delicate variable as it is potentially collinear with extension advice: we test for multicollinearity of this variable with the extension variable following the simple R^2 comparison procedure suggested by Greene 1990 (p269)[1]. The test rejects the hypothesis of multicollinearity. This solution can help us to disentangle the effect of extension on knowledge led efficiency from access to inputs minimizing the potential danger of introducing endogenous input variables into the regression.

Labour would be ideally described by a variable with specific per crop information, such as numbers of day worked per plot. Unfortunately this information is not available in the panel survey, so a family labour supply proxy is used instead. From experience on the field it was noticed that the family allocates the plots available for cultivation between adult household members which become each responsible for a plot. We therefore construct a labour proxy by using the household adult members (15 to 65 years old) divided by the number of plots cultivated by the household.

The production function approach presents one limitation: type and quantities of inputs chosen can be endogenous. As time goes by, farmers might adjust their choices to the weather or the market conditions. As we control for fixed effect, only crop/plot specific endogeneity will be a cause of concern. Solutions in the literature rely mainly

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[1] For the details of the test see the Appendix

on dual cost or dual profit functions, where these choices are explicitly modelled. This solution is often unfeasible in the context of developing countries, where few inputs go through the market and observations on prices are missing or inaccurate (as indeed is the case in Cote d'Ivoire). These concerns are more problematic than the potential endogeneity of the inputs, and therefore we stick to the original production function setting. The limitation of this choice will be kept in mind in modelling and then in interpreting the results.

Another problem is the multiple output technology. Farmers produce different combination of crops, some perennial some annual, additionally they sometimes change the crop mix from year to year. Several solutions to aggregate different crop quantities were considered. Distance functions seem to be a commonly chosen solution in the literature (see Shephard, 1970 for a theoretical treatment and Corelli and Perelman, 1999 for a recent application). Another proposed solution is to use a ray production frontier, where the euclidean norm and the angle are used to describe different output vectors and aggregate them (see Lothgren 1997). Both these solutions do not appear to be suitable in this data context. Firstly they usually require that all agents produce all outputs, a condition naturally not met by the Ivorian farmers. Secondly these methods, given the intense manipulation of the data, are very sensitive to measurement error which is often inevitable in household surveys from developing countries. A possible solution is to use prices to aggregate the data into revenue measures. This method, applicable only with price data, is based on profit, revenue or cost functions which implicitly rely on strong behavioural assumptions. The information available on prices in the Ivorian dataset is poor and the profit maximizing assumptions may turn out to be unrealistic in a context where often most of the production does not go through the market. We therefore first prefer to proceed by aggregating the different crops and setting up a single output (quantity) measure, controlling for different crops with specific dummies as dependent variables. This setting will give more power to the analysis, as farmers grow several crops simultaneously: regressing on the aggregate output allows for better controls of the unobservable quality of farmers. Also, we are able to control for some of the inputs at crop level within each household (quantity of land and density of the stems); this allows us to control for the different allocation of inputs during different crops. The drawback of this setting is that it assumes implicitly that the differences in the impact of the different inputs, including extension services, among the crops can be picked up by an intercept, i.e. it is uniform across crops. We will introduce interaction terms to allow the variation in the slopes of the inputs.

Not including information about the price levels, and therefore the overall value of production, may cause an omitted variable problem with a consequent endogeneity of some of the inputs variables (such as labour). Indeed input allocation (and effort levels) are likely to have changed over the period of analysis due to the sharp variation in price levels for key crops, such as cocoa and coffee. Further more the year to year decision of what crops to plant depends on prices, so it is important to include this information into the analysis. We will therefore try a different specification, using prices for perennial and food crops to control for the incentive structure in the rural economy. While value regressions area widely adopted solution, there are several problems connected to it. The inaccuracy of the price data can be source of biased results. But price data is typically inaccurate in household surveys because farmers have limited information on prices, often because only a small proportion of their overall production goes through the market. Care needs to be applied in interpreting the results from these regressions.

The widely used Cobb-Douglas specification for the aggregate production function seems to be the most suitable tool to model the production activities of the farmers. Previous studies have used other, more complex (and more parametric), specifications. While these models add in terms of precision in the identifications of the parameters, they introduce a problem of multicollinearity (Bindlish and Evenson, 1997). Of course the Cobb-Douglas production function imposes some restrictions on the coefficient which might not be suitable to our case: unity elasticity of substitution between the inputs, constant partial elasticity of production for all input intensities, and so on. Still, recent literature tends to confirm that the Cobb-Douglas performs well enough in rural production frameworks, with the advantage of the few parameters and of the simple implementation (Gautam and Anderson, 1999). Factors of production can therefore be incorporated rather simply using the following framework:

$$\phi_i = \Pi_k (z_{ki})^{\alpha k} \tag{4}$$

where ϕ_i is the effect on output y of number of factors (z_1, z_2, etc.) , such as the ones we have previously identified in the setting (1), and α_k are the coefficients to be estimated. Taking the logs of (4) we obtain the following linear equation:

$$\ln \phi_i = \Sigma_k \alpha_k \ln z_{ki} \tag{5}$$

If the α_k were zero, then $\ln \phi_i = 0$ would imply $\phi_i = 1$ so output would not be affected in any way by the variables. Likewise if α_k is positive, it implies a ϕ_i greater then one, therefore a positive impact of variable k on output; if α_k is negative it implies a ϕ_i smaller than one, and therefore a negative elasticity of income to variable k.

Another advantage of such setting is that zs can be either levels of variables or their exponential. Since in the econometric setting we will be working with $\ln \phi_i$ this implies that levels will lead to a specification in logarithms, while exponentials will lead to a specification in levels. If we expect output to be roughly proportional to an input, then it would make sense to enter it in log form (changes in the two variables would therefore be proportional). If, instead, we expect the input to increase the output of always the same fixed percentage, then it should be entered in levels. The interpretation of the coefficients of variables entered in levels is, naturally, different from the one for coefficients entered in logarithms. The coefficients of the variables entered in levels, in particular, will not be the elasticities (as it is the case normally with the variable entered in logarithms), but will be the power of the exponential. The coefficient of dummy variables will have yet another interpretation: it will measure the discontinuous effect on the dependent variable of the presence of the factor represented by the dummy variable (Halvorsen and Palmquist 1980).

5.1 Estimation methodology: some issues

The panel structure of the data allows the use of fixed effect estimation. This technique assumes that differences across units of the sample, in our case the households, can be captured by differences in the constant term. Such differences can be estimated, creating in fact a individual effect coefficient estimated for each household in the sample. Despite the unit of the panel is the household it is important to underline that the unit of observation of the production function is the single crop in the household. We had the choice, setting up the estimation procedure, to select as a unit of the panel each crop for each household. These would have been very helpful to control for unobservable soil differences. Crops (except perennials) are rotated every year, though, so that the soil used for each crop changes from year to year, making the panel analysis at the crops level inadequate.

Using individual fixed effects allows to remove from the regression the unobservable static differences among the households therefore taking care, at least partially, of the concerns related to the problem of selection bias. Indeed if - as in this case - time invariant household unobservables are correlated with regressors, there is no real alternative to fixed effects estimation. Previous literature has extensively used instrumental variables (IV) specifications to account for the inevitable endogeneity of input variables (in particular of the innovation variable) due to the lack of adequate information about the household unobservable differences; the conditions for this model to work are stringent: any household level variable (usually the only information available in household surveys) is potentially correlated with household unobservables, making them an inadequate instrument.

Our test will take the following regression form:

$$\begin{aligned} ln(\text{yields})_{ijt} &= \ln(\text{labour})_{it} + \ln(\text{density})_{ijt} + \text{number of plots}_{it} + \text{membership in extension}_{it} \\ &\quad + \text{material}_{it} + \text{layout}_{it} + \text{regions} * \text{year dummies} + \text{crop dummies}_{ijt} + v_i + u_{ijt} \qquad (6) \end{aligned}$$

Where:

yields: sum of the surface of the plots for each crop in the household;

Labour: number of household members in working age (15-64)

Density: average number of stems per squared meter for each food crop; number of trees per ha for tree crops.

Material: dummy for use technologically advanced seeds and techniques for each crop ($0 = no, 1 = yes$);

Layout: dummy for modern layout of the plot ($0 = no, 1 = yes$);

Number of plots: total number of plots worked by the household.

Extension: dummy for participation in the contact groups of the extension programme $(0 = no, 1 = yes)$;

Region and year dummies are interacted to pick up region specific climatic or otherwise exogenous shocks;

v_i: household individual effect;

u_{it}: "white" error term.

Notice how the information on crops, density, material and layout is observed at the crop level for each household in each year (hence the subscript ijt), while the rest of the information and the fixed effects are at the household level (hence it). J crop dummies are included among the determinants to control for different crops through different intercepts. Information on the density of the crop is crucial, especially for perennials: yields naturally will be higher the more trees in the same area. This is important in the Ivorian context where cocoa and coffee plots' thickness is an important sign of the intensity of the overall production unit, and a sign of wealth of the farmer. Density of the crop tends to change from year to year, indicating replanting, pruning or eradication of old trees.

There are several possible variations for this equation, involving different specifications both of the dependent and of the independent variables. In this model yields are used as a independent variable. While we could have used output, controlling for land, some observations relating to land size were missing in the dataset, probably due to data entry mistakes[2]. As we discussed earlier output (and yields) is measured as total quantities (per ha in the case of yields). The other specification tested uses the aggregate gross value of all crops produced as an independent variable, where dif-

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[2] Data on yields was calculated by interviewers during the survey. For completeness we report in the appendix the results of the regressions using output as an independent variable and including land size as a determinant (see table A.4).

ferent crops are aggregated using local prices; this measure incorporates information about the selection that the household does in terms of crop mix to produce each year, so that the final effect of extension will include the effect on crop choice (Weir 1999). This is an important issue, as the incentive structure created by the variation in crops prices will have an impact on the decision of the allocation of inputs, including the distribution of household (and hired) labour on different plots. Such variation is not fully controlled by the labour variable: the number of household members in working age does not contain any *decision* of the farmer. The labour variable is, in other words, inaccurately measured. But if the crop choice is determined, among other things, by the interaction with the extension agent, then the imposed exogeneity of the labour measure allows us to identify fully this effect.

While the advantages of the panel data approach, in terms of precision of the estimation, are undeniable, some concerns can derive from the implicit choice of "learning model" for the households that such methodology implies. In fact our estimation method (based on yearly differences) implies that we will look only at the farmers that "change status" in terms of contact with extension agents; computationally this means that farmers that become members of an extension group - from one year to the other - will generate a 1 in the extension variables, while farmers that loose their membership status will generate a -1 on the extension variable. It can be argued that while joining extension probably generates a certain amount of knowledge, quitting the programme does not imply losing all the knowledge previously acquired. It would be more appropriate to model the learning process with a cumulative variable, that would imply a capacity to retain the knowledge even after losing the membership in a contact group (Kortum, 1997). In other words, let K be the stock of knowledge, we would expect that people can add on to it, but not subtract from it; therefore we would like K to behave accordingly: be strictly increasing and weakly concave. It is important to keep this factor in mind when discussing the results: the individual fixed effects regression, despite the advantages in terms of precision of the estimator, allows us to look only at the impact of joining the extension programme on the variation of output. To overcome this limitation we try a different specification for extension, in which we accumulate the years of membership in the extension programme for each household. We construct the variable in the context of the panel regression: we set it up to see whether the cumulated years of experience have an impact on the variation in production efficiency from one year to the other. This specification helps overcoming the preoccupations on a potential artificially negative impact of leaving the extension programme and allows us to have estimates of a relatively longer effect of extension (limited to only two years given the limitation of the dataset). A drawback of this specification, on the other side, is that a positive coefficient implies that the longer membership in extension has a dynamic effect on production, i.e. that it is associated to increasing growth rates in output. It is not clear whether the advice that comes with extension services - especially for food crops - could have such an effect.

Another concern with the within estimator is that it will control only for fixed, i.e. time invariant, effects only. If there is an unobservable *dynamic* effect, i.e. we believe that it may influence the ability to *change* rather than (only) the levels of yields, then fixed effects techniques will not be sufficient to guarantee identification. If this was the case then only further differencing and a dynamic panel data estimator (such as the Arellano-Bond estimator) would allow to control for such an effect: this solution - though - is not feasible in this context due to the short time span available in this dataset.

The context in which this theory on the role of technology diffusion on productivity is tested has some reassuring characteristics. Firstly the problem of endogenous placement bias is not very insidious in our case, as the extension programme run by ANADER is managed out of local offices evenly spread through the country, according to quite strict regulations. Such offices were not built ex-novo, but where the long established offices part of the ANADER network, that is well known for its capillary presence on the territory. Such precise placement rules, together with the characteristics of the agency, provide good grounds to consider the placement of the programme exogenous.

Moreover the modality of the visits by the extension agents provide good grounds to dismiss concerns regarding simultaneity bias: in fact the agents have to visit the households following a strict timetable, decided together with their supervisors. They visit each of the households which are registered as members of the programme once every two weeks. Single farmers do not have the opportunity to require “ad hoc” visits from the agent, and the agent himself is subject to random checks from his/her supervisor to monitor whether he is following the visits on the timetable (ANADER, 1999).

One factor that introduces a source of concern is the quality of the extension variable. According to the officers who supervise the programme in Abidjan, some of the farmers who were originally selected for the programme did not attend regularly, while other farmers who weren’t selected started attending becoming, de facto, involved in the programme. According to the designers of the survey the people who answered yes to the involvement in the extension contact groups were both the ones who were only technically inscribed in the list but did not participate, and the ones who were actually going to the demonstrations and to the meetings despite not being officially chosen by ANADER. The effect of such a bias would anyway be a underestimation of the coefficient. There is yet another source of concern connected to the quality of the service: during the period of crisis it is likely that some of the scheduled extension visits will have not happened, mainly due to the lack of means to pay the agents and to finance their travelling to the farmers (mainly gas and motorbike maintenance costs). So farmers who were living in more isolated locations might have been disadvantaged in terms of extension received. While their location is fixed, and therefore picked up in the fixed effect estimate, the influence of the location on the estimates of the impact of extension services maybe dynamic and vary across the years of analysis. In other words some farmers who were still visited by the agent in 1997 might have been subsequently unofficially dropped from the agent's roaster since they were too far from his base. Unfortunately there is little we can do to avoid this bias: ideally we could insert a variable for the distance from the farmer's plots to the residence of the agent, but such information is unfortunately not available.

6 The results

Table 10 summarizes the results from the fixed effects regression specified in (6), where the dependent variable is yields (quantity of crop in kg per ha of land - where both harvested quantity and land are crop specific).[3] The first column reports the results for the whole sample. Labour and the number of plots available to the household seem to be the only determinants of yields. Next we look at the two crops separately (columns 2 and 3) and finally at the full sample but with the key variable interacted with the crop type (column 4): in this setting labour and density variables take the sign we expexted. The impact of extension membership on food crops' yields is positive and significant in all the specifications. The magnitude of the coefficient varies between .298 and .48, implying a elasticity between 33% and 61%[4]. The lower

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[3] Results of the OLS regressions are reported in the Appendix (table A.3)

[4] the formula used to obtain the elasticity is the following: $100 * g = 100 * \{\exp(c) - 1\}$ were g is the relative effect (so that $100 * g$ is the percentage effect, and c is the estimated coefficinet

bound coefficient seems to be a more accurate estimate of the effect: due to the fewer observations in the separate regressions for food crops the accuracy of the fixed effects is limited (the F test deteriorates considerably in this regression). This implies that the coefficients for extension - in the food crops only model - might be biased upwards due to unobservable differences among the farmers not being controlled fully by individual fixed effects. The results reported with interactions seem to be much more robust, despite introducing some inevitable rigidity in the production function. These show a coefficient of extension on foodcrops production of .298 implying a elasticity of 33.5%, which is in line with the literature (Feder et al., 1991 Evenson, forthcoming). The positive impact on food crops is coherent with the information collected on the nature of extension services over the years of analysis: the agency was in fact focusing on short term advice on food crops during the crisis period. It is likely that in this context farmers advised by extension agents switched from commercial crops to food crops; in this difficult period food crops were also a way of guaranteeing survival for the household. This might be part of the reason we see such a strong impact of extension on food crops: farmers might simply put more effort in their food crops production once they receive the agent's advice. This change in the levels of effort is not easy to detect or describe with a variable: farmers will in fact not switch crops completely, but simply invest more time and resources in more profitable crops, leaving coffee on the side but, naturally, not deplanting the existing trees. Given the data limitations it is not possible, in this context, to distinguish what proportion of the increase in productivity is due to improved technology and to increase in effort.

Table 11 reports the results of the value regressions, where the independent vari-

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for the dummy variable). See Halvorsen and Palmquist 1990 for details about the calculation of dichotomous variables elasticity in a semilogarithmic setting.

able is the aggregated value of all crops' output. Since price data series were not available for food crops (for 1997 to 2000) but only for commercial crops, the food prices had to be simulated. Prices were available for 1997 for each crop in each county[5]. These prices were therefore inflated with a food-specific price index to create a series of prices for 1998, 1999 and 2000 (IMF, 2001). The first three columns report the fixed effects regression while the last three report the results of OLS regression with robust standard errors. The impact of extension on food crops seems to disappear in this setting. In the OLS setting the impact of extension on perennial crops seem to be negative. The reasons behind such results may be linked to the fact that in this setting we are looking at revenues. In absolute terms the monetary revenue produced by commercial crops is higher than the one produced by food crops sold in the local market. This doesn't imply that commercial crops are more *profitable* in the long term: they only generate a bigger cash flow. If farmers switched from commercial crops (such as cocoa and coffee) to food crops then it is possible that their overall revenue decreases despite the choice still makes sense in terms of profitability of the choice. This seems to be consistent with the negative trends observed in the aggregate production and - especially - aggregate revenue produced by cash crops in the country over the years in analysis (see figure 2 and figure 3, IMF 2000). Furthermore if many farmers decided to focus their production on food crops, then the prices for food crops relative to commercial crops might have decreased due to the higher supply of food crops in the market. This seems to be the case looking at the relative price index of food as opposed to cash crops, at least in the period 1998-1999. This could explain while despite the more efficient production of food crops the overall revenue might have not increased proportionally. Interestingly the OLS

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[5] Crops prices were collected in 1997 in the househld survey. Due to the noisy nature of the price data, median values were constructed for each crop in each county.

regressions seem to suggest a negative impact of extension on the revenue produced by commercial crops, a result which seems to fit the proposed explanations.

As we noticed earlier the dataset does not contain specific information on variable inputs. Still household fixed effect, that is the households' unobservable "ability", will include the differences in level of usage of variable inputs, such as fertilizers and oxen pairs. Other inputs, such as machinery or tools, are less of a worry, given we can expect very little variation in households' durables over the three years of analysis. As a further check, anyway, we try a different specification of the model which trades the advantages of the panel dataset to include some of the information available on variable inputs for one year only (such as tools and livestock). The results indicate that their inclusion does not change the results in any material way. The results are reported in the Appendix (see table A.1).

Table 12 reports the results for the cumulative knowledge specification proposed. Here we assume that knowledge is retained over time, even if the household stops being an extension member. We test directly the regression for the entire sample interacting the cumulated knowledge variables with food and perennial crops dummies to increase the prediction power of the within estimator. The first column reports the results for the model with only the cumulated extension variables. Standard errors are higher than in the previous regressions, indicating that overall this specification of extension does not seem to fit the data very well. There seem to be no returns to cumulated years of extension for food crops: this indicates, as it was predictable, that in the case of food crops the advantages of extension wear off after the first year. This is consistent with the immediate impact of advice on food crops, focused mainly on pesticides treatment and product quality (see table 1). The second column reports the results for a model in which we include both our original extension membership variables and the cumulative knowledge ones. Interestingly both results seem to be robust to this new specification. We find again the familiar results with a positive and significant coefficient associated to the extension variable when interacted with the food crops dummy (with a magnitude of 0.35 equal to a direct elasticity of 42%). There is still no evidence of any impact of cumulated years of extension on the food crops' yields, confirming that the extension advice concentrated on short run solutions and wore off after the first year.

7 Conclusion

The impact of extension services on yields in the period from 1997 to 2000, which coincides with some of the worst years in the history of independent Côte d'Ivoire, has been mixed. The main conclusion of this paper is that food crops production seems to have benefited significantly from extension services. At the same time the analysis did not show any significant impact of extension on the production of coffee and cocoa - the major export crops. The magnitude of the impact must be interpreted with care: the influence of the crisis in international coffee and cocoa prices on the effort levels and crop-mix choice of farmers has played an important role in the trends of the yields of these crops. According to the various results obtained through different specifications the elasticity of production to extension lies in the 30% range. This result is in line with the existing literature on short term impact of extension on food crops. The non-significative or negative elasticity of coffee production to extension seems to suggest that the distribution of farmers' effort and resources among their crops has changed considerably during these last year.

The fact that there is apparently no effect of extension on revenue seems in line with the overall tendency to switch efforts from high-revenue crops to lower revenue ones, such as cassava and rice. Better price and labour data, together with a longer time dimension in the panel data, would allow to draw more robust conclusions on this issue (for example by enabling to introduce techniques to control for dynamic unobservable effects). Extra data would also allow further work on the impact of cumulated knowledge on yields.

References

[1] ANADER (1999). L'Enquete de base sur l'exploitation et la production agricole 1996-1997. CD-ROM. R.E.I., ANADER, Abidjan.

[2] Araujo Bonjean, C., G. Chambas and J.-L. Combes (2000). Echecs de marches et pauvreté: l'exemple de la filière cacao en Cote d'Ivoire. Comunication au Colloque "L'Avenir des Cultures Pérennes". Yamoussoukro, 5-9 novembre 2001.

[3] Benjamin, D. and A. Deaton (1993). "Household welfare and the pricing of cocoa and coffee in Cote d'Ivoire: lessons from the living standards surveys." World Bank Economic Review 7: 293-318.

[4] Besley, T. and A. Case. (1993) "Modeling Technology Adoption in Developing Countries." American Economic Review 83 (May 1993): 396-402.

[5] Bindlish, V. and R. Evenson. (1993) "Evaluation of the performance of T&V extension in Kenya". World Bank Technical Paper 208. The World Bank, Washington D.C.

[6] Bindlish, V. and R. Evenson. (1997). "The impact of the T&V extension in Africa: the experience of Kenya and Burkina Faso". World Bank Research Observer 12 (2): 183-201.

[7] Birkhaeuser, D., R. Evenson and G. Feder. (1991). "The economic impact of agricultural extension: a review". Economic Development and Cultural Change 39 (3): 507-521

[8] Carr, S. (1993). Improving cash crops in Africa : factors influencing the productivity of cotton, coffee, and tea grown by smallholders. Washington, D.C., World Bank.

[9] Coelli, Tim and Sergio Perelmean (1999). "A comparison of parametric and non-parametric distance functions: with application to European railways." European Journal of Operational Research 117(1999): 326-339.

[10] Deaton A. (1997). The analysis of household surveys: a microeconomic approach to development policy. Baltimore: Johns Hopkins University Press.

[11] Duflo, Esther and Chris Udry (2003). "Intrahousehold Resource Allocation in Cote d'Ivoire: Social Norms, Separate Accounts and Consumption Choices." Mimeo. Yale University and MIT.

[12] Etherington, D. and Matthews P. J. (1983). "Approaches to the economic evaluation of agroforestry farming systems" Agroforestry Systems (1)4: 347-60.

[13] Evenson, R. (forthcoming). “Economic Impacts of Agricultural Research and Extension”, in Gardner, B. and Rausser, G. (forthcoming) Handbook of Agricultural Economics, Elsevier Science.

[14] Evenson, R. and G. Mwabu (1998). “The effects of Agricultrual Extension on Farm Yields in Kenya”. Economic Growth Center Discussion Paper No. 798. Yale University. New Haven, CT.

[15] Fafchamps, M. and B. Minten. (2001). “Property Rights in a Flea Market Economy”. Economic Development And Cultural Change 49(2):229-267

[16] Fafchamps, M. and A. R. Quisumbing (2003). ”Social roles, human capital, and the intrahousehold division of labor: evidence from Pakistan.” Oxford Economic Papers 55(1): 36-80.

[17] Feder, G. R. Just, and D. Zilberman. (1985). “Adoption of Agricultural Innovations in Developing Countries: A Survey”. Economic Development And Cultural Change 33(1):255-298.

[18] Feder, G. and R. Slade. (1984). “Contact farmer selection and extension visits: the training and visit extension system in Haryana, India”. Quarterly Journal of International Agriculture 23(1): 6-21.

[19] Feder, G. and R. Slade. (1985). “Methodological Issues in the Evaluation of Extension Impact”. Discussion paper ARU 47. Agriculture and Rural Development Dept. Research Unit, the World Bank, Washington D.C.

[20] Foster. A. D. and M. R. Rosenzweig. (1995). “Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture”. The Journal of Political Economy 103(6): 1176-1209

[21] Gautam, M. and J.R. Anderson. (1999). “Reconsidering the evidence on returns to T&V extension in Kenya”. Policy Research Working Paper 1098, the World Bank, Washington D.C.

[22] Greene, W. (1993). *Econometric Analysis.* Second Edition. New York: Macmillan Publishing Company.

[23] Halvorsen, R. and R. Palmquist (1980). “The Interpretation of Dummy Variables in Semilogarithmic Equations.” American Economic Review vol. 70(3): 474-475.

[24] IMF (2001). *Cote d’Ivoire: Selected Issues and Statistical Appendix.* IMF Staff Country Report 00/107. International Monetary Fund, Washington, D.C.

[25] Kislev, Yoav and Nira Shchori-Bachrach (1973). "The Process of an Innovation Cycle." American Journal of Agricultural Economics, 55(1):28-37, 1973. Also in: Issues in the Economy of Israel, eds.: N. Halevi and Y. Kopp, The Maurice Falk Institute for Economic Research in Israel, Jerusalem, 1975 (English and Hebrew). Kortum, Samuel. (1994). "Research, Patenting, and Technological Change" Econometrica, 65(6), 1997, 1389-1419.

[26] Löthgren, M. (1997). "Generalized stochastic frontier production models." Economics Letters 57(3): 255-59.

[27] McIntire, J. and P. Varangis. (1999). "Reforming Côte d'Ivoire's Cocoa Marketing and Pricing System". Policy Research Working Paper 2081, the World Bank, Washington D.C.

[28] Owens, T., J. Hoddinott, et al. (2003). "The impact of agricultural extension on farm production in resettlement areas of Zimbabwe." Economic Development and Cultural Change 51(2): [337]-57.

[29] Ruf, F. and F. Gérard (2001). Agriculture in crisis : people, commodities and natural resources in Indonesia, 1996-2001. Richmond, U.K., Curzon Press.

[30] Ruf, F. (2000). "Planteurs et chocolatiers face a face". Marches Tropicaux n.o 2873, 1er décembre 2000.

[31] Ruf, F. (1995). Booms et crises du cacao : les vertiges de l'or brun. Paris, Cirad-Sar; Karthala : Ministère de la coopération.

[32] Shephard, Ronald W. (1970). *Theory of Cost and Production Functions* (Princeton, New Jersey: Princeton University Press, 1970).

[33] Umali, D. and L. Schwartz (1994). "Public and Private Agricultural Extension: Beyond Traditional Frontiers". World Bank Discussion Paper 236. The World Bank, Washington D.C.

[34] Weir, Sharada (1999). The Effects of Education on Farmer Productivity in Rural Ethiopia. WPS99-7. Working paper series. Centre for the Study of African Economies. Oxford University.

[35] World Bank. (1999). Côte d'Ivoire: Country Assistance Review. Operations Evaluation Department. The World Bank, Washington D.C.

8 Appendix

Testing for multicollinearity

We can express the kth element of the inverse matrix $(X'X)^{-1}$ as follows:

$$\begin{aligned}
(x_1'M_2x_1)^{-1} &= (x_1'x_1 - x_1'X_2(X_2'X_2)^{-1}X_2'x_1)^{-1} \\
&= (x_1'x_1(1 - \frac{x_1'X_2(X_2'X_2)^{-1}X_2'x_1}{x_1'x_1}))^{-1} \\
&= \frac{1}{S_{11}(1 - R_{1.}^2)}
\end{aligned}$$

Where $R_{1.}^2$is the coefficient of correlation obtained by regressing the x_1 on the rest of the determinant variables included in the original regression. This expression is, therefore, a valid expression for the variance of the coefficient estimated for x_1, our b_1. It is easy to see that adding to our specification a variable which is highly correlated with x_1 would imply a higher $R_{1.}^2$ and a corresponding increase in the whole variance of b_1. Simple correlation in the variables, therefore, might underestimate the impact on variances, and therefore on the precision of the estimation. A simple rule has been suggested to check the robustness of the specification to multicollinearity. Should the overall R^2 in the original regression be lower than the R_i^2 from the single "partial" regressions, then we would have reasons to worry. In fact, the estimated variance for b_1 can be expressed as follows:

$$Est.Var(b_i) = \frac{s^2}{S_{ii}(1 - R_{i.}^2)} = \frac{(1 - R^2)S_{yy}}{(n - K)(1 - R_{i.}^2)S_{ii}}$$

This expression indicates why this quick rule is a good estimate of possible bias in the results.

In our sample the total R^2 , obtained from the overall regression (estimated with OLS to obtain the R^2) is 0.8221, while the $R_{i.}^2$ once we regress the "suspect" regressors onto the rest of the dependent variables are 0.3793 for the quality of the material and 0.3303 for the layout of the fields. These results indicate that there is no risk of multicorrelation in the original regression.

Including information on capital

Table A.1

	1998: without oxen	1998: with oxen	pooled: without oxen	pooled: with oxen
	ln(yield)			
ln(density) * food crops	0.32	0.318	-0.025	-0.027
	1.62	1.57	-1.13	-1.21
ln(density) * perennials	0.076	0.055	0.127***	0.121***
	0.7	0.49	3.48	2.99
ln(labour) * perennials	0.225**	0.244**	0.285***	0.294***
	2.08	2.21	4.2	3.93
ln(labour) * food crops	0.169	0.167	0.077	0.075
	0.92	0.9	0.92	0.88
Seeds quality (crop specific)	0.052	0.069	0.044	0.041
	0.56	0.7	0.84	0.75
Plot layout (for perennials)	0.126	0.123	0.099	0.098
	1.51	1.46	1.54	1.48
Extension * perennials	0.009	0.02	-0.067	-0.063
	0.09	0.2	-1.12	-0.01
Extension * food crops	0.526***	0.537***	0.253***	0.249***
	2.94	2.96	3.2	2.97
Number of plots	0.183***	0.181***	0.231***	0.247***
	4.65	4.54	8.16	8.19
ln(numb.of oxen)* food crops		0.227		0.003
		1.43		0.03
ln(numb.of oxen) * perennials		-0.017		-0.042
		-0.31		-0.94
Fixed effects	No	No	No	No
Year dummies	No	No	Yes	Yes
Observations	345	341	1156	1063
R-squared	0.48	0.48	0.53	0.53

The panel dataset collected between 1997 and 2000 lacks also information on capital. This could be cause of concerns regarding the production function we are trying to estimate: excluding information on capital utilized by farmers might introduce an omitted variable problem. Nevertheless the survey contains, only for 1998, some information on cattle belonging to the households. Such information can be used to proxy for capital usage in the production procedures of the household (Weir, 1999). Since we cannot obtain information for the subsequent years, it is not possible to insert this variable in the within estimation setting (since it is time invariant). We report, therefore, the results of the cross sectional regression for 1998, where heteroskedasticity is corrected with robust standard errors. In 1998 only 15% of the interviewed households reported using oxen in their production. The absence of fixed effect, given the cross sectional nature of this specification, introduces a bias in the extension coefficient which seems much higher (for 1998) than the one we find in the fixed effects estimation. This effect gives an example of the caution necessary in interpreting the results deriving from single year cross sectional analysis, a problem that is emerging clearly in the literature (Owens et al. 2003). Comparing the results reported in the two columns it is clear that the introduction of the extra variable does not have a significant impact on the extension variables. Indeed the effect of oxen on yields is not significant, even if for 1998 and for food crops (which are the crops which would benefit from the use of oxen pairs) the coefficient is positive and on the edge of significant area. Running a Wald test on the oxen variables, which results are reported in the following table, confirms that the coefficients are jointly not significantly different from 0, and that the variables can therefore be omitted from the model. Pooling across years considering the oxen constant across the years of analysis as it was in 1998, the results are similar. The Wald test for the exclusion of the oxen variables indicates that they are jointly non significantly different from 0.

There seem to be enough evidence not to be too concerned about the robustness of the extension coefficients to the omission of variable capital variables such as oxen.

Table A.2

restrictions tested	1998 all crops	1998-2000 pooled all crops
ln(numb.of oxen)* perennials=0		
ln(numb.of oxen)* food crops=0		
F statistic	F(2, 311) = 1.09	F(2, 1026) = 0.45
Prob>F	Prob > F = 0.3388	Prob > F =0.6406

Table A.3
This table reports the OLS results of the regression in (X)

	all crops	food crops	perennials	all crops with interaction
	ln(yields)			
ln(labour)	0.210***	0.053	0.285***	
	4.02	0.64	4.23	
ln(labour) * perennials				0.285***
				4.2
ln(labour) * food crops				0.077
				0.92
ln(density)	0.025	0.018	0.129***	
	1.3	0.69	3.45	
ln(density) * perennials				0.127***
				3.48
ln(density) * food crops				0.285***
				4.2
number of plots	0.209***	0.437***	0.205***	0.231***
	7.58	4.13	7.11	8.16
extension	0.036	0.230***	-0.079	
	0.76	2.96	-1.32	
extension * perennials				-0.067
				-1.12
extension * food crops				0.253***
				3.2
Observations	1156	469	687	1156
fixed effects	No	No	No	No
R-squared	0.52	0.48	0.28	0.53

Notes: *t* statistics in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Table A.4

This table reports the results for the same specification as the one reported in table 10, but where the independent variable is ln(total production) and ln(total land) is included among the determinants.

	all crops	food crops only	perennials only	all crops with interaction
	ln(total production)			
ln(land)	1.511***	1.439***	1.301***	1.491***
	28.83	14.05	17.82	28.15
ln(labour)	0.394**	1.687***	-0.058	
	2.33	3.52	-0.31	
ln(labour) * perennial				0.373**
				2.2
ln(labour) * food crops				0.362*
				1.89
ln(density)	0.033	0.066	0.132**	
	1.38	1.59	2.04	
ln(density) * perennials				0.149***
				2.94
ln(density) * food crops				0.000
				0.000
extension	0.061	0.473**	-0.095	
	0.71	2.32	-0.97	
extension * perennials				0.023
				0.25
extension * food crops				0.232**
				2.04
tot number of plots	0.01	0.037	0.03	0.02
	0.24	0.22	0.62	0.51
Observations	1156	469	687	1156
Panel individuals	482	306	373	482
Average obs	2.4	1.5	1.8	2.4

Notes: *t* statistics in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 1. Innovations diffused by ANADER.

Crops	Training themes	farmers adopting innovation(%)	farmers with previous knowledge(%)
CASH CROPS			
Cocoa	Crop maintenance	25	
	Soil preparation and distancing	0	32
	Product quality	49.3	
	Pesticide treatment	32.2	
Coffee	Crop maintenance	27.9	
	Design of a plant nursery	31.9	
	Soil preparation and distancing	28.1	13
	Product quality	53.5	
	Pesticide treatment	22.2	
FOOD CROPS			
Corn	Soil preparation and distancing	23.8	20.6
	Product quality	27.5	
Cassava	Design of a plant nursery	0	
	Soil preparation and distancing	35.2	1.4
Rice	Soil fertilization	31.6	
	Design of a plant nursery	30	
	Soil preparation and distancing	21.4	20
	Pesticide treatment	35.7	
Tomatoes	Usage of manure	0	
	Soil fertilization	50	
	Design of a plant nursery	38.7	17
	Soil preparation and distancing	48	
	Pesticide treatment	42.9	

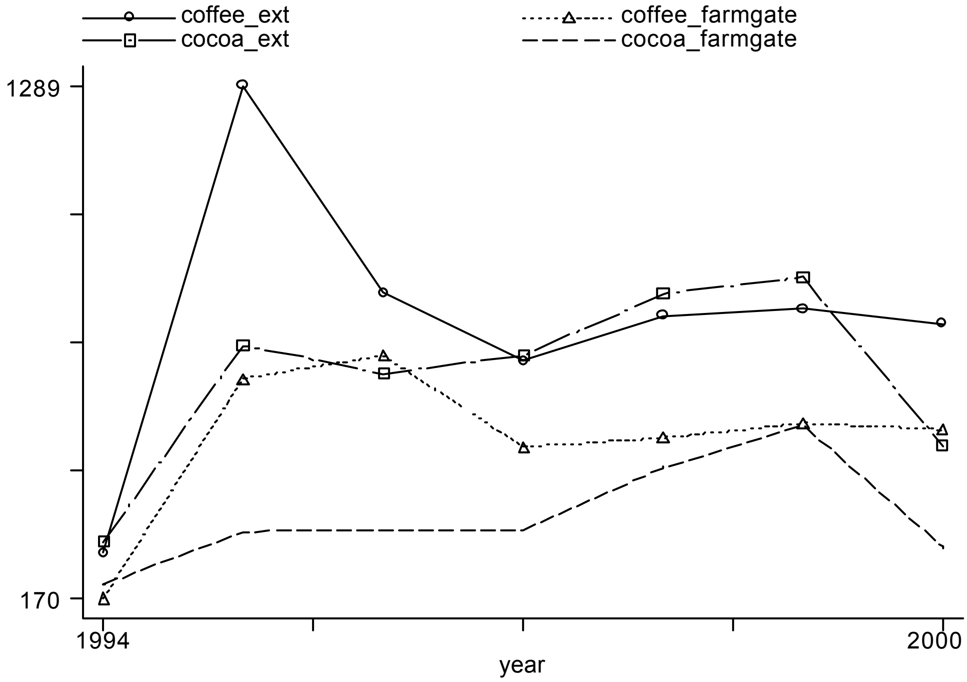

Figure 1:

International prices of coffee and cocoa 1994-2000 (fCFA/kg)
Source: IMF(2001)
Table 2. Descriptive statistics.

household characteristics	
average total land owning (ha)	3.1
average number of plots per household	4.34
average household size (numb. of members)	5.65
% of household owning livestock	2.62%
% of households using more than 30 man-days hired workforce	14.7%
% of households using fertilizers	11.7%
% of households using pesticides (more than 5kg per year)	9.25%
% of farmers owning mechanic tools	less than 1%
average distance of the household plots from the village (in Km)	4.55

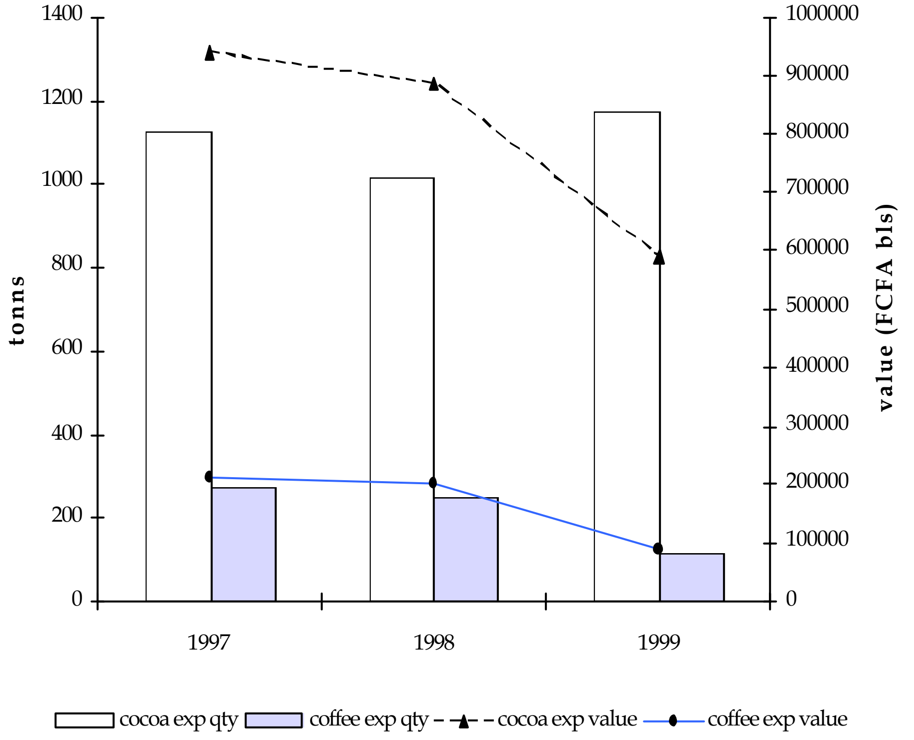

Figure 2:

Quantity and value of coffee and cocoa exported, 1997-2000

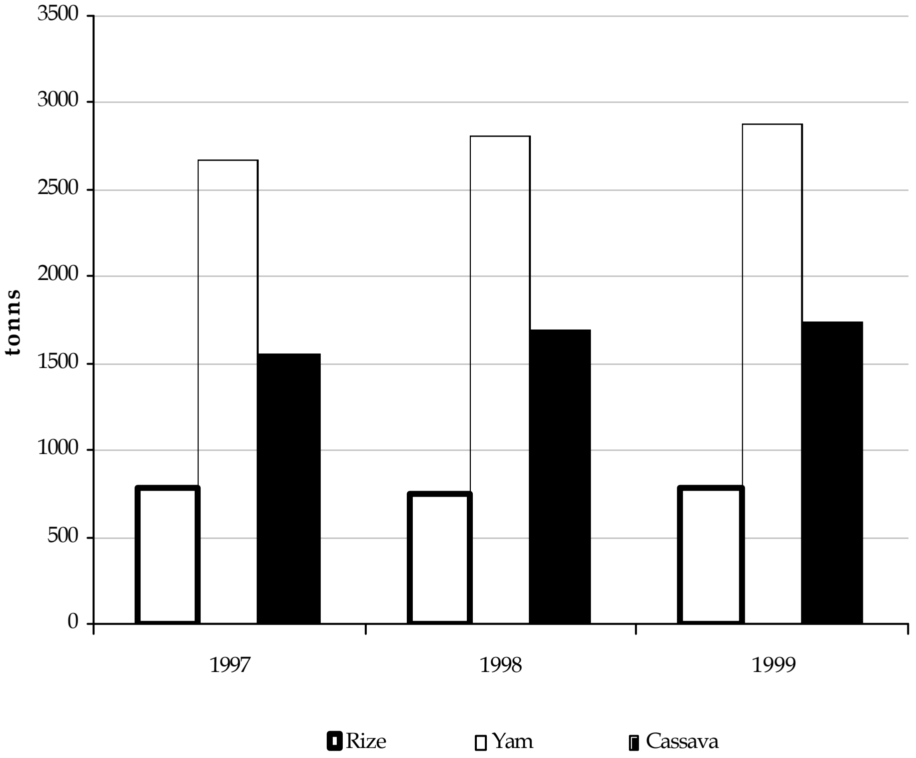

Figure 3:

Overall quantity of food crops produced in the country, 1997-2000.

Table 3. Cross sectional regression.

	Perennials	Food crops	Perennials	Food crops
	ln(output in kg)		ln(output value in 000 fCFA)	
ln(crop specific plot surface in ha)	.886**	.865**	.838**	.706**
	(0.000)	(0.000)	(0.000)	(0.000)
ln(hhsize)	.321**	.133	.392**	.140**
	(0.000)	(0.099)	(0.000)	(0.002)
ln(workforce in man-days)	.049**	.080**	.036**	.073**
	(0.020)	(0.002)	(0.008)	(0.000)
ln(pesticides in kg/year)	.236**	.061	.182**	.073**
	(0.000)	(0.080)	(0.000)	(0.008)
ln(fertilizers in kg/year)	.123*	.024	.083*	.032
	(0.033)	(0.283)	(0.039)	(0.141)
Female hh head dummy	-.241	-.088	-.253**	-.084
	(0.077)	(0.360)	(0.008)	(0.268)
Indigenous household dummy	-.309**	.044	-.215**	-.154**
	(0.008)	(0.687)	(0.001)	(0.008)
Years of schooling of hh head	-.022**	.016	-.017**	-.003
	(0.001)	(0.156)	(0.002)	(0.649)
Young trees dummy (only for perennials)	-1.176**	-	-.223	-
	(0.003)	-	(0.069)	-
Tot. observations	6724	9766	6459	6407
R-squared	0.3197	0.3006	0.3425	0.2227

Notes: $P - values$ in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 4. Descriptive statistics. Cocoa

		Ave. Output(kg)	Ave. land surf. (ha)	Ave. Density (stems/ha)	Ave. yields (kg/ha)
1998	Mean	2861.9	2.9	1034.5	943.9
	Median	**2010.5**	**2.3**	**1022.1**	**888.8**
	Std. Dev.	2305.5	2.4	315.4	341.7
1999	Mean	2136.4	3.1	982.8	542.2
	Median	**1476.8**	**2.2**	**977**	**453.3**
	Std. Dev.	2081.9	2.6	352.1	277.6
2000	Mean	1405.2	1.9	968.9	622.4
	Median	**966.4**	**1.3**	**977**	**586.7**
	Std. Dev.	1493.2	1.7	361.8	295.4

Table 5 . Descriptive statistics. Coffee.

		Ave. Output(kg)	Ave. land surf.(ha)	Ave. Density (stems/ha)	Ave. yields (kg/ha)
1998	Mean	1840.5	2.6	909.1	371.1
	Median	**1530**	**2.1**	**844.4**	**357.8**
	Std. Dev.	1166.2	1.5	278.9	124.35
1999	Mean	1973.1	2.8	911.1	327.2
	Median	**1592.9**	**2.3**	**888.9**	**333.35**
	Std. Dev.	1557.5	2.1	324	145.45
2000	Mean	1499.1	2.4	836.2	328.5
	Median	**1002.4**	**1.8**	**800**	**346.65**
	Std. Dev.	1475.8	2	257.5	145.8

Table 6. Descriptive statistics. Rice.

		Rice		
		Ave. Output(kg)	Ave. land surf.(ha)	Ave. yields (kg/ha)
1998	Mean	1421.7	.88	1590.6
	Median	**1237.5**	**.77**	**1625**
	Std. Dev.	862.6	.54	366.7
1999	Mean	1846.3	.96	1756.9
	Median	**1350**	**.83**	**1812.5**
	Std. Dev.	1490.1	.54	776.4
2000	Mean	1655.1	.86	1435.9
	Median	**1232.8**	**.76**	**1406.25**
	Std. Dev.	1340.8	.49	441.5

Table 7. Descriptive statistics. Yam

		Yam		
		Ave. Output(kg)	Ave. land surf.(ha)	Ave. yields (kg/ha)
1998	Mean	6687.9	.43	12534.2
	Median	**5019.6**	**.33**	**11500**
	Std. Dev.	4780.9	.30	3204.2
1999	Mean	6890.4	.46	1462.9
	Median	**6057.9**	**.40**	**13700**
	Std. Dev.	4914.3	.28	7351.7
2000	Mean	6121.9	.50	9984.75
	Median	**5324**	**.41**	**10045**
	Std. Dev.	4232.6	.30	2782.5

Table 8. Extension programme participation rates

Year	Member of a contact group?	
	Yes	No
1998	25.03%(194)	74.32%(576)
1999	31.88%(139)	66.74%(291)
2000	31.69%(77)	67.08%(163)

Table 9. Variation in extension programme participation

	% (total observation)
Never a member	65% (569 hh)
Left during the period	6.6% (59 hh)
Joined during the period	9.4% (83 hh)
Always member	19% (169 hh)

Table 10 - Dependent variable is ln(yields). Within estimator (with fixed effects).

	All crops	Perennials	Food crops	All crops with interaction
		ln(yields)		
ln(labour)	0.403** (2.23)	-0.071 (-0.37)	1.724*** (3.39)	
ln(labour)* perennials				0.405** (2.24)
ln(labour)* food crops				0.244 (1.20)
ln(crop density)	0.006 (0.24)	0.140** (2.11)	0.052 (1.20)	
ln(crop density)* perennials				0.162*** (2.99)
ln(crop density)* food crops				-0.040 (-1.42)
number of plots	0.136*** (3.36)	0.108** (2.37)	0.154 (0.87)	0.148*** (3.36)
extension	0.081 (0.88)			
extension * perennials		-0.086 (-0.85)		0.026 (0.26)
extension * food crops			0.481** (2.23)	0.298** (2.46)
Tot. observations	1156	687	469	1156
Fixed effects	Yes	Yes	Yes	Yes
Panel individuals	482	373	306	482
average obs. per panel	2.4	1.8	1.5	2.4
F test on fixed effects=0; Prob > F	0.0000	0.0000	0.0000	0.0000

Notes: t statistics in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 11 - Value regressions: dependent variable is ln(value of output).

	Perennials	Food crops	All crops with interactions	Perennials	Food crops	All crops with interactions
	ln(value of output in fCFA)			ln(value of output in fCFA)		
ln(crop specific plot surface in ha)	0.986***	1.426***	1.221***	1.366***	1.330***	1.394***
	6.74	10.80	9.88	18.86	16.44	16.54
ln(labour)	-0.242	1.065	-0.214	0.211**	0.211**	0.261***
	-0.69	1.51	-0.49	2.26	2.28	2.78
Plot layout (for perennials only)	-0.048	-	-0.203	0.212**	-	-0.202**
	-0.34		-1.33	2.45		-2.07
tot number of plots	-0.059	-0.053	-0.177**	0.020	0.039*	0.028
	-0.86	-0.45	-2.55	1.13	1.79	1.14
Modern seed type (crop specific)	0.089	0.047	0.294	0.123	0.133	0.292**
	0.47	0.25	1.47	1.17	1.54	2.55
extension	-0.325**	-0.039	0.121	-0.232***	0.004	-0.034
	-2.54	0.26	0.80	2.89	0.05	0.39
Tot. observations	594	647	832	594	647	832
Panel individuals	399	481	574			
average obs. per panel	1.5	1.3	1.4			
Fixed effects	YES	YES	YES	NO	NO	NO
Year dummies	NO	NO	NO	YES	YES	YES
F test on fixed effects=0; Prob > F	0.000	0.000	0.000	-	-	-

Notes: *t* statistics in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 12 - Cumulative knowledge model

	All crops with interaction	All crops with ext. var.
	ln(yields)	
ln(labour)* perennials	0.172	0.415**
	(1.08)	(2.29)
ln(labour)* food crops	0.074	0.263
	(0.42)	(1.29)
ln(crop density)*perennials	0.158***	0.168***
	(3.60)	(3.07)
ln(crop density)*food crops	-0.002	-0.051*
	(-0.09)	(1.76)
number of plots	0.026	0.151***
	(1.14)	(3.74)
cumulated knowledge * per	0.011	0.014
	(0.27)	(0.32)
cumulated knowledge * food	-0.011	-0.049
	(-0.26)	(-1.15)
extension * perennials		-0.003
		(-0.03)
extension * food crops		0.353***
		(2.79)
Tot. observations	1459	1156
Panel individuals	533	482
average obs. per panel	2.7	2.4
F test on fixed effects=0; Prob > F	0.0000	0.0000

Notes: *t* statistics in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%