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Trade, Standards and Poverty:

Evidence from Senegal

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Abstract

The debate on trade and poverty is reinforced by recent studies on the role of standards. It is argued that increasing standards act as trade barriers for developing countries and cause further marginalization of the poor. This paper is the first to quantify income and poverty effects of such high-standards trade and to integrate labor market effects, by using company and household survey data from the vegetable export chain in Senegal. We find that exports have grown sharply despite increasing standards, resulting in important income gains and poverty reduction. Our estimates indicate that poverty is 14 % points lower due to vegetable exports. Tightening food standards induced a shift from smallholder contract-based farming to large-scale integrated estate production, altering the mechanism through which poor households benefit: through labor markets instead of product markets. The impact on poverty reduction is stronger as the poorest benefit relatively more from working on large-scale farms than from contract farming.

JEL Classification: F14; F16; I3; Q12; Q13; Q17

Keywords: trade, poverty, standards, vertical coordination, contract farming

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1. Introduction

The integration of developing countries in global trade is generally believed to stimulate economic growth in those countries (Dollar and Kraay, 2002; Irwin and Tervio, 2002; Frankel and Romer, 1999).[1] However, there is much less consensus about the impact of trade on poverty. While some advocate participation in international trade as a major potential engine for global poverty reduction (Aksoy and Beghin, 2005; Anderson and Martin, 2005; Bhagwati and Srinivasan, 2002; Dollar and Kraay, 2004), in a broad survey of the evidence, Winters et al (2004, pp.106) conclude that "there can be no simple general conclusion about the relationship between trade liberalization and poverty".

The recent debate on standards and development casts further doubt on the beneficial effect of trade liberalization. The first critique is that the proliferation and tightening of quality and safety standards in high-income markets is causing new (non-tariff) barriers for developing country exports (Augier et al., 2005; Brenton and Manchin, 2002; Unnevehr, 2000). The second critique is that increasing standards result in the marginalization of small businesses and poor farm-households in developing countries as they are excluded from high-standards supply chains while the rents in the chain are extracted by large (often multinational) companies and developing country elites (Dolan and Humphrey, 2000; Farina and Reardon, 2000; Reardon et al., 1999).

However, there is considerable debate and uncertainty on the validity of these arguments, and more generally on the welfare implications of high-standards trade (Swinnen, 2007). Empirical studies have often focused on the question of small farmers' participation in high-standards food supply chains and have come to diverse conclusions.[2] However, there is a more fundamental problem with this literature on standards, trade and poverty. None of these studies actually measures

[1] See Rodriguez and Rodrik (2001) for a critique on this conclusion and Winters et al (2004) for a survey of the arguments.

[2] Many studies indicate that small farmers are excluded because of increasing food standards (Reardon et al., 2003; Key and Runsten, 1999; Gibbon, 2003; Weatherspoon and Reardon, 2003; Kherralah, 2000). Evidence from Kenya, Zimbabwe and Cote d'Ivoire e.g. suggests that horticulture exports are increasingly grown on large industrial estate farms, thereby excluding smallholder suppliers in the export supply chain (Dolan and Humphrey, 2000; Minot and Ngigi, 2004). Others find very different effects. For example, Minten et al. (2007) show that in Madagascar most FFV export production is on very small farms, often on a contract-basis with the agro-food industry, and with important positive effects on farmers' productivity. Similar results are found by studies in Asia (Gulati et al. 2006) and in Eastern Europe (Dries and Swinnen, 2004).

welfare and poverty effects and most studies ignore labor market effects, which are possibly extremely important in this debate.

The aim of this study is to contribute to both the literature on standards and development and the more general literature on trade and poverty by assessing the welfare and poverty implications of increasing standards on fruit and vegetable (FFV[3]) exports in Senegal. We first analyze how the structure of the FFV export supply chain in Senegal has changed in response to tightening food standards and then investigate how this has affected welfare of poor households. Our study uses household level data to assess the poverty effects of FFV trade. In doing so, we attempt to contribute to filling the empirical gap identified by Winters et al (2004, pp.107) who conclude that "there is relatively little empirical evidence about the effects of trade … on poverty dynamics at the household level, and on how households respond to … potential opportunities". Our approach is also in line with Srinivasan and Bhagwati's (2001) argument that more convincing evidence may be derived from country case studies than from cross-country regressions.

High-standards FFV exports from Senegal is a particularly relevant case for a number of reasons. First, Sub Sahara Africa is the region generally considered most lagging in global market integration and poverty reduction. Second, FFV is one of the most dynamic export sectors, especially for developing countries where they have grown importantly in recent years – from 14% of total food exports in 1980 to 22% in 2000 (Aksoy, 2005). Given the intensity of land and unskilled labor in this sector, the longer cultivation periods in tropical countries, and export incentives such as preferential trade agreements, developing countries have been able to capture a significantly increased share of world FFV trade (Diop and Jaffee, 2005). Third, FFV exports are increasingly confronted with tightening food standards – arising from public legislation as well as from private multinational companies who increasingly dominate world trade (Maertens and Swinnen, 2007; Reardon and Berdegué, 2002).

To measure the poverty and welfare impacts of high-standards horticulture exports in Senegal, we collected data at three different levels. First, we collected statistics on horticulture

[3] The term FFV, standing for "fresh and processed fruits and vegetables", is used throughout the paper. The term was defined by Diop and Jaffee (2005, pp. 237) to comprise all SITC (Standard International Trade Classification) Revision 1, Chapter 5 items except nuts, roots, and tubers.

production and exports from existing data sources and conducted a series of qualitative expert interviews. Second, in April 2005, we conducted quantitative and structured interviews with nine of the 20 horticulture exporting companies in the Dakar region. Third, in the period August-September 2005, we organized a large survey among farm-households in the main horticulture zone *Les Niayes* from where the large majority of export produce originates.

Our study yields several important findings. First, we find that FFV exports from Senegal to the EU have increased sharply over the past decade, despite increasing food standards in the EU. Second, these FFV exports contribute to poor household incomes in the FFV producing regions. Third, tightening food standards induced structural changes in the supply chain, including a shift from smallholder contract-based farming to large-scale integrated estate production. Fourth, despite these changes, the welfare implications of high-standards FFV export production for rural households are found to remain strongly positive. Supply chain restructuring has altered the mechanism through which local households benefit: increasingly through labor markets instead of through product markets. Fifth, this induced change in the mechanism of income gains guarantees an equitable distribution of the gains within rural communities as the poorest benefit relatively more from working on large-scale farms than from contract farming.

The structure of the paper is as follows. In the next section we describe FFV exports from Senegal and the increasing EU standards. Section three deals with standards-induced structural changes in the export supply chain. We look at household participation in the chain and overall welfare implications of this participation – in terms of income and poverty – in section four. A comprehensive econometric analysis of the income and poverty effects is presented in section five and six. In a final section, we present the main conclusions and implications.

2. Horticulture exports from Senegal

2.1. Increasing exports

The horticulture sector plays a central role in Senegal's export diversification strategy towards high-value commodities. FFV exports increased sharply over the past 15 years: from 2,700 ton in 1991 to 16,000 ton in 2005 (figure 1). The period of the sharpest growth was after 1997 when the export of French beans alone increased from 3,000 ton to almost 7,000 ton. French beans represent almost half (42%) of the total FFV export volume aside from other major crops including cherry tomatoes (23%) and mangoes (16%).

Apart from some small volumes exported to neighboring countries, FFV are exported to the EU; in particular to France (40%), the Netherlands (35%) and Belgium (16%). Senegal ranks fourth as external supplier of beans to the EU, after Morocco, Egypt en Kenya (Eurostat, 2006).

2.2. Increasing standards

The FFV sector in Senegal experienced accelerated export growth during a period when food standards increased substantially. FFV exports to the EU now have to satisfy a series of stringent public and private quality and safety standards. EU legislation imposes (1) common marketing standards for FFV[4]; (2) sanitary and phytosanitary (SPS) measures; (3) general hygiene rules based on HACCP control mechanisms; and (4) traceability standards. The latter two requirements came into force with the General Food Law of 2002. Traceability implies that EU food companies have to document from/to whom they are buying/selling produce such that products can be traced back to their origin in case of food safety problems. Also SPS measures became much more stringent; e.g. decreasing tolerance for chemical residue levels[5], treatment of wooden packaging material (since 2005) and maximum levels of contamination by heavy metals (since 2002).

Moreover, in addition to increasing public standards, many large trading and retailing companies have engaged in establishing private food standards that are even stricter. For example, the Euro-Retailer Produce Working Group (Eurep) has engaged in adapting food quality and safety standards into the EurepGAP certification protocol. On top of public traceability regulations that apply within the EU, they require complete traceability throughout the chain up to the level of overseas producers. Agri-food businesses in the EU increasingly require such private certification from their suppliers.

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[4] Commission Regulation (EC) No 912/2001, an amendment of EC No 2000/96, specifies a classification for French beans based on quality and size, and stipulates provisions concerning the presentation and marketing of the beans.
[5] Since 2000 there have been 29 new EU notifications of maximum residue levels (MRL) to the WTO (World Trade Organization, 2006).

Despite these increasing standards, Senegal has been able to increase horticulture export earnings – as was also the case for e.g. Kenya (Jaffee, 2003). This proves that tightening standards do not necessarily undermine the competitive position of developing countries in international agricultural markets. The World Bank (2004) argues that the development of a certification scheme and validation of the label *Origine Sénégal* has played an essential role in raising the quality and standards of Senegalese FFV, and thereby realizing export growth.

3. Structural changes in the export supply chain

Changes in EU standards put pressure on FFV exporters in Senegal to stay up to date with the changing requirements and to make additional investments for compliance. The growing demands also increase the need for tighter coordination and have led to important structural changes in the FFV export supply chain in Senegal, with major implications for Senegalese farmers. Key structural changes are (1) increased consolidation at the level of the agro-exporting industry as well as at the level of the primary producers; and (2) increased vertical coordination with downstream buyers in the EU as well as with upstream suppliers. This translates into a decreasing volume of French beans that is procured from small farmers and an increase in vertically integrated FFV estate production.

We document and analyze these structural changes in more detail with information from quantitative interviews with nine of the 20 horticulture exporting companies in the Dakar region. Our company sample constitutes a mixture of firms recently entering the market and older firms, a mixture of smaller and larger exporter, and a mixture of domestic and foreign companies, jointly representing 44% of the exported volume French beans (table 1).

3.1. Increased consolidation

Because of financial constraints, only larger firms are able to comply with increasingly stringent food standards. Since 1994, most exporters are member of the organization SEPAS[6] which coordinates transport, provides market information and assists its members in the contact with overseas buyers. However, following the increasing EU standards, the seven largest FFV exporters

[6] *Syndicat des Exportateurs des Produits Agricoles*

founded the organization ONAPES[7] in 1999. One of their specific aims was to comply with traceability standards and become EurepGAP certified. Four ONAPES companies are in our sample (table 2) among which one is EurepGAP and HACCP certified (since 2004). Three other firms are in the process of certification and made substantial investments for this in the past couple of years. The remaining exporters, mainly smaller ones, are not certified and not undertaking particular investments in the scope of certification.

As a result, since 2000, the export sector is consolidating with mainly smaller exporters dropping out. While the number of French bean exporting companies dropped from 27 to 20 firms in the past three years, the market share of the three largest companies increased from less than half in 2002 to two-thirds in 2005.

3.2. Increased vertical coordination

Vertical coordination increased, both downstream and upstream. First, FFV exporters – especially larger firms – increasingly engage in tighter coordination with downstream importers and wholesalers in the EU market. Smaller exporters deal with importers through non-binding indicative agreements on the supplied quantity. Larger exporters have recently changed to more binding contracts with overseas buyers; including price, quantity and timing of delivery, and sometimes also pre-financing. Exporters mention the volatility of EU market prices and the incidence of produce refusal by importers to be the main reasons to engage in tighter coordination.

Second, to guarantee product quality, food safety, and traceability throughout the supply chain and to assure accurate timing of production and harvesting exporters – especially larger firms – increasingly rely on tighter vertical coordination with upstream suppliers of primary produce. This occurs in two ways. The first is through more elaborate production contracts and tighter coordination within those contracts. Contracts signed with small family farms are typically specified for one season – lasting from November till April – and indicate the area to be planted – usually 0.5 or 1 ha – all technical requirements and the price. As part of the contract, the firms provide technical assistance and inputs to the farmers; especially seeds and chemicals, sometimes also cash credit. Some firms go as far in contract-coordination as the complete management of fertilizer and pesticide

[7] *Organisation National des Producteurs Exportateurs de Fruits et Légumes de Sénégal*

application and daily or weekly inspection of the farmers' fields. Also field preparation, planting and/or harvesting can be coordinated and financed completely by the contractor firm. Especially larger exporters provide pre-financing and apply tighter contract-coordination while smaller exporters leave management decisions to the farmers.

A second, and even more radical, change towards vertical coordination is the shift from smallholder contract-based farming to large-scale estate production. Larger exporters are increasingly engaging in fully integrated estate production. In fact, the ONAPES exporting companies have agreed among themselves that each member should seek to process every season a volume of at least 200 ton of which at least 50% should originate from the companies own estate production – a measure that is having a profound impact on the structure of the export supply chain. Three firms in our sample have already substantially reduced procurement through smallholder contract-farming: from 100% in their first year of operation to respectively 60% and 20% in the last season (table 2). These companies cited quality rather than quantity to be the reason for this change. Also other firms in the sample mentioned fully integrated production to be an important strategy for compliance with food standards in the future and hence for the survival and growth of the firm.

Similar observations of standards-induced consolidations and vertical coordination – including a shift towards large-scale estate farming – have been noticed in the FFV export sector of other African countries; e.g. in Kenya, Zimbabwe and Cote d'Ivoire (Dolan and Humphrey, 2000; Minot and Ngigi, 2004). It is generally argued that this leads to the marginalization of small farmers. In the next sections we will provide evidence that this has not been the case in Senegal.

4. Household participation and welfare in FFV export production

4.1. Survey and data

To measure the effects of FFV exports for local households, we organized in August – September 2005 a large household survey in the main horticulture zone *Les Niayes* – from where over 90% of exported French beans originate (Gergely, 2001). The majority of households in this area are smallholder horticulture farmers producing – next to French beans for export – a large variety of vegetables and basic food crops for the local market and for direct consumption (Fall and Fall, 2000).

We randomly selected 23 villages in three rural communities – Sangalkam, Diender and Noto – in the region Dakar and Thiès[8] (figure 2). Within those villages we selected 300 farm-households to be included in the sample, of which 59 produced French beans on contract with an agro-exporting company during the 2005 export season. Due to this selection contracted farmers are over-sampled. To draw correct inferences we use sampling weights calculated – with information gathered at the village and community level – as the inverse of the probability of contracted and non-contracted households to be selected in a particular rural community.

The sample represents small household farms in the area. Among the sampled households, agriculture constitutes on average more than 80% of total household income and the average farm size is 5 ha. Eighty-eight percent of the sampled households cultivate less than 10 ha – which is in the region considered as the threshold to be classified as a smallholder (Fall and Fall, 2000).

4.2. Household participation

Along with increasing exports also the participation of rural Senegalese households in high-standards horticulture export production increased dramatically over the past 15 years: from less than 10% in 1991 to 40% in 2005 (figure 3). However, as a result of standards-induced structural changes in the supply chain the nature of increased household participation differed strongly in the 1990s from more recent years. During the 1990s households increasingly took part in export production through contract farming. By 2000 an estimated 23% of households in the research area were contracted to produce beans for export. However, from 2000 onwards, the incidence of contract farming decreased – from 23% in 2000 to 10% in 2005 – while that of wage employment on estate farms increased sharply – from less than 10% of households in 2000 to 34% in 2005. As a result of the supply chain restructuring in the period 2000-2005, 72% of contracted farmers lost their French bean contract. Almost half of them (43%) started to work on estate farms. The exporting firms that dissolved the contracts either exited the market or started their own estate production.

[8] This area was selected for the research as these communities are strongly influenced by the horticulture export sector. The effects of FFV exports however reach further as also other communities in Les Niayes are influenced and as the sector attracts temporary migrant workers. The effect of this can however not be measured with our sample design and the derived results are specific for the selected research area.

Still, on aggregate, participation of rural households in high-standards FFV production continues to increase with their role shifting from contract farmers to estate farm workers. Based on company level data for the 2005 season, we estimate that almost 1,000 farmers produce French beans on contract and that FFV exporting companies employ almost 12,000 workers (mostly temporarily).[9] The shift from contract farming to estate farming[10] has important implications for the distribution of rural incomes, which we analyze in detail in the next sections.

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4.3. Characteristics of FFV producers

The distributional implications of high-standards FFV exports critically depend on the participation of poorer households in the supply chain. The figures in table 3 indicate that households differ substantially in their access to human, physical and social capital. First, both contract farmers and estate farm workers come from households with more laborers and a slightly higher education. Participants in estate farm work are slightly older households with more dependents. No female-headed households are involved in contract farming. Second, contract farmers have on average larger farms – 6.8 ha compared to 4.9 ha for non-participating households – and more livestock – 4.1 units compared to 2.9 units. These comparatively larger contracted farms are in per capita terms, however, still small with 1 ha of land per capita – compared to 0.83 ha for non-participating households. Estate wage workers tend to be households with less land – 0.78 ha per capita – less livestock – 1.8 units – and less non-land assets – 176 thousand FCFA compared to 320 thousand FCFA for other households. Third, among the estate farm workers there are less ethnic minority households. More contracted farmers are a member of a farmers' organization. Fourth, in the region Dakar – which is closer to exporting companies and shipping facilities – there are more farms involved in FFV export production than in Thiès.

[9] It is unclear how many households in total are involved in FFV estate employment (which complicates a comparison of these figures with those from the household survey). The 12,000 workers might include several members of the same households and might include temporary migrants from outside the research area.
[10] It is important to note that the shifting role of households in the export supply chain should not be perceived as an absolute change in household status from independent farmers to subordinate workers. French bean export production is concentrated in one season (from November till April – which does not coincide with the main 'rainy' agricultural season) and households generally allocate only a share of their land and/or labor to these activities – either as contract farmer or as estate farm worker – thereby continuing to primarily be independent smallholders. Moreover, the expansion of the estate sector does not come at the expense of the smallholder farming operations. Companies seeking to expand estate production either buy or rent land from large commercial farms (usually over 100 ha), integrate with these farms or invest in uncultivated land belonging to the government

4.4 Income and poverty[11]

The participation of rural households in the supply chain of high-standards FFV exports is associated with sharp welfare differences. A simple comparison of means reveals large differences in household income: 1.8 million FCFA for non-participating households compared to 4.5 million and 6.4 million for FFV estate workers and FFV contract farmers respectively (figure 4). These differences in income remain large in per capita terms: the average per capita income[12] for estate wage workers is 552,000 FCFA and for contract farmers 924,000 FCFA, which is respectively double and more than triple the per capita income of non-participating households (266,000 FCFA). On average, agriculture is the main source of income in the area and two thirds of household income is derived from own farming (figure 4). Yet, estate farm workers derive more than one third of their income from agricultural wages – mainly (more then 80 %) earned at vegetable estate farms – while still having farm incomes that are higher than non-participating households.

The incidence of poverty in the research area is estimated to be 42 % – which is considerably lower than the national rural poverty rate of 58 %. Poverty is much higher among households who do not participate in export production (47%) than among households employed in FFV estates (40%) and especially among FFV contract farmers (13%) (figure 5). The incidence of extreme poverty is 12% in the surveyed region but is much lower among households involved in FFV export production – 5% among FFV estate workers and 2% among FFV contract farmers – then among non-participating households (17%).

In conclusion, both relatively larger farms or better-off households, and poorer households participate in high-standards vegetable production but the former rather as contract farmers and the latter as estate employees while both have incomes that are substantially higher than for non-participating households. These correlations suggest that the current structure of the export supply chain with the coexistence of smallholder contract-based production and large-scale estate farming

[11] We use the national rural poverty lines that were constructed using data from the ESAM I and II surveys conducted in 1994 and 2002 (République du Sénégal, 2004) and adapt them for changes in consumer price indices (African Development Bank, 2006). The poverty lines that are used are 143,080 FCFA/year/adult equivalent for poverty and 31,812 FCFA/year/adult equivalent for extreme poverty. As no data are available on household expenditures and consumption, we use income data to derive poverty indicators.

[12] Per capita incomes are calculated using the modified OECD adult equivalence scale.

guarantees a more equitable participation in the export supply chain and translates into a more equitable distribution of the gains from high-standards exports.

5. Econometric analysis of income effects

The data and descriptive analysis presented in the previous section show substantial differences in income across households. However, based on a simple comparison of means it is impossible to identify causality and to satisfactorily attribute these differences to the impact of FFV export production. In this section we present a comprehensive econometric analysis to address this causality. We first discuss the potential sources of selection bias and present three different methods we use to correct for this bias. We then discuss the results and perform some robustness and sensitivity checks.

5.1. Selection bias

There are various potential sources of selection bias that obscure the causal relation because participation in FFV export production is likely to be non-random. First, households can decide – based on their access to resources and their preferences – to participate and self-select into contract-farming or into FFV estate employment. Second, exporting companies might select or exclude potential employees and potential contractors based on their skills, access to resources, etc. Third, there might be some geographic selection because firms face increasing transaction costs in sourcing from distant (or isolated) farmers or because workers' travel costs increase with distance from employment location.

The possibility to correct for selection bias crucially depends on the availability of observable covariates that are correlated with selection into contract-farming or estate employment, and/or with the outcome variable of interest – household income. Observable characteristics related to households' access to resources (land, capital, labor); their access to information (organization membership); their skills and ability (age, education); their preferences (age, ethnicity, demographic structure); and geographic location (village, region) are hence potential covariates for selection adjustment. Variables that are correlated with selection into contract farming or estate employment and/or household income, are identified in table 4. To avoid endogeneity problems some potentially relevant but likely endogenous covariates (such as livestock holdings and farm assets) are not considered while lagged variables – based on recall data – are considered for the covariates land and organization membership (table 4).

5.2. Correction for selection bias

To correct for potential selection bias we apply regression and matching techniques from the average treatment effects literature[13] in estimating the impact of two treatments – participation in FFV estate wage employment (W_1) and in FFV contract-farming (W_2) – on household income (Y). We are ultimately interested in estimating the average treatment effects ATE_1 and ATE_2, with Y_1 and Y_2 representing the income with treatment and Y_0 the income without treatment:

$ATE_1 = E(Y_1 - Y_0)$ for W_1: FFV estate employment (1)

$ATE_2 = E(Y_2 - Y_0)$ for W_2: FFV contract-farming (2)

We hypothesize that high-standards FFV exports has positive welfare implications and hence expect both ATEs to be significantly positive.

We are dealing with two treatments W_1 and W_2 that are not mutually exclusive as 26 households are involved in both contract farming and estate employment. The literature generally deals with describing methods (regression, matching and propensity score methods) for estimating the ATE for one single treatment. These methods logically extend for multiple (mutually non-exclusive) treatments as long as the basic assumptions apply to the vector of treatments (Lechner, 2000; Wooldridge, 2004) – an issue addressed in the next section.

In a first model – referred to as *regression on covariates* – we control for selection bias by including a large set of observable covariates (X) as control functions in the regression of W on household income. The ATEs can be estimated with OLS as the regression coefficients on W_1 and W_2 (Imbens, 2004; Wooldridge, 2002). We include in X all the covariates identified in table 4 to be correlated with selection into treatment and/or household income, including also village dummies.

[13] The techniques described in this literature were initially applied to the impact evaluation of job training programs but have since known a wide application in the development economics literature.

To account for the fact that the two treatments are mutually non-exclusive, we include the interaction term of the two treatments W_1W_2.

$$Y_i = \theta + \alpha_1 W_{1i} + \alpha_2 W_{2i} + \alpha_3 W_{1i} W_{2i} + \beta X_i + \varepsilon_i \qquad \text{(MODEL I)}$$

Rather then correcting for a large number of relevant covariates directly[14], adjustments can be made based on the propensity score – defined as the conditional probability of receiving treatment (Imbens, 2004; Dehejia and Wahba, 2002) – a method pioneered by Rosenbaum and Rubin (1983). As we have two different treatments that are not mutually exclusive, we use a bivariate probit model to estimate the propensity scores. Covariates that are significantly (at the 5 % level) correlated with the treatment indicator and/or the outcome variable are included as explanatory variables (table 5). This specification assures that overlap assumptions and balancing properties are satisfied (see further).

In a second model – referred to as *regression on the propensity score* – we use the estimated bivariate probabilities (p) as propensity score (PS) correction functions in the regression of W_1, W_2, and W_1W_2 on household income. Here again, the ATEs can be estimated using OLS (Imbens, 2004; Wooldridge, 2002).

$$Y_i = \theta + \alpha_1 W_{1i} + \alpha_2 W_{2i} + \alpha_3 W_{1i} W_{2i} + \phi_1 PS_{1i} + \phi_2 PS_{2i} + \phi_3 PS_{12i} + \varepsilon_i \qquad \text{(MODEL II)}$$

with $PS_1 = \hat{p}(W_1 = 1, W_2 = 0 \mid X)$; $PS_2 = \hat{p}(W_2 = 1, W_1 = 0 \mid X)$;

$PS_{12} = \hat{p}(W_1 = 1, W_2 = 1 \mid X)$

Thirdly, we estimate the ATEs with a *propensity-score matching* method. Matching involves pairing treatment and comparison units that are similar in terms of their observable characteristics (Dehejia and Wahba, 2002; Abadie and Imbens, 2002). As the dimensionality of the set of potentially relevant observable covariates X is large, matching directly on the covariates is not straightforward. Therefore, we match treated and control units according to the estimated propensity score and calculate the ATEs as a weighted average of the outcome difference between treated and

[14] Regression on covariates might obscure information on the distribution of covariates in the treated and the untreated group. Propensity score methods reduce this problem to a single dimension.

matched controls as in Dehejia and Wahba[15] (2002). We use single-nearest-neighbor matching, which according to Imbens (2004) leads to the most credible inferences with the least bias. Matching is done with replacement as to assure that each treatment unit is matched to the nearest comparison unit, which reduces bias (Dehejia and Wahba, 2002). Moreover, only observations in the common support region – where the propensity score of the treated units are not higher than the maximum or less than the minimum propensity score of the control units – are used for calculating the ATEs (Becker and Ichino, 2002). The propensity matching method estimates the ATEs as follows:

$$ATE_1 = \frac{1}{N_1}\sum_{i \in N_1}\left(Y_{1i} - Y_j\right); \quad ATE_2 = \frac{1}{N_2}\sum_{i \in N_2}\left(Y_{2i} - Y_j\right) \qquad \text{(MODEL III)}$$

with N the number of treated units, Y_j the income of the control unit C(i) that is matched to the treated unit i: $C_1(i) = \min_{j \in C}\left\| PS_{1i} - PS_{1j} \right\|$; $C_2(i) = \min_{j \in C}\left\| PS_{2i} - PS_{2j} \right\|$ and with $PS_1 = \hat{p}\left(W_1 = 1, W_2 = 0 \mid X\right)$; $PS_2 = \hat{p}\left(W_2 = 1 \mid X\right)$.

To deal with the two mutually non-exclusive treatments in this matching method we define the treatment group N_1 (83) as households only participating in FFV estate employment; the treatment group N_2 (59) as households participating in FFV contract farming; and the control group C (159) as those households not participating in export production. Matching between treated and controls is done on the propensity scores estimated with the bivariate probit model specified above as the bivariate probability in case of W_1 and the marginal probability in case of W_2.

5.3. Results and discussion

The estimation results are presented in tables 5 and 6 and tables A1 - A.2 in appendix. The main results, i.e. the estimated treatment effects, are presented in table 6. The results of the bivariate probit model estimating the propensity scores used in models II and III are presented in table 5. The estimated coefficients of the covariates in the full structural regression models I and II have the expected sign and are presented in appendix tables A.1 and A.2.

[15] The propensity score matching method discussed and applied by Dehejia and Wahba (2002) differs from earlier methods in that unmatched control units are discarded and not directly used in estimating the ATE. This avoids extrapolating or smoothing across the treatment and comparison groups.

The applied regression, matching and propensity score methods yield qualitatively identical and quantitatively similar estimations of the treatment effects – which indicates that the estimated effects are robust to changes in the econometric approach. There are three main results. First, the estimated effects for both treatments – FFV estate employment and FFV contract farming – are significantly (at the 1% level) positive. This confirms our hypothesis that participation in FFV export production, whether through contract farming or through estate employment, has positive effects on rural incomes. After correction for potential selection bias (and taking the most conservative among the three estimators) we estimate that FFV estate employment increased household income with 1.9 million FCFA and FFV contract farming with about 4 million FCFA. So, participants in FFV export production have incomes that are 60% to 130% higher than the average income in the research area – indicating very strong positive effects.

Second, our estimations indicate that the impact on household income from FFV contract farming is about two times higher than the impact from FFV estate employment. For both regression models (model I and II), equality of the coefficients on W_1 and W_2 is rejected at the 10% significance level while the hypothesis that the coefficient on W_2 is double that of W_1 cannot be rejected[16].

Third, the results of the bivariate probit model (table 5) confirm that FFV contract farming is biased towards households with initially larger farms while FFV estate employment is not. Every additional hectare of initial (1995) landholdings increases the likelihood of a household having a contract for FFV export production with 3.5%. There is no significant effect of initial landholdings on the probability of being a FFV estate worker which indicates that also the smallest farmers participate in estate employment. The results further indicate that larger households with more labor endowments and households in the Dakar region – closer to exporting companies – are more likely to be involved in FFV contract farming and/or FFV estate employment. Also ethnicity and membership of a farmers' organization influence selection into FFV estate employment.

[16] An adjusted Wald test for equality of the coefficients on W_1 and W_2 yields F-values of $F(1, 297) = 2.77$ in model I and $F(1, 297) = 4.16$ in model II – both rejecting the hypothesis that those coefficients are equal at the 10% significance level. An adjusted Wald test for the hypothesis $W_2=2W_1$ yields F-values of $F(1, 297) = 0.01$ in model I and $F(1, 297) = 0.07$ in model II – both not rejecting the hypothesis at the 1% significance level.

5.4. Assessing the assumptions

The applied regression and matching methods can yield unbiased estimates of the income effect of FFV contract-farming and FFV estate employment subject to two main assumptions (Deheija and Wahba, 2002; Imbens, 2004; Wooldridge, 2002). The first assumption – referred to as conditional independence[17] (CI) – denotes that, conditional upon observable covariates, the receipt of treatment is independent of the potential outcomes with and without treatment (Imbens, 2004). Hence, participation in FFV contract-farming and/or FFV estate employment cannot depend on unobservable characteristics that are arbitrarily correlated with household income[18]. This assumption is not directly testable[19] (Imbens, 2004) but Ichino, Mealli and Nannicini (2006) proposed a method for addressing robustness of matching estimators to failure of the CI assumption. The method simulates a binary confounder in the data that is used as additional matching factor[20]. We use the method with a neutral confounder and with confounders calibrated to mimic observable binary covariates as in Ichino et al. (2006). The results (table 7) show that the estimators with binary confounder differ less than 5% from the baseline matching estimator for treatment 1 and less than 10% for treatment 2. This is an indication of the robustness of the ATE estimates and the validity of the CI assumption.

The second key assumption in estimating ATE requires sufficient overlap and balancing in the covariate distribution between treated and untreated observations (Imbens, 2004). If participating and non-participating households differ substantially in observable characteristics, the ATE is difficult to estimate – whether using regression, matching or propensity score methods (Imbens, 2004). Figure 6 compares the distribution of the propensity scores between treated and untreated

[17] Different versions of this assumptions are referred to as *unconfoundedness*, *selection on observables*, *ignorability of treatment*, or *conditional independence* (Imbens, 2004; Rosenbaum and Rubin, 1983; Lechner, 1999).
[18] This is a strong assumption and, in general, the plausibility of this assumption in an economic setting has been questioned. Optimizing behaviour would preclude choices being independent of potential outcomes. Imbens (2004) however provides some basic arguments for using the assumption and the econometric techniques relying on the assumption in economic settings.
[19] The conditional independence assumption is intrinsically non-testable because the data are completely uninformative about the distribution of the untreated outcome for treated units and vice versa (Imbens, 2004; Ichino et al., 2006).
[20] The central presumption in this method is that the assignment to treatment is not independent given a set of covariates X but that the CI does hold given X and an unobserved binary covariate (see Ichino et al. (2006) for more details). In our setting the unobserved binary covariate could e.g. measure some unobservable component of ability that simultaneously influences participation in FFV contract farming and/or FFV estate employment, and household income.

(control) observations for both treatments. The estimated propensity scores are strictly between 0 and 1 – which is a first requirement (Imbens, 2004) – and show distributions with sufficient overlap between treated and control units and with a sufficiently large region of common support – where the propensity score of the treated units are not higher than the maximum or less than the minimum propensity score of the control units. Moreover, we address balancing properties by testing for equality of means between treated and (matched) control units for all relevant covariates. The results of this test (table 8) show that there is a strong bias for most covariates but that matching eliminates this bias such that there is a good balance in covariate distribution between treated and matched control units (for both treatments).

5.5. Sensitivity to the choice of covariates

The literature on ATE and propensity score methods emphasizes the importance of including a "proper" set of covariates (e.g. Imbens, 2004; Dehija and Wahba, 2002; Becker and Ichino, 2002). The results of ATE estimations may be sensitive to different specifications of conditioning variables but little is known about strategic covariate choice (Imbens, 2004). The generally applied strategy is to include covariates that are highly correlated with treatment indicators and/or the outcome variable – as we did in the baseline models specified above. To test the sensitivity of our baseline results we additionally estimate the ATEs using alternative sets of covariates and model specifications. The estimated ATEs using these alternative specifications (table 9) are qualitatively and quantitatively very similar to the estimates in the baseline models – which is an indication that the results are robust to the choice of covariates.

5.6. Summary

In summary, the results from the econometric analysis are found to be robust to different estimation techniques and alternative model specifications. The findings imply that (a) participation in high-standards agricultural trade results in significantly higher rural incomes; (b) this income effect is larger for contract farmers than for estate farm workers; (c) participation in contract farming is biased towards the relatively larger farms among the smallholders while participation in estate employment is not. In the next section we examine how these findings translate into poverty effects.

6. Simulation of poverty and inequality effects

To assess the poverty effects, we simulate household income for two alternative scenarios and compare the outcomes with the actual income situation. For the first scenario *("No Exports")* both participation variables W_1 and W_2 are set to zero for all households in the sample, which simulates a situation in which there would be no exports of French beans at all. The second scenario *("Contract")* corresponds to the case where French bean exports would have been mainly realized through contract farming – as was the case till 2000 before increasing standards induced a shift from smallholder contract farming to large-scale estate farming. For this scenario participation in contract farming W_2 is set as if none of the farmers who had a contract in 2000 lost their contract in the period 2000-2005. For these two scenarios we simulate household income based on the results of the baseline propensity score matching estimator (model III), calculate per capita incomes and derive poverty indicators.

The results are striking (figure 6). First, the incidence of poverty in the research area is estimated to be 14 % points lower due to high-standards vegetable exports. Without the possibility for rural households to participate in high-standards export production (*No Export* scenario), the incidence of poverty in the region would be 56 % – similar to the average rural poverty rate for Senegal – while the actual poverty rate is only 42 %. Moreover, the incidence of extreme poverty would be three times higher: an estimated 35 % in the *No Export* scenario compared to 12 % in the actual situation. These are very large and important effects.

Second, we find that per capita incomes do not differ much between the *Contract* scenario (0.44 million FCFA) and the actual situation (0.41 million FCFA) while they are much lower in the *No Export* scenario (0.26 million FCFA). Also poverty rates are not significantly different in the actual situation compared to the scenario *Contract* (figure 6). However, the incidence of extreme poverty is much lower in the actual situation – 12 % compared to 21% in the *Contract* scenario (figure 6). Hence the results imply that the high-standards FFV trade has a beneficial impact even if it is realized through large-scale estate farming. In fact, by creating employment opportunities that are relatively more accessible for the smallest farmers, FFV estate farming contributes even more to the alleviation of (extreme) poverty.

These findings demonstrate that high-standards agricultural production and trade can directly reduce poverty and improve welfare even if it is realized through large-scale agro-industrial production. This challenges the general view in the literature of increasing food standards and agro-industrialization leading to a concentration of the gains from trade with large food companies and to the marginalization of the smallest farmers and the poorest households.

7. Conclusion

The impact of trade on poverty remains the subject of considerable controversy, reinforced by recent studies on the growing importance of public and private standards in trade. This paper has analyzed these effects using micro-data from Senegal. FFV exports from Senegal to the EU grew sharply over the past decade despite increasing standards in EU markets. The response of FFV exporting companies to these increased standards has resulted in consolidation and increased vertical coordination at different levels of the supply chain. Part of the institutional response has been a shift away from smallholder contract-based farming towards large-scale agro-industrial production. Based on conventional arguments in the literature, one could expect these developments to be particularly bad for the smallest farmers and the poorest households.

However, our analysis in this paper shows that this is not the case. We find that more and poorer households participate in and share in the gains from high-standards FFV export production. Supply chain restructuring has altered the mechanism through which local households benefit – increasingly through labor markets rather than through product markets – and thereby improved the distribution of gains within rural communities.

We find highly significant and large effects on income and poverty, which demonstrate that rural households involved in high-standards export supply chains, either through contract farming or as workers on estates, do share importantly in the gains from export. This is a key empirical finding as it has repeatedly been argued in the literature that the gains from international trade and the rents in high-standards supply chains are captured by foreign investors and large agro-food companies while small farmers and poor households are marginalized. Especially contract farming has often been criticized as a tool for agro-industrial firms and multinationals to exploit unequal power relationships vis-à-vis farmers and extract rents from the supply chain.

Furthermore, our results demonstrate that high-standards agricultural trade benefits rural incomes and reduces poverty even if the export industry is consolidating and even if export production is realized on industrial estate farms. In fact, we find that this model has the strongest positive effects on poverty reduction. The findings challenge the implicit assumption underlying many empirical studies that high-standards food production and trade needs to integrate farm households as primary producers in the supply chain if it is to benefit rural incomes. We show that also households involved as wage workers reap significant benefits from high-standards trade.

The insight from this study that poorer households benefit from agricultural export development through the labor market rather then through product markets – has so far been neglected in the empirical literature on trade, standards and modern supply chains. We could draw the analogy with insights from the Green Revolution of the 1960s – that triggered major productivity growth and rural income rises in South-East Asian countries. The Green Revolution was at first believed to benefit richer farmers while marginalizing poorer farmers because of the specific constraints they face in accessing and using Green Revolution inputs. However, David and Otsuka (1994) were the first to document that poorer households did benefit from this technology-driven agricultural development because of labor market effects. The same might hold for standards-driven (or supply chain-driven) agricultural development.

Another important finding from this study is that high-standards agricultural export development in poor African countries is possible, despite the many constraints. This case-study on Senegalese FFV exports could add to the existing evidence of high-standards export development in Sub Sahara Africa (e.g. in Kenya, South-Africa, etc) and thereby shift the balance from viewing standards as barriers to trade to the standards-as-catalysts view – put forward by Jaffee and Henson (2005). In analogy with the technology-driven developments in South East Asia in the 1960s, there might be scope for standards-driven agricultural development – in which Sub Sahara Africa and its poor are not left behind.

Appendix

Table A.1. Results of structural regression model I (Regression on covariates)

Covariates	Coefficient	Linearized Std. Err.	t
W_1 (FFV estate employment)	2.269	1.014	2.24
W_2 (FFV contract farming)	4.253	1.324	3.21
W_1*W_2	-2.801	2.208	-1.27
LAND	0.060	0.072	0.82
LABOR	0.469	0.150	3.13
AGE	-0.270	0.211	-1.28
AGE^2	0.001	0.002	0.85
D-RATIO	-0.822	1.928	-0.43
EDUCATION	2.070	1.584	1.31
ETHNICITY	0.230	0.635	0.36
UNION	-0.813	0.851	-0.96
$VILLAGE_1$	-0.270	1.028	-0.26
$VILLAGE_2$	-0.685	1.157	-0.59
$VILLAGE_3$	-1.950	1.541	-1.27
$VILLAGE_4$	-1.317	1.440	-0.91
$VILLAGE_5$	11.306	5.621	2.01
$VILLAGE_6$	-0.196	1.259	-0.16
$VILLAGE_7$	-0.757	1.306	-0.58
$VILLAGE_8$	7.470	4.396	1.70
$VILLAGE_9$	-2.078	1.693	-1.23
$VILLAGE_{10}$	0.014	0.944	0.02
$VILLAGE_{11}$	-2.137	1.495	-1.43
$VILLAGE_{12}$	-2.635	1.298	-2.03
$VILLAGE_{13}$	-0.465	1.134	-0.41
$VILLAGE_{14}$	-0.307	1.275	-0.24
$VILLAGE_{15}$	-0.383	1.070	-0.36
$VILLAGE_{16}$	-0.096	1.351	-0.07
$VILLAGE_{17}$	1.002	1.944	0.52
$VILLAGE_{18}$	2.802	1.493	1.88
$VILLAGE_{19}$	-1.292	2.172	-0.59
$VILLAGE_{20}$	-1.809	1.391	-1.30
$VILLAGE_{22}$	1.005	1.380	0.73
$VILLAGE_{23}$	-1.883	1.432	-1.32
CONSTANT	8.610	6.308	1.37

Table A.2. Results of structural regression model II (Regression on propensity scores)

Covariates	Coefficient	Bootstrap Std. Err.	t
W_1 (FFV estate employment)	1.931	0.966	1.59
W_2 (FFV contract farming)	4.650	1.759	2.78
W_1*W_2	-2.729	2.221	-1.04
PS_W_1	8.750	5.820	1.33
PS_W_2	6.255	13.55	0.50
PS_W_1W_2	-13.04	24.52	-0.54
CONSTANT	-0.270	1.215	-0.20

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Tables

Table 1. Selected horticulture exporting companies

Company name	Export volume (ton), 2004 FB[1]	other FFV[2]	Year entering FB export	Foreign ownership
Soleil Vert	800	1,100	2000	80%
Sepam	883	1,410	1992	0
Master	68	0	1989	0
Baniang	80	150	1999	51%
Agriconcept	100	80	2002	0
ANS Interexport	64	0	2001	0
Pasen	30	0	2000	0
Agral Export	180	0	1992	0
PDG	173	239	1993	0

[1] FB: French beans; [2] FFV: fresh and processed fruits and vegetables

Table 2. Changing procurement of selected horticulture exporting companies

Company name	Organisation membership	% of supply from smallholder contract-farming: 1st year of operation	last season
Soleil Vert	ONAPES[1]	100	20
Sepam	ONAPES	100	60
Master	ONAPES	50	40
Baniang	ONAPES	85	85
Agriconcept	SEPAS[2]	30	30
ANS Interexport	SEPAS	100	100
Pasen	SEPAS	100	60
Agral Export	SEPAS	100	100
PDG	SEPAS	100	100

[1] ONAPES – *Organisation National des Producteurs Exportateurs de Fruits et Légumes de Sénégal*

[2] SEPAS – *Syndicat des Exportateurs des produits*

Table 3. Household characteristics: averages across contract farmers, estate employees and non-participants in horticulture export production

	total sample	non-participants in FFV export production	Participants in FFV export produciton	
			FFV estate employees	FFV contract farmers
Number of households in the sample	300	158	109	59
HUMAN CAPITAL				
Age of the household head	54	53	56	53
Number of laborers	6.9	6.4	7.7	7.7
Dependency ratio	0.568	0.571	0.566	0.527
Female headed households	3.0%	3.3%	2.8%	0%
Household head with primary education	17.6%	16.5%	18.8%	19.4%
PHYSICAL CAPITAL				
Farm size (ha)	5.03	4.92	5.05	6.82
Per capita[1] landholdings (ha)	0.83	0.84	0.78	1.03
Units[2] of livestock	2.64	2.87	1.84	4.14
Value of non-land assets (1,000 FCFA)	270.7	320.9	176.9	308.8
SOCIAL CAPITAL				
Ethnicity (non Oulof)[3]	27%	31%	17%	32%
Membership of a farmer's organisation	58%	54%	62%	77%
LOCATION				
Dakar region	50%	42%	60%	67%

[1] Per capita landholdings are calculated using the modified OECD adult equivalence scales

[2] One livestock unit equals 1 cow, 0.8 donkey and 0.2 sheep/goat

[3] Oulof are the majority ethnicity group in Senegal.

Table 4. Observable covariates for selection bias adjustment

Description of covariates			Sample mean	Correlation coefficient with outcome and treatment variables		
				Household income	FFV estate employment	FFV contract-farming
Continious variables						
LAND	Household landholdings in 1995[1]		4.24	0.121**	0.056	0.162***
LABOR	Household labor endowments		6.9	0.219***	0.202***	0.143**
AGE	Age of the household head		54	-0.084	0.109*	-0.014
D-RATIO	Dependency ratio		0.57	0.005	-0.023	-0.100*
Dummy variables						
EDUCATION	Hh head with primary education		0.18	0.106*	-0.057	0.033
ETHNICITY	Non-oulof household		0.27	-0.092	-0.171***	0.027
UNION	Membership of farmers' union in 1995[1]		0.31	0.022	-0.125**	0.097*
REGION	Dakar region		0.50	-0.009	0.143**	0.053
VILLAGE$_{1-23}$	Village dummies	lowest corr.		-0.076	-0.162***	-0.109*
		highest corr.		0.400***	0.161***	0.361***

legend: * p<.1; ** p<.05; *** p<.01

[1] Data for 1995 are based on recall data

Table 5. Propensity score estimating using a bivariate probit model

Treatment:	**W1: FFV estate employment**		**W_2: FFV contract farming**	
Covariate	Coefficient	Robust Std. Err.	Coefficient	Robust Std. Err.
LAND	0.014	0.020	0.036 **	0.017
LABOR	0.353 ***	0.123	0.050 **	0.025
$LABOR^2$	-0.017 **	0.008		
ETHNICITY	-0.453 **	0.183		
UNION	-0.570 ***	0.189		
REGION	0.491 ***	0.174	0.584 ***	0.175
CONSTANT	-1.908 ***	0.480	-2.151 ***	0.257
rho	0.112	0.106		
Wald test rho=0:	$\chi2(1) = 1.096$;	Prob > $\chi2 = 0.296$		

legend: * p<.1; ** p<.05; *** p<.01

Table 6. Estimated treatment effects using regression, matching and propensity score methods

	Estimated treatment effects	
	W_1: FFV estate employment	**W_2: FFV contract farming**
MODEL I: Regression on covariates	2.27**	4.25***
	(1.014)	(1.324)
MODEL II: Regression on propensity scores[1]	1.93**	4.65***
	(0.966)	(1.759)
MODEL III: Matching on propensity scores[1]	1.90**	4.01***
	(0.928)	(1.074)

legend: * p<.1; ** p<.05; *** p<.01
(numbers) are standards errors, [1] standard errors are bootstrapped

Table 7. Simulation-based sensitivity analysis for propensity score matching estimators[1]

	Estimated treatment effect	Outcome effect[2]	Selection effect[3]
Treatment W_1: FFV estate employment			
Baseline propensity score matching estimator (MODEL III)	**1.897**		
Matching estimators with simulated binary confounder:			
Neutral confounder	1.884	2.118	1.048
Confounder calibrated to mimic ETHNICITY	1.953	1.256	0.458
Confounder calibrated to mimic UNION	1.925	1.084	0.465
Confounder calibrated to mimic REGION	1.975	1.954	2.167
Treatment W_2: FFV contract farming			
Baseline propensity score matching estimator (MODEL III)	**4.265**		
Matching estimators with simulated binary confounder			
Neutral confounder	4.654	1.796	1.087
Confounder calibrated to mimic REGION	4.742	1.680	1.370

[1] The method is described by Ichino, Mealli and Nannicini (2006) and builds on Rosenbaum and Rubin (1983) and Rosenbaum (1987). It is supposed that the conditional independence assumption is not satisfied but that it would be satisfied if an additional binary variable could be observed. The method simulates this binary confounder in the data that is used as an additional matching factor. A comparison of the estimates obtained with and without matching on the simulated confounder informs to what extent the estimator is robust to this specific source of failure of the conditional independence assumption (Ichino et al., 2006).
[2] The outcome effect measures the estimated effect of the simulated binary confounder on the outcome variable – household income.
[3] The selection effect measures the estimated effect of the simulated binary confounder on the selection into treatment.

Table 8. Balancing properties of covariates in treated and control groups

Covariate	Sample	Mean treated units	Mean control units	% bias between treated and controls	% reduction in bias	t-test Mean(treated) = Mean(control): t	Prob.> |t|
Treatment W_1: FFV estate employment							
LAND	Unmatched	3.765	3.676	2		0.15	0.883
	Matched	3.858	3.932	-1.7	17.2	-0.10	0.924
LABOR	Unmatched	7.482	6.153	43.5		3.18	0.002
	Matched	7.432	6.940	16.1	63.0	1.07	0.288
$LABOR^2$	Unmatched	64.687	47.631	35.6		2.62	0.009
	Matched	64.049	56.651	15.4	56.6	1.00	0.320
ETHNICITY	Unmatched	0.181	0.331	-34.9		-2.49	0.013
	Matched	0.185	0.181	1	97.0	0.07	0.942
UNION	Unmatched	0.181	0.338	-36.2		-2.59	0.010
	Matched	0.185	0.133	12.2	66.4	0.92	0.359
REGION	Unmatched	0.663	0.497	33.9		2.48	0.014
	Matched	0.654	0.699	-9.1	73.2	-0.61	0.545
Treatment W_2: FFV contract farming							
LAND	Unmatched	5.662	3.676	38.1		2.60	0.010
	Matched	5.481	5.868	-7.4	80.5	-0.34	0.733
LABOR	Unmatched	7.759	6.153	50.7		3.31	0.001
	Matched	7.632	6.877	23.8	53.0	1.28	0.202
REGION	Unmatched	0.621	0.497	25		1.62	0.107
	Matched	0.614	0.684	-14.2	43.3	-0.78	0.437

Table 9. Sensitivity analysis

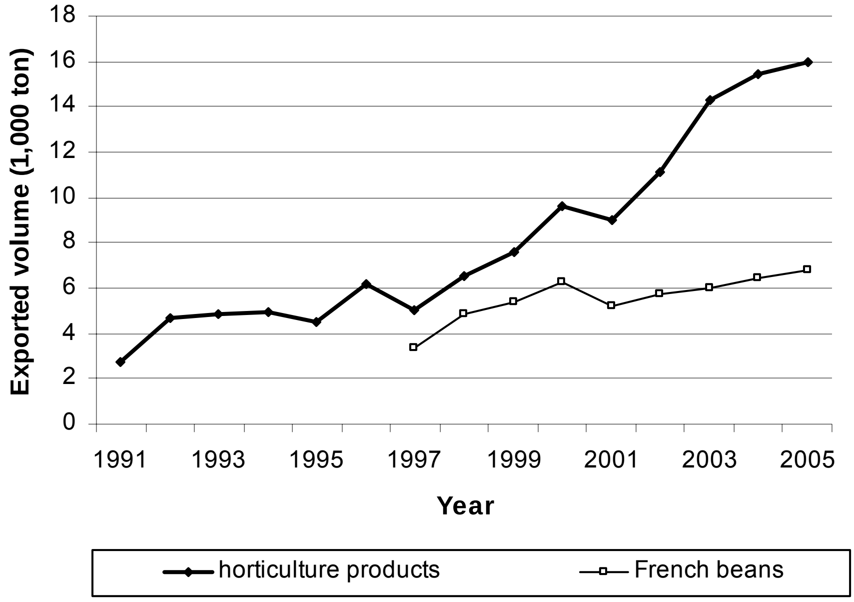
	Estimated treatment effects	
	W_1: FFV estate employment	**W_2: FFV contract farming**
Regression on covariates		
Baseline specification (MODEL I)	2.27 **	4.25 ***
	(1.014)	(1.324)
Specification A	2.47 **	5.23***
	(1.079)	(1.433)
Regression on the propensity score[1]		
Baseline specification (MODEL II)	1.93 **	4.65 ***
	(0.966)	(1.759)
Specification B	1.94 **	4.49 ***
	(0.980)	(1.811)
Specification C	2.15 **	4.52 **
	(0.901)	(1.934)
Specification D	2.10 **	4.38 ***
	(1.066)	(1.810)
Matching on the propensity score[1]		
Baseline specification (MODEL III)	1.90**	4.01***
	(0.928)	(1.074)
Specification B	1.85 **	4.37 ***
	(0.969)	(1.174)
Specification C	2.27 ***	4.16 ***
	(0.930)	(1.228)
Specification D	1.37 **	4.92 ***
	(1.081)	(1.265)

legend: * p<.1; ** p<.05; *** p<.01
(numbers) are standards errors, [1] standard errors are bootstrapped

Specification A: right-hand side variables include next to the two treatment variables and the vector of covariates X as in the baseline model I, the interaction terms between the demeaned covariates and the treatment variables:
Specification B: propensity scores are estimated with a bivariate probit model including covariates that are correlated at the 1% significance level with the specific treatment variable and/or the outcome variable (household income). X = LAND, LABOUR, $LABOUR^2$, ETHNICITY.
Specification C: propensity scores are estimated with a bivariate probit model including village dummies and covariates that are correlated at the 1% significance level with the specific treatment variable and/or the outcome variable (household income). X = LAND, LABOUR, $LABOUR^2$, ETHNICITY, $VILLAGE_{1\text{-}23}$
Specification D: propensity scores are estimated with a bivariate probit model including covariates that are correlated at the 10% significance level with the specific treatment variable and/or the outcome variable (household income). X = LAND, LABOUR, AGE, D-RATIO, EDUCATION, ETHNICITY, UNION, REGION.

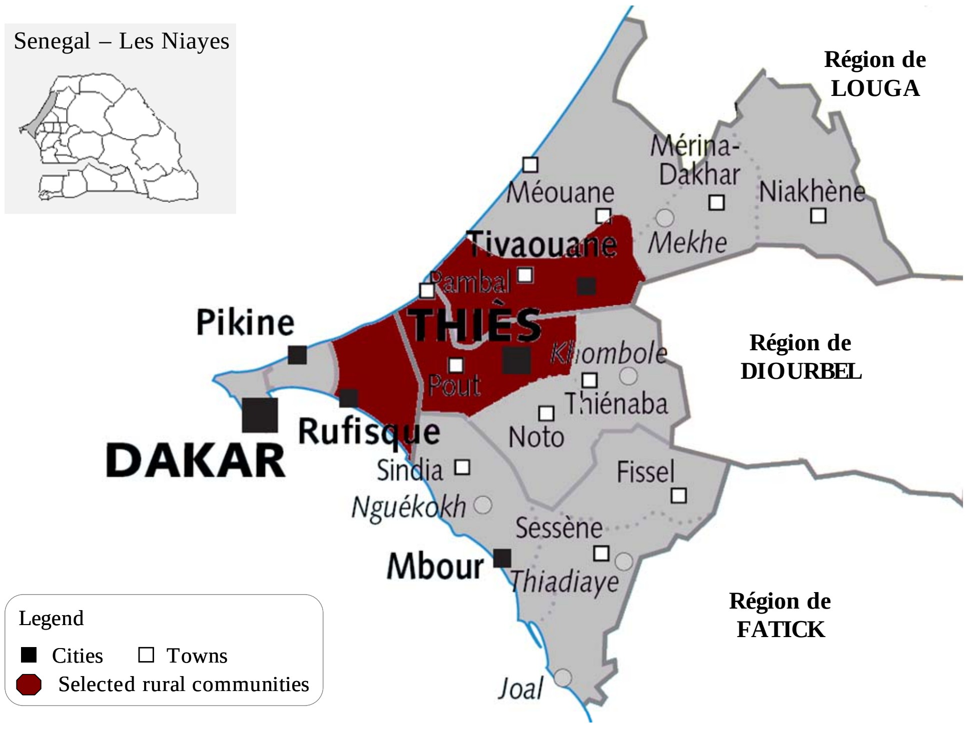
Figures

Figure 1. Export volume (thousand ton) horticulture products from Senegal, 1991 – 2005



Source: data from DH – Direction de l'Horticulture (2005)

Figure 2. Research area: selected rural communities for a household survey



Source: map from Atlas du Sénégal – IRD – Cartographie A. LE FUR -AFDEC

Figure 3. Household participation in French bean export production, 1991 – 2005

The figure is based on recall data collected in 2005. To account for demographic effects, households for which the household head did not reach the age of 25 in a particular year and households who migrated to the area after a particular year are not taken into account for the figures of that year.

Figure 4. Household income from different sources: averages across contract farmers, estate employees and non-participants in horticulture export production

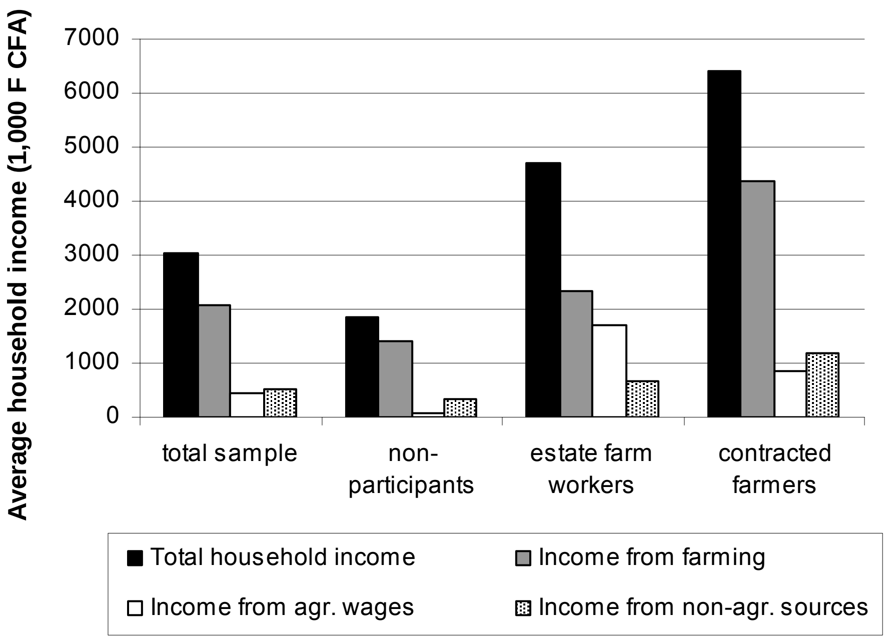
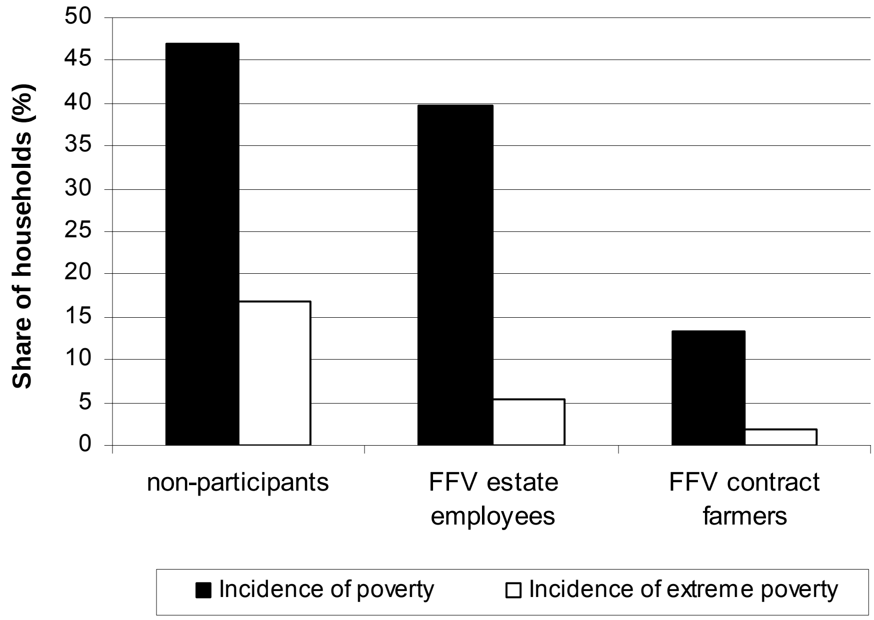


Figure 5. The incidence of poverty and extreme poverty across contract farmers, estate employees and non-participants in horticulture export production



National rural poverty lines are used – constructed using data from the ESAM I and II surveys conducted in 1994 and 2002 (République du Sénégal, 2004) and adapted for changes in consumer price indices (African Development Bank, 2006), resulting in poverty lines 143,080 FCFA/year/adult equivalent for poverty and 31,812 FCFA/year/adult equivalent for extreme poverty. Poverty indicators are derived from household income data.

Figure 7. The incidence of poverty and extreme poverty for two alternative scenarios

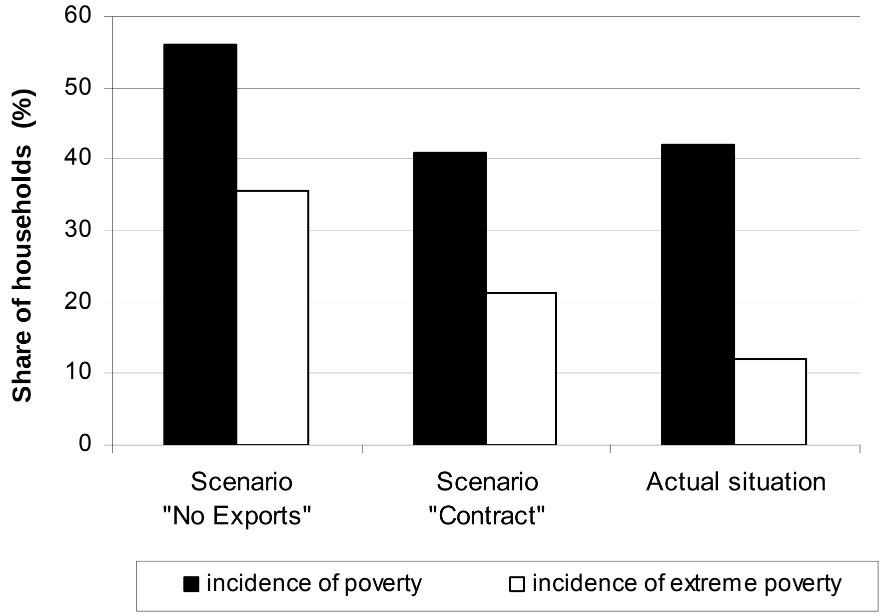
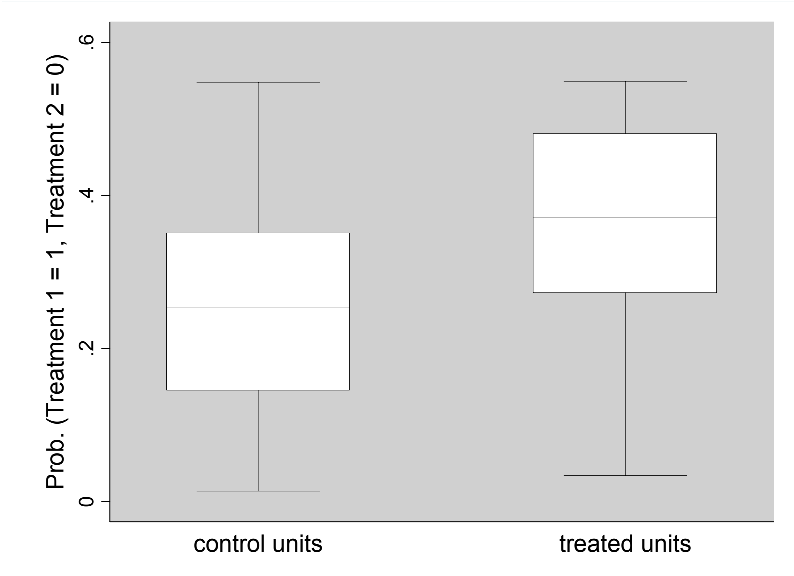


Figure 6. Distribution of propensity scores over control and treated units

Treatment 1: *FFV estate employment*



Treatment 2: *FFV contract-farming*