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Abstract

There is no consensus about how globalization –trade and foreign investments – affects poverty reduction. Using household survey data, this study contributes to the empirical literature on globalization and poverty by analyzing the household-level implications of increased foreign investments and trade in the horticulture sector in Senegal. In many aspects this represents what many would consider a "worst-case scenario". Stringent rich country standards are imposed on exports and the supply chain is controlled by a single multinational company with extreme levels of supply base consolidation, full vertical integration and complete exclusion of smallholder suppliers. We analyze and quantify income and poverty effects under these "worst-case conditions" and find significant positive welfare impacts through employment creation and labor market participation.

Keywords: trade, FDI, poverty, vertical coordination, modern supply chains

JEL: F2, J43, O12, Q12, Q17

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Globalization and Poverty in Senegal:

A Worst Case Scenario?

1. Introduction

There is no consensus about how globalization – trade and foreign investments – affects poverty reduction. Participation in international trade has been advocated as a major engine of growth in poor countries[1] (Dollar and Kraay, 2002; Frankel and Romer, 1999; Irwin and Tervio, 2002). In addition, developing countries are said to benefit considerably from the inflow of foreign direct investment (FDI) through direct growth effects and a variety of growth spillover effects[2] (Blalock and Gertler, 2008; Borenzstein et al., 1998; Choe, 2003; Hansen and Rand, 2006; Xu, 2000). However, there is much less consensus about how foreign trade and investment specifically affect the poor in these countries. Some authors point to evidence of poverty-alleviating effects of trade (Ben-David, 1996; Bhagwati and Srinivasan, 2002; Dollar and Kraay, 2004;) while others contradict this assertion (Fosu and Mold, 2008; Lundberg and Squire, 2003; Ravallion, 2001 & 2006). Likewise, some see FDI as an effective tool in the fight against poverty (Klein et al., 2001; UNCTAD, 2005) while others argue this is highly overestimated (Nunnenkamp, 2004). Some studies present evidence of a negative link between FDI inflows and inequality in developing countries (Feenstra and Hanson, 1997; Jensen and Rosas, 2007) while others have demonstrated the absence of such a link (Lindert and Williamson, 2001; Milanovic, 2002) or even the opposite (Agénor, 2004; Choi, 2006; Tsai, 1995). In summary, there is no general conclusion about how the integration of developing countries in global

[1] See Rodriguez and Rodrik (2000) for a critique on this conclusion and Winters et al. (2004) for a survey of the arguments.
[2] See Kosack and Tobin (2006) for a critique on this conclusion. See Klein et al. (2001) and Colen et al. (2008) for a review of the direct and indirect growth effects of FDI and Hansen and Rand (2006) for a discussion on the factors conditioning the magnitude of the growth effect of FDI in poor countries.

markets affects poverty and income inequality in these countries (Winters et al., 2004; Cooper, 2002). This lack of consensus has induced a call for more convincing empirical evidence on the link between globalization and poverty dynamics at the household level (Winters et al., 2004, pp.107) and for evidence from country case-studies – rather than cross-country regressions (Srinvasan and Bhagwati, 2001).

The aim of this study is therefore to contribute to the empirical literature on globalization and poverty by using household data to study the effects of what many would *ex ante* consider a "worst case scenario", i.e. FDI and trade growth in the tomato export sector in Senegal. This case of globalization has several characteristics which have been argued to be detrimental to the rural poor in developing countries: (a) Senegal is a very poor country with many institutional problems and market imperfections; (b) the fresh fruit and vegetable (FFV) sector has faced rapidly tightening and currently very stringent standards on products and production processes; (c) the export tomato chain is characterized by extreme consolidation, as a single company controls all the production, processing, and trade; (d) the monopoly exporting company is a foreign multinational company; (e) the various levels in the supply chain are fully vertically integrated; and (f) smallholders are completely excluded as all tomatoes for export are produced on large scale farms owned by the exporting company.

The agri-food sector is of particular relevance to situate the impact of economic globalization on poverty. On the one hand, stimulating agri-food exports and attracting FDI in the agri-food sector have been promoted as pro-poor growth strategies because of the direct link the sector has with the rural economy – where poverty rates are often much higher than in urban areas – and because of the intensive use of unskilled labor in the sector (Aksoy and Beghin, 2005; Anderson and Martin, 2005; Carter et al., 1996; World Bank, 2008). On the other hand, increased globalization of the agri-food sector has been argued to be detrimental for global poverty reduction as the poorest countries and the poorest farmers are increasingly excluded and marginalized. Rapidly growing foreign investments in food processing and retailing sectors[3] and the recent proliferation of stringent food standards – resulting from these investments as well as from increased attention to food quality and safety in high-income countries and markets – are causing shifts in global food supply chains with an increased dominance of large multinational food companies, consolidation of the supply base and increased vertical coordination in the chains (Farina and Reardon, 2000; Reardon et al., 1999; Swinnen, 2005 and 2007; Swinnen and Maertens, 2007; Weatherspoon and Reardon, 2003). Major concerns of these recent developments are (a) that standards act as new non-tariff barriers diminishing the export opportunities of the poorest countries for whom compliance costs are inhibitingly high[4]; (b) that poor farmers are exploited in vertically coordinated food supply chains because of reduced bargaining power vis-à-vis large multinational food companies; and (c) that poor suppliers are excluded from high-standards global food supply chains because of their inability to comply with high standards[5].

These arguments are subject to debate. First, some studies have pointed to cases where increasing food standards are applied to the competitive advantage of developing countries, resulting in upgrading of the food sector and enhanced market access (Jaffee and Henson, 2004 & 2005; Henson and Jaffee, 2008; Maertens and

[3] One of the most publicized aspects of these investments is the so-called supermarket revolution, discussed by Reardon and Berdegué (2002); Reardon et al. (2003), and Weatherspoon and Reardon (2003).
[4] See Jaffee and Henson (2005); Garcia Martinez and Poole, 2004; Unnevehr (2000); and Wilson and Abiola (2003) for a more detailed discussion.
[5] Gibbon (2003), Key and Runsten (1999), Maertens and Swinnen (2007); Swinnen (2007), and World Bank (2005) discuss the grounds for the marginalisation and the exclusion of small and resource-poor farmers.

Swinnen, 2007). Second, rather than being exploited, small farmers can gain importantly in vertical coordination schemes with the agro-industry through enhanced access to inputs, reduced production and marketing risks, improved technology and productivity, and ultimately higher incomes – which has been empirically demonstrated by various authors (Dries and Swinnen, 2004; Gulati et al., 2007; Minten et al., 2008; Swinnen, 2005). Third, the extent of smallholder exclusion in globalized food supply chains is a controversial issue. Some empirical studies find that the reorganization of global food supply chains have led to a shift from smallholder production to agro-industrial production, thereby excluding smallholders from profitable trading opportunities and resulting in negative welfare effects (Danielou and Ravry, 2005; Farina and Reardon, 2000; Key and Runsten, 1999; Reardon et al., 1999; Reardon et al., 2003; Weatherspoon and Reardon, 2003). Others have come to more moderate conclusions on the extent of smallholder exclusion (Jaffee, 2003 ; Kherralah, 2000; Minot and Ngigi, 2004; Swinnen, 2007).

However, surprisingly little research has focused on the overall poverty effects of globalization in agri-food sectors of developing countries. Most of the above mentioned studies focus only on production linkages when analyzing the effects of increased agri-food trade and investments. Yet, the poor may benefit through labor markets as well. The intensive use of unskilled labor in agri-food sectors has been put forward as a main potential source of poverty reduction (e.g Carter et al., 1996). A couple of recent studies have indeed pointed to the welfare gains from employment opportunities in the emerging agro-industry (Barron and Rello, 2000; Maertens and Swinnen, 2008; McCulloh and Ota, 2002). Apart from the latter studies, surprisingly little attention has been paid to labor markets in the discussion on the link between globalization in the agri-food sector and poverty – and none has analyzed an extreme case as is the very subject of our research.

We use unique household level survey data combined with complementary data from company and village interviews to assess the implications of production and trade in the tomato sector in Senegal for income and poverty dynamics. Our study yields several important findings. First, we find that tomato exports from Senegal to the EU have increased sharply over the past decade, despite increasing standards in the EU. Second, despite the extreme consolidation and vertical integration in the supply chain and the exclusion of smallholder farms from export tomato production, tomato exports contribute importantly to poor household incomes and poverty reduction in the tomato producing regions through employment effects. Third, we do not find evidence that asset-poor households or unskilled individuals are disadvantaged in accessing employment in the tomato export chain.

The structure of the paper is as follows. In the next section we discuss the developments in the tomato export supply chain in Senegal – including the importance of standards. In section three we present details on the survey data that are used to analyze the welfare implications of export tomato development. In section four we discuss the implications for rural employment, income mobility and poverty based on descriptive statistics. In section five we present an econometric model to analyze the income effects and discuss the derived results. We draw some conclusions in a final section.

2. The Tomato Export Supply Chain

Horticulture Export Growth

Exports of fresh fruits and vegetables (FFV) from Senegal have increased tremendously in the past 10 years: from 4,800 ton in 1998 to almost 25,000 ton in 2007 (Figure 1). FFV exports also became more diversified. In 1997 more than 75% of FFV exports consisted of one crop (French beans). Since the early 2000s also the export of tomatoes and mango has grown. The export volume of tomatoes – mainly cherry tomatoes – has increased from less than 1,000 ton in the year 2000 to almost 7,000 ton in 2007, accounting for 28% of total FFV exports.

The large majority of exported fruits and vegetables are destined for the EU-market, mainly France, Belgium, Luxembourg and the Netherlands. Some minor volumes of mango and other fruits are exported to neighboring countries such as Mali, Mauretania, and Cape Verde.

Foreign Direct Investment

Foreign direct investment has played a major role in the boom of cherry tomato exports. The initial export of tomatoes in the 2000/2001 season was realized through two Senegalese companies specialized in the export of French beans. However, in 2001 a foreign company – *Grands Domaines du Senegal* (GDS), a subsidiary of a French holding with food production and distribution affiliates in a number of countries in Europe, Africa and Latin-America – entered the FFV export market in Senegal. After an initial start-up period, this company began to export significant volumes of cherry tomatoes to the EU from 2003 onwards. After the entrance of the FDI company, the market structure significantly changed. The market share of GDS increased from 43% of tomato exports during the 2004/2005 season to 99% during the last completed export season (2006/2007).

GDS is exporting cherry tomatoes from the area of the Senegal River Delta in the region of Saint-Louis. The company chose this area close to the Senegal River to avoid problems of land and water shortage that is plaguing horticulture production in other regions.

Public and Private Standards

It is remarkable that Senegal experienced accelerated export growth to the EU in the horticulture sector during a period when food quality and safety standards increased substantially, especially for fresh food products such as fruits and vegetables. First, FFV exports to the EU have to satisfy a series of stringent public quality and safety standards. EU legislation imposes (1) marketing standards for fresh fruits and vegetables; (2) labeling requirements for foodstuffs; and (3) health control of foodstuffs. The latter includes general conditions concerning contaminants in food, general hygiene rules based on HACCP control mechanisms, and traceability requirements – laid down in the General Food Law of 2002.

Second, private standard play an increasingly important role in trade of fresh fruit and vegetables. Private retailers, traders and food processors have engaged in initiatives to establish private standards (often more stringent than public requirements) and adapt food quality and safety standards in certification protocols. Although private standards are legally not mandatory they have become de facto mandatory as a large share of buyers in EU markets is requiring compliance with such standards, for example the EurepGAP standards.

In response to these increasing food standards, GDS has obtained EurepGAP certification for the production and export of cherry tomatoes since 2003. In fact, the multinational holding to which GDS belongs, specifically aims at high-standards production and seeks compliance with a large variety of private standards including food quality standards, food safety standards, ethical and environmental standards. For all its plantations the holding is certified by several private certification schemes including the International Organization for Standardization (ISO), British Retail Consortium (BRC), European Retail Produce Working Group (EurepGAP), Ethical Trade Initiative (ETI), Tesco Nature Choice, etc.

Consolidation and Vertical Integration

Many studies have documented important structural transformations in the supply chains of fresh produce for export to high-standards markets (Swinnen, 2007). High-standards agri-food supply chains have become increasingly consolidated, with fewer and larger firms, while the level of vertical coordination in the chains is increasing. In some cases – for example in the Malagasy FFV sector (Minten et al., 2006) – increased standards have led to institutional innovations, such as extensive monitoring and complex contracting, to source from small farmers. In other cases this is associated with a shift from smallholder contract-based production to large-scale integrated estate production, documented e.g. by Jaffee (2003) for Kenyan vegetable exports, Minot and Ngigi (2004) for FFV exports from Cote d'Ivoire, Maertens and Swinnen (2008) for French bean exports from Senegal, and Danielou and Ravry (2005) for pineapple exports in Ghana. Increasing quality and safety requirements are usually mentioned as the main driving factor behind the observed supply chains restructuring.

The case of cherry tomato exports in Senegal represents an extreme case of these developments of consolidation and increased vertical coordination in food supply chains. Ninety-nine percent of the tomato exports from Senegal are handled by one multinational company. Moreover, at several nodes in the chain, vertical coordination takes the extreme form of complete ownership integration. Downstream trading, transport and distribution activities are completely integrated within the multinational holding with own transport and distribution subsidiaries. The maritime company of the group has eight specialist vessels and organizes overseas transport between 4 ports in West-Africa – including Dakar – and several ports in the EU, mostly France, Belgium and the UK, from where further distribution in Europe is handled by several trading affiliates of the group.

Also upstream the cherry tomato supply chain is completely vertically integrated. For the supply of primary produce, the company relies completely on their own integrated agro-industrial production. In the Senegal River Delta, GDS has established a conditioning station for handling and processing fresh vegetables and two production sites, including 40 ha of greenhouse production and 150 ha of open field production. The company invested in irrigation infrastructure and high-technology production techniques, including mechanized and computerized irrigation, fertilization and phytosanitary care in a drip-to-drip system. These technologies – along with the required inputs such as improved seeds, fertilizers and phytosanitary products – are imported from the EU.

Hence, the tomato export supply chain excludes smallholder producers completely as production is realized exclusively on the large-scale plantations of the exporting company. It is important to note however, that this integrated agro-industrial farming was not developed by buying or renting land from small farms, but by investing in previously uncultivated land allocated to them by the government. An additional 400 ha of land in the region of the Senegal River Delta has been assigned to GDS by the government to expand its production and export activities in the future.

During interviews with GDS in September 2005 and March 2006, two main reasons were mentioned for this strategy of complete vertical integration. First, this strategy is in line with the policy of the French holding to which GDS belongs and which owns similar vertically integrated production and exporting facilities in other developing countries (e.g. in Mauretania and Côte d'Ivoire). Second, high EU requirements on quality and food safety – such as traceability, maximum residue levels, etc. - combined with the general low capacity and limited access to resources (especially irrigation-water) of the local smallholder farmers induced the company to integrate the production stage of the chain and set up their own agro-industrial farms.

A Worst-case Scenario of Supply Chain Development?

In the development literature consolidation and increased vertical integration in agri-food supply chains – often produced under pressure of increasing food standards – are usually considered to be particularly detrimental from a development perspective. The main argument is that local small – often poor – farmers are increasingly excluded from high-standards supply chains if these chains move towards more vertical coordination and that hence the benefits of high-standards trade are concentrated in the hands of a few large companies (Gibbon, 2003; Farina and Reardon, 2000; Kherralah, 2000; Reardon et al., 1999). Moreover, consolidation and FDI in the agri-food industry is expected to lead to unequal bargaining power for farmers vis-à-vis large (multinational) companies, resulting in rent extracting by these companies (Gibbon, 2003; Warning and Key, 2002). In addition, vertical integration is argued to limit the possibilities of additional beneficial development effects through spillover effects in down- and upstream activities. So, in many respects the sector which we study represents what many would consider a "worst-case-scenario" of supply chain development.

3. Data and Research Area

To study the welfare implications of the growth of the tomato export chain in Senegal, we organized extensive primary data collection. First, in September 2005 and again in March 2006, we conducted interviews with the company GDS that started to export tomatoes from Senegal in 2003 and accounted for 99% of tomato exports in 2006/2007. These were mainly qualitative interviews on a diversity of topics related to the production and exporting activities of the company. Second, we collected qualitative information in three villages (Ndioudoune, Maka and Mbarigo) near the production- sites of the firm through informal group interviews with the village chief, the council of village elderly, and representatives of village organizations. This information was mainly used to fine-tune further quantitative data collection. Finally, in the period February-April 2006 we organized a large and comprehensive household survey in the area surrounding the tomato exporting company and complemented this with a village census in all sampled villages.

The surveys covered 299 households in 18 villages in 2 rural communities – *Gandon*, the community where the company is based, and *Ross Bethio*, an adjacent community. Both communities are located in the region Saint-Louis, in the north of the country along the Senegal River (Figure 2). Villages in the sample were selected randomly while households within the villages were stratified according to whether or not one or several members of the households are employed in the tomato export industry. The household selection resulted in an oversampling of households having members employed in the tomato export industry. To draw correct inferences, this oversampling is corrected for using sampling weights that are calculated with information from a village census in all sampled villages.

The survey data – including recall data – provide details on household demographic characteristics, land and non-land asset holdings, agricultural production, off-farm employment, non-labor income, credit, and savings; and allow the calculation of household net income from farm and off-farm sources. For each household we collected detailed and recall information on the employment of household members in the tomato export agro-industry.

4. Rural Employment, Income and Poverty – Descriptive Analysis

We want to investigate the impact of the growth in tomato exports – taking into account the specific supply chain structure – on the welfare of the local population. Since the chain is completely integrated and smallholder producers are not included in the chain, the main effects come from employment creation. In this section we first describe the participation of local households in this employment and then present some descriptive statistics on how employment is correlated with household income and poverty in the region. In section 5 we will use more sophisticated statistical methods to assess the employment effects.

Employment in the Tomato Export Agro- industry

The increased export of tomatoes by GDS was accompanied by a large increase in employment in this sector. Although parts of the production process is mechanized and high-technology techniques are used, tomato production and handling remains a labor-intensive business. While irrigation, fertilization and phytosanitary care is completely mechanized and computerized with a drip-to-drip system, the harvesting of tomatoes is done manually and requires substantive amounts of labor. Also processing and handling of the tomatoes is labor intensive as packing and labeling is done manually – while sorting is mechanized.

The growth of tomato exports has created employment opportunities in the vast rural area of the Senegal River Delta. In 2006 GDS employed more than 3000 workers – on the fields as well as in the processing unit. About 80% of those workers are temporary seasonal workers or day laborers. The large majority of workers are recruited from nearby villages. The rest of the employees are seasonal migrants from more distant locations. In our sampled villages more than one third of households have one or more members working as employee in the tomato export industry. This share increased from 14% in 2003 to 39% in early 2006 (Figure 3). The share is highest – almost 50% of households – in the community *Gandon* which includes villages in the immediate surroundings of the production sites and processing unit of GDS. However, also in the adjacent community – *Ross Béthio* – with more distant villages, the share of households employed by GDS is about 30%. The largest increase in employment in this community was in 2005 when recruitment from villages in *Gandon* stagnated.

The impact of tomato export growth and the associated employment on rural income mobility, income equality and poverty reduction depends on which households are selected into this employment and on how much they benefit. Such employment growth could exacerbate rural income inequality if entry-constraints – e.g. the need for a minimal level of education or certain assets – exist that limit the off-farm employment opportunities for the poorest households. Such increase of inequality has been observed by Dercon (1998) and Barrett et al. (2001) in studies on rural off-farm employment in Sub-Saharan Africa. However, we find that in the case of employment growth in the tomato export industry in Senegal, there appears to be no increase in inequality, to the contrary.

In Table 1 we compare the characteristics of households with one or more members employed in the production and/or handling of tomatoes for export, and households without such employment. The figures show that these two groups of households differ substantially in certain household characteristics. Employees in the tomato export industry come from significantly larger households, with an older household head, significantly larger labor endowments and fewer dependents. There is no disparity between the two groups of households in their level of education and their ethnicity. Yet, households with employees in the tomato export industry initially – in 2001, before GDS invested and started to recruit local households – had significantly smaller landholdings. They also have slightly lower initial livestock and non-land asset holdings, but none of these differences are significant at the 0.1 level. In summary, this comparison suggests that employment in the tomato export industry is not biased towards relatively better-off or more educated households; in contrast, the employment is biased towards households with smaller landholdings. No major entry constraints in the form of education or wealth seem to exist for entry into employment in the tomato export sector.

Household Income

Total household income is calculated from the survey data for the 12-month period prior to the survey (2005-2006) and using the modified OECD adult equivalence scale for *per capita* measures. Comparing incomes for households with member(s) employed in the tomato export industry and households without such employment, we find that employment in the sector is associated with larger total and *per capita* incomes. Households with members employed in the tomato export industry have an average income of 1.95 million FCFA. This is more than two times larger than the average income of other households, which is 0.88 million FCFA (Figure 4). Also in *per capita* terms these income differences remain large: 277,000 FCFA *per capita* for households with GDS employees versus 212,000 FCFA *per capita* for other households – this is more than 30% higher.

The wages received from working on the fields and in the conditioning centre of GDS add substantially to rural incomes. One third of total household income in the survey region is derived from these wages (Figure 4). Looking only at those households taking up this employment, this even increases to 54%. Hence, the tomato export sector – despite the fact that its activities are very seasonal and associated employment mostly temporarily – has become the main source of income in the region. Nevertheless, most households continue to have diversified income portfolios (Figure 4). Income sources include – apart from wages received from GDS (34%) – farming (21%), self-employment (mostly small trading activities – 18%), other wages (11%) and non-labor income (mostly remittances and public transfers – 16%).

Poverty Rates

Based on household *per capita* incomes, we calculate the incidence of poverty in the research area. We use a poverty line of 143,080 FCFA *per capita* for poverty and 31,812 FCFA *per capita* for extreme poverty and calculate the share of households living below these national rural poverty lines. The poverty lines are calculated from the ESAM I and II surveys in 1994 and 2000 (République du Sénégal, 2004), and are updated to the period of our survey (2005-2006) using consumer price indices (African Development Bank, 2006).

The incidence of poverty in the research area is 13% for extreme poverty and 42% for poverty, which is lower than the average national rural poverty rate of 58% (Figure 5). Poverty is much lower among households that are employed in the tomato export industry (35%), compared to those without such employment (46%). The same is valid for extreme poverty: 6% compared to 18% (Figure 5). These are large and important differences. Poverty is 11 percentage points – and extreme poverty 12 percentage points – lower among households with employment at GDS. These effects appear especially remarkable since our earlier comparison indicated that employment in GDS was not biased towards initially better-off households (see Table 1). Although we cannot yet derive causal relations based on the descriptive analysis so far, the figures suggest that the growth in tomato exports and associated employment have lead to upwards rural income mobility and poverty reduction in the research region.

5. Econometric Analysis

The descriptive analysis in the previous section indicates that there is a substantial difference in income across households and that this difference is correlated with employment in the tomato export industry. However, to identify whether we can attribute these differences to the causal impact of this employment, we need more detailed econometric analysis. In this section we identify and describe various econometric models to estimate the effect of employment in the tomato export industry on household income, and present and discuss the results of the estimations.

5.1. Methodology

We are interested in estimating the effect of employment with GDS – expressed by a treatment variable[6] T_i – on household income Y_i. Apart from the treatment effect, income is determined by other relevant covariates represented by the vector X_i, including household productive asset holdings and other characteristics that may affect productivity and profits.

$$Y_i = \theta + \alpha T_i + \beta X_i + \varepsilon_i\ , \ \forall\ i \qquad (1)$$

Difficulties may arise in estimating the effect of T_i on Y_i because the treatment variable T_i can be arbitrarily correlated with the error term or unobserved heterogeneity. This may be the case as selection into employment in the tomato agro-industry is likely to be non-random. The company-employer may select households based on their location and certain characteristics. Indeed, GDS recruits daily laborers through local village organizations[7] and mobilizes trucks to pick-up laborers in nearby and easily accessible villages. In addition, households may self-select into employment, e.g. because they have relatively small landholdings and no other employment opportunities.

We use two different sets of techniques to deal with the potential bias. In a first set of models the problem is treated as an endogeneity problem where the partial effect of the treatment variable depends only on observed exogenous variables. Accordingly, we use simple OLS estimation and IV estimation to reveal the effect of employment in the agro-industry on household income. In a second set of models, we treat the unobserved heterogeneity as a sample selection problem arising from the fact that household income without treatment is unobserved for treated unites (and vice

[6] We will use techniques described in the literature on average treatment effect and therefore call our dummy variable of interest the treatment variable. 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 development economics studies.
[7] To recruit workers GDS is working with the so-called GIE – *Groupement d'Interet Economique*, village organizations – such as farmer unions and other business associations – who call together teams of laborers for daily labor on the fields or in the conditioning centre of GDS.

versa) and estimate the effect using propensity score matching techniques. We describe the models in detail below.

OLS Estimation

In a first model we use the selection-on-observables method first described by Heckman and Robb (1985). We estimate equation (1) using OLS estimation and including a large set of covariates X_i, anticipating these can correct for unobserved heterogeneity. The vector X_i includes the following covariates: the number of laborers in the households and its square (Labor & Labor^2), the cultivated area (Farm size), the number of livestock units (Livestock), the value of non-land assets (Non-land assets), the age of the household head (Age), a dummy variable for household heads with at least primary education (Education), a dummy variable for households belonging to an ethnic minority (non-Wolof) group (Ethnicity), and the distance from the residence village to the nearest city Saint-Louis and its square (Distance & Distance^2).

Instrumental Variable Estimation

In a second model – the dummy endogenous variable model, first described by Heckman (1978) – we estimate equation (2) using an instrumental variable estimation technique to control for the endogeneity of treatment. We use a standard IV method in which the probability of employment in the tomato export industry $Prob(T_i)$ is estimated in the first-stage probit model and the estimated probabilities used as an instrumented covariate in the second-stage structural model:

$$Y_i = \theta + \alpha Prob(T_i) + \beta X_i + \varepsilon_i\,, \ \forall i \qquad (2)$$

with $Prob(T_i) = \lambda + \gamma Z_i + \mu_i\,, \ \forall i$

We use the same vector of covariates X_i as in the previous model. Yet, we estimate the IV model twice with slightly different specifications of the vector Z_i in the first-stage probit model. In a first specification A, the vector Z_i includes all covariates potentially relevant for determining selection into treatment. On the one hand, households may self-select into employment in the tomato agro-industry based on their access to resources and their preferences. On the other hand, the company itself can select or exclude potential workers based on their skills, access to resources, etc. In addition, there might be some geographic selection because the company's transportation costs for searching for/picking up laborers increases in more distant and more remote villages, or because workers' travel cost increases with distance. For the same reason, the company may prefer to recruit in larger villages with a larger number of potential laborers. We also need to account for the fact that the company recruits laborers through village organizations.

To account for all these potential sources of bias in the selection of employees in the tomato export industry we include the following covariates in the vector Z_i: the number of laborers in the households (Labor), initial *per capita* landholdings (Land), initial *per capita* livestock holdings (Livestock), initial *per capita* non-land assets (Other assets), the age of the household head (Age), a dummy variable for household heads with at least primary education (Education), a dummy variable for belonging to an ethnic minority (non-Wolof) (Ethnicity), a dummy variable for initial household membership of a professional organization (Organization), a dummy variable for households living in a village along a paved road (Road), and the population size of the village the household lives in and its square (Population and Population^2). Covariates referring to the initial situation are based on recall data for the year 2001, before GDS started its investments in the region. Hence Z_i includes a mixture of covariates that are also incorporated in the vector X_i and covariates that are not. In a second specification B, we use a subset of these covariates and include in Z_i only those covariates that have a significant effect (at the 0.1 level) in the probit model.

Propensity Score Matching Techniques

Treating the unobserved heterogeneity as a sample selection problem, we want to estimate the effect of employment in the tomato export industry on household income – the average treatment effect *ATE* – as the difference between the income with treatment Y_1 and the income without treatment Y_0:

$$ATE = E(Y_1 - Y_0) \qquad (3)$$

The ATE can be consistently estimated using propensity score matching techniques, as first described by Rosenbaum and Rubin (1983). This involves pairing treatment and comparison units that are similar in terms of their observable characteristics and calculating the ATE as a weighted average of the outcome difference between treated and matched controls (Abadie and Imbens, 2002; Dehejia and Wahba, 2002; Imbens 2004; Wooldridge, 2002). We first estimate the propensity score as the conditional probability of treatment $Prob(T_i=1| Z_i)$ using a probit model. For the probit model, we use the same specifications A and B as described above in equation (2). Then treatment units and control units are matched on the estimated propensity scores.

We use two different matching techniques: nearest neighbor matching (model 3) and kernel matching (model 4). The nearest neighbor matching method calculates the ATE as the weighted average of the difference in outcomes of treated and matched control units. 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 control unit with the closest propensity score, which reduces bias (Dehejia and Wahba, 2002). The kernel matching method computes the ATE as the average difference in outcome of treated and matched control case, where the matched control case is obtained as the kernel weighted average of nearest control unit outcomes. Kernel matching is particularly suited for ATE estimation with small sample sizes – such as sample of 299 households – as each treated unit is compared to a whole set of near control units; and hence more information is used leading to improved estimates. In both models 3 and 4, only observations in the common support region – where the propensity score of the treated unit is not higher than the maximum or less than the minimum propensity score of the control units – are used for calculating the ATE (Becker and Ichino, 2005).

Finally, note that there are two main assumptions underlying the consistency of propensity score matching techniques. First, the conditional independence assumption denotes that conditional upon observable covariates, the receipt of treatment is independent of the potential outcome with and without treatment (Dehejia and Wahba, 2002; Imbens, 2004). This assumption is intrinsically non-testable because the data are uninformative about the distribution of the untreated outcome for treated units and *vice versa* (Ichino et al., 2006; Imbens, 2004). Yet, Ichino et al. (2006) proposed a method for addressing robustness of matching estimators to failure of this assumption. We use this method and simulate a binary confounder – as in Ichino et al. (2006) we use a neutral confounder and a confounder calibrated to mimic observable binary covariates in the model – that is used as additional matching factor. The results (Annex 3) that the estimates with binary confounder differ by less than 20% from the baseline matching estimators of model 3 and 4; which indicates that the propensity score matching techniques yield robust estimates of the ATE.

Second, propensity score matching requires balancing in the covariate distribution between treated and untreated observations (Dehejia and Wahba, 2002; Imbens, 2004). The balancing properties are addressed by testing for equality of means between treated and matched controls for nearest neighbor matching in model 3 (Annex 1) and for kernel matching in model 4 (Annex 2). The results of these tests show that there is no problem of unbalanced covariates in any of the models. For many covariates there is a strong bias but matching eliminates this bias.

Robustness Tests and Interpretation

The use of four different econometric techniques to estimate the employment effect already provides an important indication on the robustness of the estimated results. In addition, we use two different specifications (model A and B) for the first stage probit model, in the IV estimation (model 2) as well as in the propensity score matching (model 3 and 4). This is done because the results of IV and ATE estimations are known to be possibly sensitive to the choice of a proper set of covariates (Becker and Ichino, 2005; Dehejia and Wahba, 2002; Imbens, 2004). Little is known about strategic covariate choice (Imbens, 2004) and therefore we use two different specifications to test the sensitivity of the results to covariate choice. As will be documented in the next section, the estimated effects are extremely robust to the various different techniques and the different specifications used in the models.

It should be noted that with the chosen approach we estimate the overall impact of employment in the tomato export industry on household income. This overall impact can stem from the direct effect of wages adding to household income but also from indirect or secondary effects. These include for example the effect on households' own farm and other businesses from employee training in the tomato industry or from increased investments in these activities with wages earned in the tomato industry. In addition, there might be indirect or spillover effects for the rural economy as a whole; for example because increased incomes might have price effects in rural markets. Not all these effects are separately measurable with the data and therefore we look at the overall effects without distinguishing between direct and indirect effects.

5.2. Results and Discussion

Probability of Employment

The results of the first stage probit models estimating the probability of employment in the tomato export industry are presented in Table 2. The relatively high R^2 of the models show that the probability of employment is well explained by a combination of household and village characteristics. In addition, the two different specifications have identical results.

First, we find that households with a larger number of workers are more likely to have members employed in the tomato export industry. Second, initial *per capita* landholdings negatively affect the likelihood of having household members working with GDS: for every additional ha of land the probability of employment in the tomato export industry reduces with about 70 %. This indicates that households with limited access to land and excess labor self-select into off-farm employment in the agro-industry. Third, as expected, we find that households from larger villages and from villages situated along a paved road have a higher likelihood of being employed. This reflects the geographic selection resulting from transport costs, as mentioned in the previous section. Fourth, education has no significant effect, indicating again that education is not a constraint for entry into wage employment in the tomato sector.

Fifth, also other household characteristics such as initial livestock holdings, non-land asset holdings, ethnicity or membership of a village organization have no significant effect in the probit model. The latter result – on organization membership – is somewhat surprising since it is known that GDS recruits laborers through village organizations. The lack of an effect might be explained by the fact that villagers likely seek membership of an organization to have access to GDS employment (rather than having access to the employment because of their membership) and that hence initial membership is not correlated with employment.

We can conclude that rather than being biased towards relatively better-off and better educated households – as found by some studies on rural off-farm opportunities in developing countries – wage employment in the tomato agro-industry in Senegal is accessible for the households with low levels of education and assets.

Income Effects

Table 3 presents the results of the four models estimating the treatment effect. The main result of the analysis is that in all tested models we find a very significant and strong positive impact of employment in the tomato export industry on total household income. This result is consistent across the different estimation techniques – OLS, IV estimation and propensity score matching techniques – and across the different covariate specifications in the first-stage equation. This consistency suggests a firm robustness of the results. The estimated effect varies between 0.61 and 1.09 and is substantially larger in model 2 (IV estimation) compared to the other models. This might result from the fact that the usual IV estimator is generally inconsistent for binary treatment effects[8] (Wooldridge, 2005). With propensity score matching techniques we find more conservative – and probably more consistent and more realistic (Wooldridge, 2005) – estimates of the income effect: between 0.61 and 0.73.

From this analysis, we can derive that households with members employed in the tomato agro-industry have incomes that are between 610,000 FCFA to 730,000 FCFA higher than for households who do not take up such employment. This means that these households have incomes that are 47% to 57% higher than the average income in the region and 70 to 83% higher than those of households not employed in the tomato sector. These are extremely large and important effects; especially since entry into such employment is biased towards households with smaller land and excess labor endowments.

Finally, the results of the second-stage income regression show that household income is correlated with its labor, land and capital endowments. Labor has a significant positive but decreasing effect on income. A larger farm size and more non-land assets significantly increase household income. We find for example that an increase of 1ha in the farm size increases household income with 300,000 FCFA. The age and education of the household head have no significant effect on household income. In addition, location with respect to the city Saint-Louis matters: being located in a village 1 km further away from the city decreases household income with 80,000 to 90,000 FCFA.

6. Conclusions

[8] The use of the IV estimation technique for an endogenous binary treatment is based on the simulation results found by Angrist (1991) that the usual IV estimator can provide a good estimate of the average treatment effect while in fact sufficient conditions for consistency of IV do not hold in the binary treatment case. However, the results of Angrist (1991) are a special case as he considers only a model without additional exogenous covariates (Wooldridge, 2005).

The impact of developing countries' integration in global markets on poverty and income inequality in these countries remains the subject of considerable controversy. This paper has analyzed the household level effects – including income mobility and poverty reduction – of increased foreign trade and investments in the tomato sector in Senegal using a unique set of survey data. Our study shows that FDI in the FFV sector and sharply expanded tomato exports has importantly benefitted poor rural households through wage employment in the emerging agro-industry. Using several different econometric techniques we find robust, significant and large positive effects on income and poverty reduction.

Although, these conclusions are obviously drawn from the specific sector which we studied and one should be careful to generalize, we believe that these findings are particularly important. First, our case-study provides evidence at the household level of a positive and direct link between globalization and poverty reduction and thereby contributes to filling a gap in the empirical literature. Second, our results challenge the general view in the literature that the gains from expanded agri-food trade are concentrated with foreign investors and large food companies while poor farmers are increasingly marginalized. Even with extreme levels of supply base consolidation and complete vertical integration in the chains, there are important benefits for the poor. Third, the results show that important benefits may come through labor market effects rather then through product markets. This challenges the implicit assumption underlying many empirical studies that export supply chains need to integrate farm household as primary producers if agri-food trade is to benefit rural incomes and poverty reduction. Fourth, related to this, we find that wage employment in the agro-industry is accessible for resource-poor and less educated households, indicating that rural off-farm employment creation might be an important poverty-alleviation strategy.

Moreover, the case-study documented in this paper shows that pro-poor globalization is possible, even in poor SSA countries, despite the many constraints. This case-study on Senegalese tomato 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.

Finally, it needs to be mentioned that the benefits from (foreign) investments in the horticulture sector and expanded horticultural exports from Senegal are concentrated in some regions and not yet shared equally all over the country. Yet, our results indicate that there is scope for ongoing investments in other regions of the country to result in expanded poverty-alleviating impacts.

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Tables

Table 1. Comparison of household characteristics

	Total sample	Household with members employed in the tomato export industry	Households without members employed in the tomato export industry	t - Statistic
Number of households	299	171	128	
Human and social capital				
Household size	13.4	18.1	10.5	7.42***
Age of the household head	56	59	54	3.30***
Labor	6.6	9.3	4.8	7.81***
Dependency ratio[a]	0.511	0.484	0.528	-1.90*
Female headed households	3.8 %	5.5 %	2.7 %	1.07
Elementary education[b]	26.7 %	24.3 %	28.3 %	-0.66
Ethnicity (non-Wolof)[c]	54.6 %	50.4 %	57.3 %	-1.06
Membership of an organization[d]	49.9 %	53.4 %	47.6 %	0.90
Initial per capita assets [d, e]				
Landholdings (ha)	0.18	0.13	0.20	-1.72*
Livestock units[f]	0.79	0.68	0.86	-0.98
Non-land assets[g] (1,000 FCFA)	15.5	12.7	17.4	-0.61
Consumer durables[h] (1,000 FCFA)	21.9	17.8	24.5	-0.68

Characteristics of employed households are compared to those of other households using *t*-test. Significant differences are indicated with * : p < .1; ** : p < .05; *** : p < .01

[a] Dependency ratio is calculated as the number of dependents (children below the age of 17, and those unable to work) over the total household size.
[b] Household head has at least elementary education.
[c] Non-Wolof households refer to ethnic minorities in Senegal.
[d] Organization membership and initial assets are indicated for the year 2001, i.e. before the entry of GDS. These data are based on recall questions.
[e] Initial assets are expressed in *per capita* terms, using the modified OECD adult equivalence scales.
[f] One livestock unit equals 1 cow/horse/camel, 0.8 donkey, 0.2 sheep/goat/pork.
[g] Non-land productive assets include all equipment and machinery for farming as well as non-farm businesses.
[h] Consumer durables include furniture, vehicles and durable household equipment.

Table 2. First stage probit estimation: probability of selection into treatment

Covariates	Description of covariates	Model A	Model B
Treatment: employment in the tomato export industry			
Labor	Household labor endowment	0.14***	0.15**
Land	Initial per capita landholdings	-0.73**	-0.66**
Livestock	Initial per capita livestock holdings	-0.03	
Other assets	Initial per capita non-land assets[a]	0.81	
Age	Age of the household head	0.01	
Education	Household head with at least elementary education	-0.02	
Ethnicity	Non-Wolof household	0.11	
Organization	Initial organization membership	0.10	
Road	Village situated along paved road	0.88**	0.92***
Population	Village population (1,000 inhabitants)	0.79*	0.71***
Population²	Village population²	-0.298***	-0.207***
R^2		0.302	0.291
Chi-square		107.43***	92.81***

* : p ≤ .1; ** : p ≤ .05; *** : p ≤ .001

[a] Initial assets variables are for 2001, based on recall data.
[b] P*er capita* figures are calculated using the modified OECD adult equivalence scales.
[c] Non-land assets include non-land productive assets (equipment and machinery for farm and non-farm business) and consumer durables.

Table 3. Estimation of income effects.

Y = total household income	OLS regression	Two stage IV estimation		Propensity score matching			
				Nearest neighbor matching		Kernel matching	
	Model 1	Model 2		Model 3		Model 4	
		A	B	A	B	A	B
Employed in tomato export industry	0.69***	1.08***	1.09***	0.61***	0.73***	0.66***	0.63***
Labor	0.14***	0.11***	0.11***				
$Labor^2$	-0.00***	-0.00***	-0.00***				
Farm size	0.30***	0.30***	0.30***				
Livestock	-0.01	0.00	0.00				
Nonland assets	0.33***	0.35***	0.35***				
Age	-0.01	-0.01	-0.01				
Education	0.25	0.24	0.24				
Ethnicity	0.32***	0.32**	0.33***				
Distance	-0.09***	-0.08**	-0.08***				
$Distance^2$	0.00	0.00	0.00				
Constant	1.92***	1.90***	1.81***				
R^2	0.399						
F-test	12.98***	12.32***	12.54***				

* : $p \leq .1$; ** : $p \leq .05$; *** : $p \leq .001$

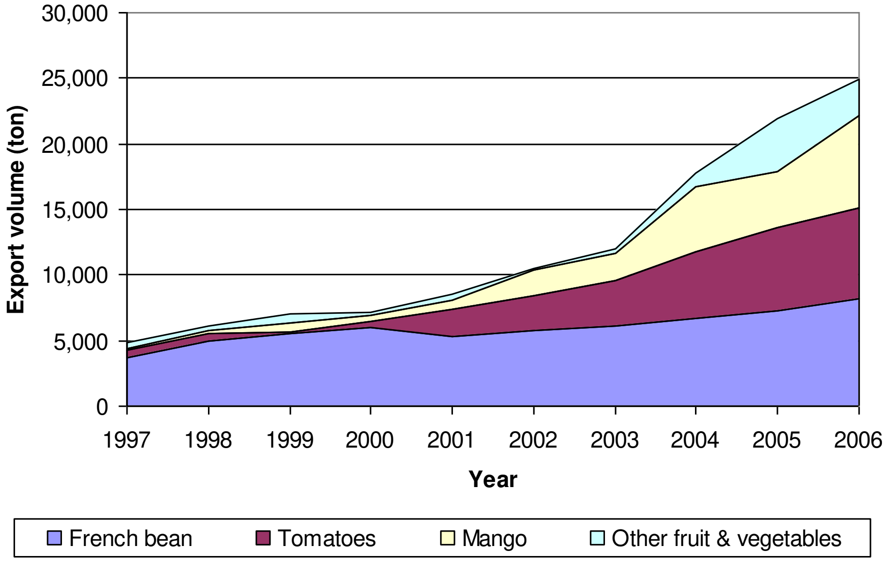
Total household income and value of nonland assets are measured in million FCFA.

Specification A refers to the use of model A in the first stage of IV or propensity score estimation (including Labor, Land, Livestock, Other assets, Age, Education, Ethnicity, Organization, Road, Population, $Population^2$ as covariates, see Table 2).

Specification B refers to the use of model B in the first stage of IV or propensity score estimation (including Labor, Land, Age, Education, Road, Population, $Population^2$ as covariates, see Table 2).

Figures

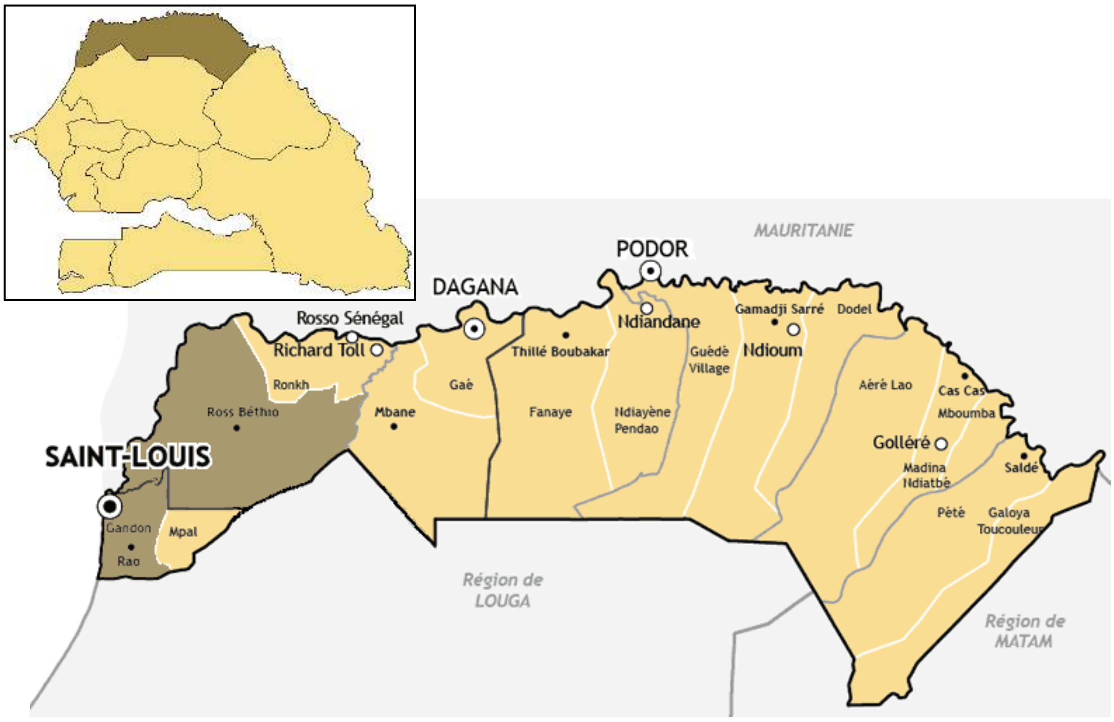
Figure 1. Horticulture exports (ton) from Senegal, 1997 – 2006.



Source: Eurotrans – Senegal

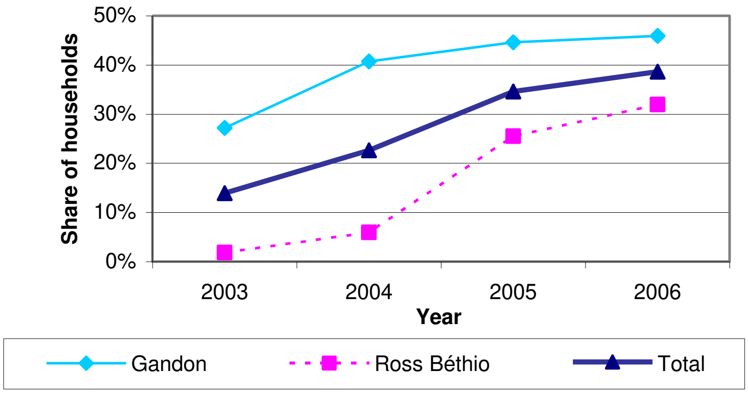
Figure 2. Research area: Rural communities Gandon and Ross Béthio selected for household survey.

Senegal – Saint-Louis



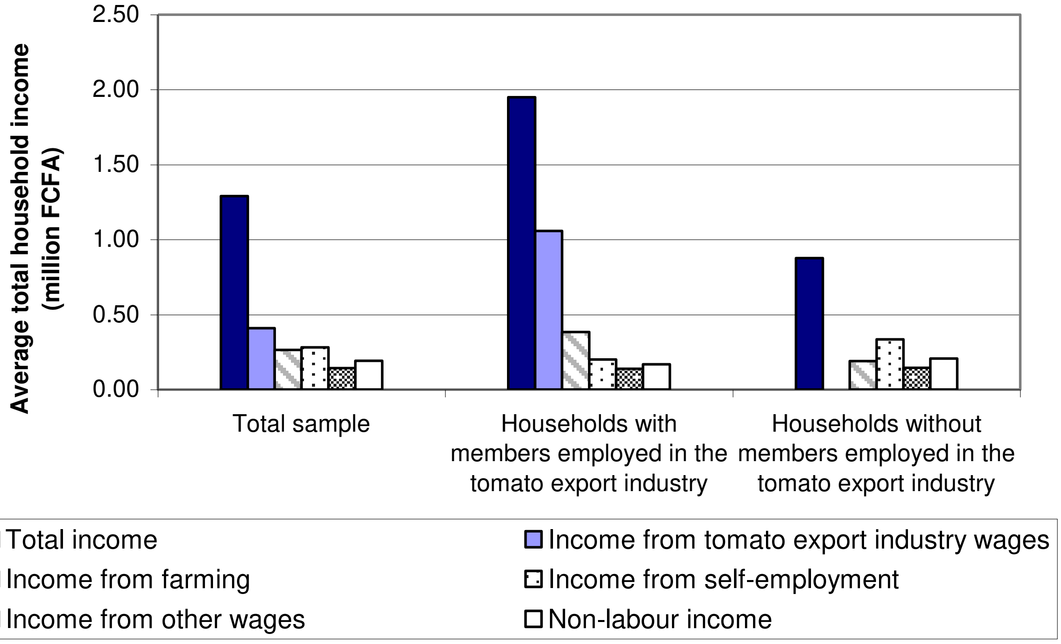
Source: IRD Cartographie

Figure 3. Household employment in tomato export industry, 2003-2006.



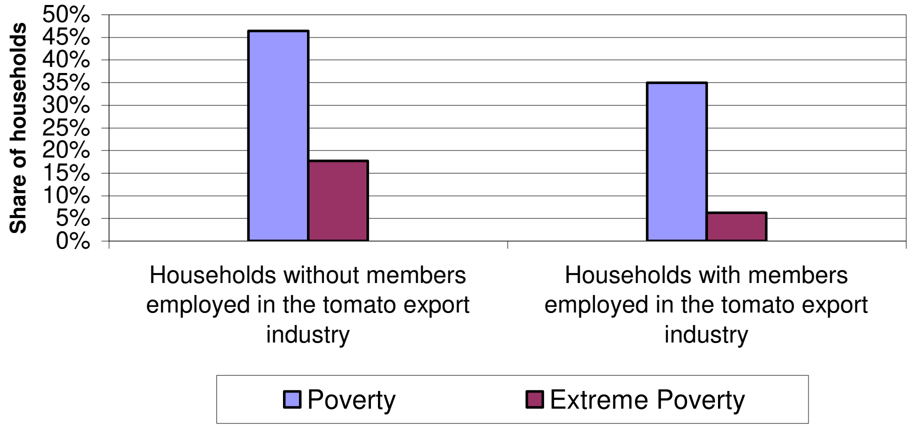
Employed households are households with one or several members working as an employee in the tomato export industry. Based on household survey recall data collected in 2006.

Figure 4. Comparison of income from different sources across households.



The household *total income* is yearly income calculated for the 12 month period prior to the survey, February 2005-06. *Income from tomato export industry wages* is the wage income from employment of household members in the tomato export industry. *Farm income* is calculated taking into account total production (valued at market prices) in three different seasons ("contre-saison chaude" 2005, "hivernage" 2005, and "contre-saison froide" 2005-06), the cost of variable inputs, cost of hired labor, and the depreciation of machinery and equipment. *Income from self-employment* is income derived from small business or trading activities, taking into account costs of inputs and depreciation of machinery and equipment. *Income from other wages* are wages resulting from employment in agricultural or non-agricultural activities, different from the tomato export industry. *Non-labor income* results mainly from remittances and public transfers.

Figure 5. Comparison of poverty levels across households.



Poverty and *Extreme Poverty* indicate the share of households living with per capita incomes below a poverty line of 143,080 FCFA for poverty and 31,812 FCFA for extreme poverty.

These poverty lines are calculated from the ESAM I and II surveys in 1994 and 2000 (République du Sénégal, 2004), and are updated to the period of our survey (2005-2006) using consumer price indices (African Development Bank, 2006).

Annexes

Annex 1. Balancing properties of covariates in treated and control groups for nearest neighbor matching on propensity scores (model 3 - A and B).

Covariates	Sample	Mean treated units	Mean control units	% Bias between treated and controls	% Reduction in bias	t-Test Mean(treated) = Mean(Control)	
						t	Prob > t
Model 3-A							
Labor	Unmatched	9.462	5.000	79.5		6.50	0.000
	Matched	9.462	6.476	53.2	33.1	0.29	0.774
Land	Unmatched	0.159	0.242	-22.2		-2.01	0.045
	Matched	0.159	0.195	-9.7	56.2	-0.34	0.731
Livestock	Unmatched	0.756	1.034	-15.6		-1.33	0.184
	Matched	0.756	0.690	3.7	76.3	0.75	0.457
Other assets	Unmatched	0.031	0.041	-11.4		-0.99	0.322
	Matched	0.031	0.032	-1.5	87.0	-0.70	0.482
Age	Unmatched	58.825	53.227	46.8		3.99	0.000
	Matched	58.825	57.184	13.7	70.7	-0.19	0.846
Education	Unmatched	0.205	0.211	-1.5		-0.13	0.895
	Matched	0.205	0.126	19.3	-1153.6	1.50	0.135
Ethnicity	Unmatched	0.474	0.633	-32.3		-2.76	0.006
	Matched	0.474	0.553	-16.2	49.9	-1.11	0.267
Organization	Unmatched	0.556	0.461	18.9		1.62	0.106
	Matched	0.556	0.612	-11.2	40.7	-1.40	0.162
Road	Unmatched	0.860	0.758	26.0		2.26	0.025
	Matched	0.860	0.922	-16.0	38.4	-1.15	0.252
Population	Unmatched	908.46	1063.4	-16.3		-1.45	0.147
	Matched	908.46	786.25	12.9	21.1	0.97	0.335
Population²	Unmatched	1.2e+06	2.5e+06	-31.6		-2.84	0.005
	Matched	1.2e+06	1.1e+06	2.0	93.4	0.25	0.805
Model 3-B							
Labor	Unmatched	9.462	5.000	79.5		6.50	0.000
	Matched	9.462	7.178	40.7	48.8	0.47	0.642
Land	Unmatched	0.159	0.242	-22.2		-2.01	0.045
	Matched	0.159	0.201	-11.2	49.4	-0.87	0.385
Road	Unmatched	0.860	0.758	26.0		2.26	0.025
	Matched	0.860	0.915	-14.1	45.9	-1.38	0.169
Population	Unmatched	908.46	1063.4	-16.3		-1.45	0.147
	Matched	908.46	969.92	-6.4	61.0	-0.81	0.418
Population²	Unmatched	1.2e+06	2.5e+06	-31.6		-2.84	0.005
	Matched	1.2e+06	1.4e+06	-4.1	87.0	-0.55	0.581

* : p < .1; ** : p < .05; *** : p < .001

Annex 2. Balancing properties of covariates in treated and control groups for Kernel matching on propensity scores (model 4 - A and B).

Covariates	Sample	Mean treated units	Mean control units	% Bias between treated and controls	% Reduction in bias	t-Test Mean(treated) = Mean(Control) t	Prob > t
Model 4-A							
Labor	Unmatched	9.462	5.000	79.5		6.50	0.000
	Matched	9.462	7.717	31.1	60.9	0.46	0.649
Land	Unmatched	0.159	0.242	-22.2		-2.01	0.045
	Matched	0.159	0.150	2.3	89.8	0.41	0.682
Livestock	Unmatched	0.756	1.034	-15.6		-1.33	0.184
	Matched	0.756	0.715	23	85.3	0.22	0.827
Other assets	Unmatched	0.031	0.041	-11.4		-0.99	0.322
	Matched	0.031	0.021	9.8	14.3	1.00	0.316
Age	Unmatched	58.825	53.227	46.8		3.99	0.000
	Matched	58.825	57.286	12.9	62.8	0.67	0.505
Education	Unmatched	0.205	0.211	-1.5		-0.13	0.895
	Matched	0.205	0.185	4.9	72.5	0.89	0.375
Ethnicity	Unmatched	0.474	0.633	-32.3		-2.76	0.006
	Matched	0.474	0.455	3.7	-217.9	-0.18	0.857
Organization	Unmatched	0.556	0.461	18.9		1.62	0.106
	Matched	0.556	0.591	-7.0	88.5	-0.18	0.858
Road	Unmatched	0.860	0.758	26.0		2.26	0.025
	Matched	0.860	0.897	-9.6	62.9	-0.38	0.702
Population	Unmatched	908.46	1063.4	-16.3		-1.45	0.147
	Matched	908.46	847.97	6.4	61.0	1.12	0.264
Population²	Unmatched	1.2e+06	2.5e+06	-31.6		-2.84	0.005
	Matched	1.2e+06	1.0e+06	5.5	82.5	1.18	0.240
Model 4-B							
Labor	Unmatched	9.462	5.000	79.5		6.50	0.000
	Matched	9.462	8.449	18.1	77.3	-0.06	0.949
Land	Unmatched	0.159	0.242	-22.2		-2.01	0.045
	Matched	0.159	0.163	-1.2	94.7	-0.19	0.853
Road	Unmatched	0.860	0.758	26.0		2.26	0.025
	Matched	0.860	0.855	1.3	95.0	0.79	0.429
Population	Unmatched	908.46	1063	-16.3		-1.45	0.147
	Matched	908.46	837.13	7.5	54.0	1.31	0.190
Population²	Unmatched	1.2e+06	2.5e+06	-31.6		-2.84	0.005
	Matched	1.2e+06	1.0e+06	5.6	82.2	1.14	0.256

* : p < .1; ** : p < .05; *** : p < .001

Annex 3. Simulation-based sensitivity analysis for robustness to failure of the conditional independence assumption in propensity score matching techniques

	Estimated treatment effect	Outcome effect[a]	Selection effect[b]
Nearest neighbor matching			
Baseline propensity score matching estimator (Model 3 A)	0.607		
Matching estimators with simulated binary confounder			
Neutral confounder	0.607	1.317	1.029
Confounder calibrated to mimic Ethnicity	0.597	1.263	0.429
Confounder calibrated to mimic Road	0.732	0.207	2.411
Confounder calibrated to mimic Education	0.606	2.585	0.941
Confounder calibrated to mimic Organization	0.602	0.829	1.540
Baseline propensity score matching estimator (Model 3 B)	0.729		
Matching estimators with simulated binary confounder			
Neutral confounder	0.717	1.138	1.049
Confounder calibrated to mimic Road	0.726	0.236	2.430
Kernel matching			
Baseline propensity score matching estimator (Model 4 A)	0.664		
Matching estimators with simulated binary confounder			
Neutral confounder	0.572	1.258	1.061
Confounder calibrated to mimic Ethnicity	0.613	1.213	0.457
Confounder calibrated to mimic Road	0.711	0.232	2.506
Confounder calibrated to mimic Education	0.609	2.528	1.005
Confounder calibrated to mimic Organization	0.595	0.921	1.552
Baseline propensity score matching estimator (Model 4 B)	0.634		
Matching estimators with simulated binary confounder			
Neutral confounder	0.718	1.224	1.062
Confounder calibrated to mimic Road	0.762	0.230	2.357

The method is described by Ichino et al. (2006) and builds on Rosenbaum and Rubin (1983). 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 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).

[a] The outcome effect measures the estimated effect of the simulated binary confounder on the outcome variable: household income.
[b] The selection effect measures the estimated effect of the simulated binary confounder on the selection into treatment: employment in the tomato export industry.