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Essays on agricultural productivity and intrahousehold dynamics in the Philippines

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Essays on agricultural productivity and intrahousehold dynamics in the Philippines

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La rédaction d'une thèse de doctorat est généralement considérée comme une entreprise solitaire, et dans une certaine mesure, c'est certainement le cas. Cependant, tout comme l'arbre ne peut pousser sans un sol accueillant, de la lumière et de l'eau, cette thèse n'aurait pas été possible sans l'expertise et le soutien des nombreuses personnes qui m'ont accompagné au cours des six dernières années.

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Deux des trois chapitres de cette thèse utilisent des données de ménage recueillies dans la vallée du Pulangi supérieur aux Philippines. Ce travail de terrain faisait partie du projet de recherche LUCID, piloté par Stéphane Leyens et a largement bénéficié du soutien logistique de Environmental Science for Social Change (ESSC) dont je remercie le staff, et plus particulièrement Pedro Walpole et Alberto Marin. La réussite de cette enquête – et de cette thèse – doit énormément à Andres Ignacio, également de ESSC. Lister toutes ses contributions serait impossible tant son rôle a été central et polyvalent. Je le remercie pour m'avoir partagé ses données, pour son rôle de facilitateur et de traducteur dans les premières phases du projet et pour avoir servi de pont entre mon monde et celui de la vallée du Pulangi. Mon initiation à la culture philippine lui doit beaucoup, de la séance de karaoké à la dégustation du balut – cet œuf de canard cuit dur contenant un fœtus couvé pendant 18 jours. C'est également grâce à lui que j'ai eu accès aux données de recensement agricole utilisées dans le deuxième chapitre de ma thèse.

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Naviguer les aspects administratifs de la thèse peut se révéler un véritable challenge. Heureusement, j'ai pu me reposer sur la compétence et le dévouement de Pierrette Noël, la secrétaire du département, sans qui beaucoup seraient perdus. Merci aussi à Pierre-Alexandre Sacré et Fabrice Orbant d'avoir pris soin de mes ordinateurs et pour leur disponibilité. Et parce que l'université va au-delà de la faculté d'économie, je tiens à remercier les membres du Groupe Université en Transition d'avoir remis en question mes certitudes et élargi ma compréhension des enjeux les plus urgents de notre société.

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AVANT-PROPOS

Une fois terminée, une thèse peut paraître découler d'une longue ligne droite. Les questions de recherche semblent avoir toujours été là, les données et les méthodes utilisées pour y répondre paraissent évidentes et les résultats, une fois interprétés et contextualisés, peuvent sembler logiques et évidents. En vérité, le processus de création d'une thèse s'apparente plus à un chemin de montagne avec ses virages, ses incertitudes, ses moments où on a l'impression de revenir sur nos pas, ses embranchements qui disparaissent dans la nature... Certains moments d'apparence insignifiants peuvent se révéler décisifs plusieurs années plus tard. Dans le cas de cette thèse, un de ces évènements s'est déroulé en janvier 2017. Cela faisait un an que je travaillais à l'Université de Namur, donnant des séances de travaux pratiques et suivant des cours doctoraux. Mes travaux de recherches devaient porter sur la gestion communautaire des forêts au Népal, mais la collection de données mettait du temps à se préparer. Durant une discussion avec mon promoteur, Jean-Marie Baland, il m'a invité à l'accompagner sur un voyage de terrain aux Philippines. Il s'agissait d'un voyage d'exploration dans le but de lancer un projet de recherche sur les impacts socio-économiques de la culture du maïs OGM dans une zone reculée de l'île de Mindanao. A l'origine, ce projet devait être réalisé par une autre doctorante qui avait récemment décidé de donner une autre direction à sa vie professionnelle. Nous accompagneraient notre collègue, Catherine Guirkinger, ainsi que Clarice Manuel, une étudiante Philippine qui allait bientôt débuter sa thèse à Namur.

C'est ainsi que je me suis retrouvé, après plus de 24 heures de voyage, dans le village de Bendum, perché dans les montagnes Pantaron en bordure d'une des dernières forêts primaires des Philippines, village qui allait rapidement devenir central pour ma thèse de doctorat. J'y fis la connaissance de Pedro Walpole, un père jésuite installé dans la région depuis plus de vingt ans, fondateur d'une école et directeur de l'institut ESSC (Environmental Science for Social Change). Il nous expliqua les profonds changements qu'a connu la région au cours des dernières décennies, entrainant une remise en question radicale du mode de vie ses habitants historiques, les Lumads. En l'espace de quelques décennies à peine, ceux-ci sont passés d'une existence semi-nomade en quasi-autarcie à la pratique de l'agriculture moderne et à la vie sédentaire. L'arrivée de semences de maïs génétiquement modifiées, au début des années 2000, vint renforcer l'expansion inexorable de la logique de marché dans la production agricole, érodant un peu plus leurs coutumes et pratiques ancestrales. De plus, l'arrivée des OGM augmenta la financiarisation de l'agriculture, la plupart des fermiers n'ayant pas les fonds nécessaires pour acheter les intrants plus couteux. De nombreuses histoires circulaient de fermiers perdant accès à leur terre au profit de leur débiteur suite à une mauvaise récolte, laissant présager une augmentation des inégalités et de la pauvreté.

Avant de préparer l'enquête proprement dite, il nous fallait d'abord nous familiariser avec le contexte et les pratiques agricoles locales. Durant les 5 jours suivants, nous nous sommes donc rendus dans différents villages de la vallée et avons discuté avec plusieurs cultivateurs de maïs, en compagnie de notre guide et traducteur Andres. C'est au cours de ces journées que furent plantées les graines qui devaient donner, 5 ans plus tard, cette thèse de doctorat. Au cours de nos déplacements, nous avons été frappés par le nombre de glissements de terrain qui étaient visibles dans le paysage. Selon nos interlocuteurs, ce phénomène naturel s'était fortement renforcé au cours des dernières années. Nous avons donc décidé d'inclure des questions sur les glissements de terrain dans notre enquête, ce qui a permis la rédaction du premier chapitre de ma thèse, *Biotech Crops, Input Use and Landslides - Case Study of Herbicide Tolerant Corn in the Philippine Highlands*. La question de la confiscation des terres par les financiers m'a amené à m'intéresser à la distribution des terres agricoles et est à l'origine du deuxième chapitre, *Agricultural productivity and land inequality - Evidence from the Philippines*.

Finalement, lors de nos entretiens avec les cultivateurs, nous avons été frappés du rôle occupé par les femmes dans les discussions. Les Philippines sont connues pour être un pays où les femmes sont relativement émancipées, en témoigne leur haut taux de migration internationale, activité réservée aux hommes dans de nombreux autres pays. Si l'activité agricole est généralement le domaine des hommes, ce sont les femmes qui gèrent les finances du ménage. A plusieurs reprises dans nos discussions, lorsque le sujet passait des pratiques agricoles vers les aspects financiers, les hommes arrêtaient de parler et leur femme prenait le relais. L'une d'entre elle nous a même dit, devant son mari, que si elle ne gérait pas leur argent, il dépenserait tout en alcool et cigarettes... Un tel niveau de franchise et d'émancipation nous a surpris, mes collègues étant plus habitués à travailler dans des contextes où l'épouse n'a que peu de poids dans les décisions du ménage. Nous avons donc décidé d'agrémenter notre enquête d'un lab-in-the-field, une série de jeux de rôle dans lesquels les répondants doivent prendre une série de décisions financières. Les résultats quelque peu surprenants de ces jeux sont analysés dans le troisième et dernier chapitre de cette thèse, *Sharing norm, household efficiency and female demand for agency in the Philippines*.

C'est ainsi qu'en l'espace de quelques jours, le focus de ma thèse s'est déplacé des forêts népalaises aux collines philippines. J'ai commencé à me renseigner sur la question des organismes génétiquement modifiés, sur laquelle je ne connaissais pas grand-chose et dont le peu de connaissances que j'avais s'est révélé parfois inexact. Je suis encore retourné trois fois à Bendum, une première pour réaliser davantage d'entretiens individuels et de focus groups, une deuxième pour tester la version préliminaire de notre questionnaire d'enquête et finalement une dernière fois pour former les enquêteurs et superviser la collecte de données. Au cours de ces voyages de terrain, j'ai eu la chance de discuter avec de nombreux acteurs du marché agricole mais aussi de m'immerger dans la culture locale. J'ai été très touché par l'accueil chaleureux que j'ai reçu partout où j'allais, ainsi que par celui qui a été réservé à ma famille lorsqu'elle m'a accompagné durant le dernier voyage. La bonté et la maturité de nos enquêteurs, malgré leur jeune âge, n'ont eu de cesse de m'impressionner et superviser leur équipe reste une expérience qui m'a profondément marqué tant au niveau professionnel qu'au niveau personnel et humain.

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Introduction

How can we guarantee access to sufficient quality food for a growing population given the inherent physical and environmental limits of our world? As income growth is transforming eating patterns around the world and the global population is predicted to reach almost 10 billion people by 2050, the demand for food is expected to increase in the coming decades. In order to meet this increasing demand, the FAO (2018) projects that the gross agricultural output will have to increase by 40-50% between 2012 and 2050. In a world where more than 70% of the available land is already exploited by humans (IPCC, 2019), the potential for further agricultural land expansion appears limited. Instead, producing more food will require an increase in the amount of food produced per unit of land - also known as farmland productivity or crop yields.

In the past two centuries, the yields of most agricultural commodities have already been multiplied several times thanks to the introduction of new agricultural practices, machinery and inputs. Since the 1960s, the global cultivated area has not changed much, while the total food production has more than tripled. Concurrently, 9% of the world population still lives below the absolute poverty line of USD 1.9 a day (World Bank, 2020), 65% of which are employed in the agricultural sector (Castañeda et al., 2016). Similarly, an estimated 2 billion people - over 30% of the world population - lacked regular access to safe, nutritious and sufficient food in 2019 (FAO, 2021). Making sure that the gains realized in agricultural production are fairly distributed and benefit the poorest categories of the population therefore appears as a moral imperative and a key step towards the achievements of the Sustainable Development Goals.

Moreover, this agricultural intensification, has been a key driver of many environmental problems, including ground water depeletion for irrigation (Rodell et al., 2009; Scanlon et al., 2012), run-off contamination (NSTC, 2000; Rabalais et al., 2007), biodiversity loss (Beketov et al., 2013; Gibbs et al., 2009; Relyea, 2005), soil degradation (FAO, 2015) and adverse effects on human and fetal health (Brainerd and Menon, 2014; Dias et al., 2019; Maertens, 2017). Ensuring the sustainability of our agricultural systems is however of utmost importance if we want these productivity gains to persist in the long run.

This calls for an absolute decoupling between agricultural production and natural resource use, i.e. an increase in production concurrent with a decrease in environmental impact. One promising avenue towards this decoupling is the development and deployment of new technologies, such as improved crop varieties. These have already proven extremely successful as they account for 50% of yield gains in major cereals between 1980 and 2000 (Evenson and Gollin, 2003). For thousands of years, breeders have improved their seeds using cross-breeding techniques. The major limit of this practice is its reliance on the existing genetic variability within a particular species. This constraint was however lifted in the 1990s as advances in the understanding of plant genomes allowed the isolation of specific genes and their transfer between organisms of different species, creating many opportunities for crop improvement. It also made crop breeding much more trageted and precise compared to previous techniques, such as induced mutations.

As defined by Qaim (2016), a genetically modified crop is therefore "*a plant used for agricultural purposes into which one or several genes coding for desirable traits have been inserted through genetic engineering.*". GM crops started being commercialized in the second half of the 1990s and have been largely adopted in North and South America and in several Asian countries. According to the ISAAA (2019), GM crops were grown on 190 million ha in 2019 - 12.7% of the world crop area -, soybeans and maize accounting for over 80% of that area.

Despite all their promises and their fast adoption, GM crops remain highly controversial, as illustrated by the ban on the technology voted by many European countries including France and Germany. The reasons invoked to oppose GMOs are diverse and include ethical concerns surrounding genome editing and patenting of life, health risk from eating modified food, threats to ecosystems integrity, market power of agribusiness corporations and adverse social justice implications. Indeed, GM crops are developed by large corporations which are unlikely to take into account the needs of smallholder farmers in developing countries in their research and development decisions. As a result, existing GM varieties are more likely to be tailored to large farmers, thereby increasing existing inequality and further marginalizing poor farmers (Qaim, 2016).

This thesis focuses on the case of genetically modified corn in the Philippines, which was approved in 2003. The first generation of GM corn was pest resistant thanks to the added *Bt* trait. Originally from a bacteria called Bacillus thuringiensis, this trait allows the plant to produce insecticidal proteins, thereby protecting it against corn borer infestation, the most common pest in the Philippines. In 2006, new varieties with herbicide tolerance (*Ht*) were commercialized, along with stacked *Bt/Ht* varieties, which soon became dominant. Herbicide tolerance allows spraying glyphosate herbicide on the field during the growing season without harming the plant. This induces a strong reduction in manual weeding and in the resulting labor costs.

The first and second chapters of this thesis respectively investigate the impact of GM corn adoption on environmental degradation - the incidence of landslides - and on land inequality. The third and final chapter is not directly linked to agriculture but studies intra-household dynamics using experimental data collected from farming couples. Most microeconomic models use the household as the unit of analysis, an approach known as the unitary model. For example, in their literature survey on agricultural technology adoption, Foster and Rosenzweig (2010) always consider the *farmer's* decision whereas in many settings, it is really a *household* decision. This approach overlooks the fact that households are composed of several individuals, which may not have the same tastes and preferences and that observed decisions are the result of complex interactions between them. For example, an extensive literature has documented the fact that income increases are spent differently, depending on the recipient's gender (Armand et al., 2020; Attanasio and Lechene, 2010; Duflo, 2003). The main alternative model, the collective model, rests on the assumption that households are efficient (Chiappori, 1992), an assumption that has also been challenged. In line with this literature, the third chapter of this thesis documents a high level of inefficiency among couples in the Philippines and discusses potential explanations.

While the second chapter is based on secondary data sources, the first and third chapters rely on original household data collected in 14 villages on the island of Mindanao (South), in a region known as the Upper Pulangi valley. This data collection effort was part of the LUCID research project, funded by ARES - the Belgian federation of French-speaking universities - in partnership with Environmental Science for Socal Change (ESSC). This interdisciplinary project aimed to study the social justice implications of land use change in the uplands and included economists, philosophers and geomatics experts. In order to set the stage and give the reader an insight on the context that allowed this thesis to emerge, I will first give some general background information regarding the area and our sampling population before briefly summarizing each chapter.

The Upper Pulangi valley is located in the center of Mindanao, in the province of Bukidnon. It contains the headwaters of the Pulangi River, which is part of the largest river system of the island. Until the 1960s, the region was entirely forested and home to a few semi-nomadic indigenous tribes practicing swidden agriculture. As logging companies entered the area, they built roads which were then used by migrants from the center of the Philippines. They cleared the rest of the forest and introduced sedentary agriculture to the region. Nowadays, the population is almost equally divided between indigenous (mostly Lumads) and migrants and their descendants. The valley is situated in the Pantaron range, the Central Cordillera of Mindanao. Because of the rugged nature of the terrain, infrastructures are very poor, the first sealed road only opening a few years before our data collection and many areas still lacking cell phone signal. The poverty rate in the region is high, with 79% of the population living below the national threshold of around USD 1.4 per day and per person. Taking advantage of the weak presence of the state, communist guerilla groups from the New People's Army (NPA) have been able to settle in the forests surrounding the valley. The resentment caused by the high level of poverty makes the area a fertile ground for recruitment. Extortion attempts and armed encounters with the police or the army are not uncommon.

The main economic activity in the Upper Pulangi is agriculture, especially corn farming as this crop can be grown on slopy terrain. Rice is also grown in the flat areas close to the river and other crops include rubber, ginger, sweet potatoes, hemp and vegetables. There are two main corn varieties: white and yellow corn. White corn is traditionally cultivated by smallholder farmers, mostly for the purpose of self-consumption. Pounded corn is indeed the staple food of poor farmers as it constitute a cheaper alternative to rice. Yellow corn, on the other hand, is rarely consumed by humans and is sold to feeding mills, to cater for the booming livestock and poultry industries. Nowadays, all the yellow corn cultivated in the area is GM. While there is no white GM corn, most farmers grow a variety known as *sige-sige*, which exhibits herbicide tolerance. This variety is the result of cross-breeding between GM seeds and local varieties, although its exact origin remains shrouded in mistery. Qualitative interviews conducted both by myself and by De Jonge et al. (2021) converge to say that it was first developed in southern Mindanao around 2005-10 before spreading to the rest of the island and the Visayas. The herbicide tolerance trait appears to be stable across generation, which allows farmers to replant seeds from year to year. However, compared to real GMO, the herbicide tolerance of sige-sige is not 100%, which implies that 5-10% of plants are lost when sprayed with glyphosate. These seeds are however much cheaper and are sold directly from farmer to farmer in an underground market. Yellow sige-sige varieties also exist but are not very popular in the Upper Pulangi region.

The primary prupose of the economists in the LUCID project was to study the profitability of GM corn, the distribution of the profit along the value chain and the social justice impact of the financing system in place. Indeed, although GM seeds are more productive, they are also more expensive compared to alternative varieties such as *sige-sige*. In order to make up for this price, farmers tend to use more fertilizer, further increasing the total cost of production. Formal financial institutions have a weak presence in the area and farmers generally borrow from informal financers to finance their activity. These financers are usually better-off farmers with a large landholding. The interest rates are high, between 5-10% per month. They are however only calculated over the 4-month cropping season, and do not compound in case of default. Land-pawning agreements - *prenda* - are common and anecdotal evidence suggests that defaulters are sometimes forced to pawn their land to their financer until full repayment of the debt. As a result, some financers end up with large amounts of land while indebted farmers lose their livelihoods and have to work as laborers.

Despite the anecdotal evidence, such a practice does not appear to be the norm. Indeed, in the data we collected from 448 households, only 7% of defaults result in *prenda* and these cases represent a small fraction - 14% - of all the *prendas*. Manuel (2022) uses this data to analyize the relative profitability of GM and *sige-sige* corn varieties. GM corn is almost twice as productive, which leads to higher revenue. However, input and processing costs are also much larger, leading to a small difference in overall profitability and to a 50% increase in the probability of experiencing a financial loss. While more profitable, GM corn therefore appears riskier, at least in the particular context of the Upper Pulangi region.

The **first chapter**, *Biotech Crops, Input Use and Landslides, Case Study of Herbicide Tolerant Corn in the Philippine Highlands*, documents an increased likelihood of landslides on plots planted with GM corn, further increasing the risk associated with this variety. This result is based on recall data covering ten years and obtained thanks to an original survey method. Over the period, 35% of plots have been hit at least once by a landslide. Surprisingly, the probability of experiencing a landslide in a given year is 4 percentage points higher on plots planted in GM corn compared to alternative corn varieties. Contrary to our initial belief, this difference is not explained by differences in plot characteristics - e.g. GM corn being cultivated on steeper plots. Indeed, when controlling for plot fixed effects, the landslide probability is 6.3 percentage points higher with GM than non-GM corn. This increase is similar in magnitude to that observed between other crops and non-GM corn. I find evidence that heavy herbicide users are more likely to be affected by landslides and that herbicide is used more intensively when GM corn is cultivated. This suggests that the increased probability of landslides is driven by the heavier use of herbicide, which destroys all plant cover and leaves the soil unprotected against heavy rains.

The **second chapter**, *Agricultural productivity and land inequality, Evidence from the Philippines*, studies how the introduction of GM corn impacted the landholding inequality in the country. Although this question was at the heart of the LUCID project, the data collected in the Upper Pulangi only covered a small geographical area and excluded large farmers, making it inadequate to address it. Instead, I use three waves of the Census of Agriculture and Fisheries (CAF) covering the period 1991-2012. Thanks to the extensive coverage, I was able to study the evolution of landholding inequality at the level of the municipality, something that had never been done before in the economic literature over an entire country. Results show an increase in inequality following the introduction of GM corn in 2003. Such a temporal correlation, however, does not indicate that GM corn are responsible for this increase as it may have been caused by many other factors. In order to identify a causal effect, I use exogenous variations in local soil and weather, creating differences in the impact of the new technology. I therefore compare the evolution of landholding inequality between municipalities that largely benefited from the new technology and those where yields only marginally increased. This approach allows me to address the question without observing actual adoption and having to deal with the endogeneity of this adoption - an increase in inequality being possibly a cause and a consequence of GM corn adoption. Results show that landholding inequality increased more in municipalities that benefited more from the new technology, an effect driven by the last decile of the distribution. Furthermore, while land inequality, is not associated with any adverse effect on a range of socio-economic indicators, it is positively correlated with terrorist activity.

Finally, the **last chapter**, *Sharing norm, household efficiency and female demand for agency in the Philippines*, co-authored with Jean-Marie Baland, Catherine Guirkinger and Clarice Manuel, studies intra-household dynamics among couples who responded to the LUCID survey. It is based on the striking observation, during the early phases of the project, that women in the Philippines enjoy a high level of empowerment within the household. They are generally in charge of the money and expect their husband to hand over all his earnings, giving him some pocket money for his daily expenses. Furthermore, other institutional features including the stability of unions makes this setting ideal for efficient cooperation between spouses. We run a lab-in-the-field experiment, playing variations of the Dictator and Trust Games between couples and document a large level of inefficiency in their decisions. Couples leave on average 46% of potential earnings on the table and women are particularly inefficient. Lack of trust can only explain a small proportion of this inefficiency. Instead, we argue that this reveals a strong, latent demand for agency by women who express a strong preference for hidden money over (larger) transfers from their husband as the latter involve an implicit control over their use. These findings challenge a naive view of female empowerment that solely focuses on the apparent control over household resources.

CHAPTER 1

BIOTECH CROPS, INPUT USE AND LANDSLIDES: CASE STUDY OF HERBICIDE TOLERANT CORN IN THE PHILIPPINE HIGHLANDS

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Abstract: Improved seeds varieties have led to an increase in agricultural production as well as to a change in agricultural practices and input use. While some of these new practices can be more environmentally sustainable, others may lead to a higher level of environmental degradation. In a case study using an original survey method of farming households on the Philippine island of Mindanao covering the past ten years, this paper finds a very robust positive correlation between herbicide tolerant corn cultivation and landslide occurrence. This effect is robust to the inclusion of plot fixed effect, indicating that physical characteristics of the farm do not explain the results. Instead, more aggressive weed control via broad-spectrum herbicide appears as a likely mechanism.

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"Land degradation represents, like climate change, one of the biggest and most urgent challenges for humanity." (IPCC, 2019)

1.1 Introduction

Over the past decades, soil erosion has become a major concern for policy makers. In the Report on the Status of the World's Soil Resources, the FAO states that the majority of the world's soils are in "fair, poor or very poor condition". In the Philippines, 10 million ha of land, corresponding to 38% of the total country area, are moderately to extremely affected by water erosion, which is seen as a major threat to food security (FAO, 2015). High population density induces a strong pressure on the country's agricultural lands while its tropical climate is associated with heavy rains and frequent violent storms. In mountainous regions, landslides are frequent and can be exacerbated by agricultural activity as the cultivation of row crops, such as corn, is notable for inducing erosion (Pimentel, 2006).

Corn is the second most common crop in the Philippines after rice, accounting for 18.9% of the total agricultural area in 2017. Since 2003, genetically modified (GM) corn seeds are commercialized and the majority of corn now cultivated exhibits stacked traits of pest and herbicide tolerance (*Bt/Ht*).[2] This new technology induced a change in the inputs used by farmers, away from insecticide and towards herbicide. Some NGOs have complained that this lead to an increase in soil degradation and landslides occurrence (Masipag, 2013). However, this has only been documented by anecdotal evidence with little regard to causality, mechanisms or overall profitability of the technology. This paper rigorously examines this relationship between agricultural practices and landslides using a case study in a mountainous region of the Philippines.

Using recall data covering the past ten years, collected among 448 farming households on the island of Mindanao, I am able to reconstruct the recent history of the farms, including information on crops cultivated, land use and landslide occurrence. Landslides are very common in the region, with 47 percent of the surveyed households experiencing at least one over the past ten years. Controlling for village-year and household fixed effects, results show that landslides are more frequent on farms cultivating biotech corn, compared to alternative corn varieties (traditional varieties and illegal copies of GM seeds with attenuated Ht gene). The expected income

[2]Bt corn seeds were first commercialized in 2003 while Ht corn seeds were only introduced later in 2006, with stacked traits taking over the whole GM corn seeds market (Aldemita et al., 2014). By 2014, 62% of the hectarage devoted to corn was planted with GM seeds. Since then, the adoption rate has declined by almost 20 percentage points due to the spread of counterfeit seeds locally known as *ukay-ukay* and *sige-sige* (ISAAA, 2017). This sharp decrease and prompted a call for stronger regulation from one of the largest biotech companies of the country (Aguiba, 2018). To date, however, the government of the Philippines does not appear to have taken any significant measure to address this issue.

loss associated with this increased risk is very close to the average gain in profitability from GM corn cultivation. This differential landslide risk for GM corn cultivation does not appear to be driven by an endogenous allocation of crops on plots as the results are robust to the inclusion of plot fixed effects and plot-specific time trends. Instead, I find suggestive evidence that a more intensive use of herbicide on herbicide tolerant GM corn increases land vulnerability to landslides, through its reduction of plant cover.

Several papers have already investigated the link between agricultural productivity and land degradation in developing countries (Pender et al., 2004; Raut et al., 2010). Most recent papers, however, look at the adoption of sustainable agricultural practices, such as conservation agriculture, and their impacts on farmers' welfare (Abdulai and Huffman, 2014; Abdulai, 2016; Manda et al., 2016; Michler et al., 2019; Wossen et al., 2015). The present work, on the other hand, investigates the drivers of environmental degradation and is more closely related to a somewhat older literature on the determinants of soil erosion (Ananda and Herath, 2003; Boserup, 1981; Gebremedhin and Swinton, 2003). To the best of my knowledge, this is the first paper in the economics literature focusing specifically on landslides.

Second, this work is related to the large literature in agricultural economics studying the profitability of GM crops, which has emereged over the past 25 years. Available meta-analyses show that this technology has positive impact on yield and farm profits, especially in developing countries (Carpenter, 2010; Finger et al., 2011; Klümper and Qaim, 2014; Qaim, 2016). In the Philippine, Yorobe and Smale (2012) use an instrumental variable strategy to account for adoption and find that GM corn cultivation increases net farm income by USD 105 per hectare and monthly off-farm income by USD 49 through a reduction in labor requirements. Moreover, Mutuc et al. (2013) estimate heterogeneous effects with propensity score matching and show that the farmers benefiting the most are smaller, poorer and less likely to adopt biotech seeds.

GM crops are generally associated with positive environmental outcomes, summarized in the recent review by Qaim (2020) (see also Qaim (2016) for a more detailed review). The most commonly studied impact is the reduction in pesticide use following the adoption of the technology (Klümper and Qaim, 2014). While a decreased use of pesticide on pest-tolerant crops is intuitive, the impact of herbicide-tolerance on herbicide use is more controversial (Bonny, 2016). On the one hand, the enormous increase in glyphosate based herbicide use over the past 20 years can partly be attributed to the tolerance traits added to specific crops (Benbrook, 2016). On the other hand, this strong increase was accompanied by a substitution away from other types of - more toxic - herbicides, leading to a decrease in herbicide expenditure and, potentially, in herbicide-related environmental impact (Qaim and Traxler, 2005). The global effect of GM crops on herbicide use remains however difficult to estimate due to the scarcity of farm-level data (Brookes and Barfoot, 2017).[3] This is especially true for developing countries where herbicide use has dramatically increased over the past decades and where constructing a reliable counterfactual is therefore especially challenging (Haggblade et al., 2017; Huang et al., 2017). In any case, the actual environmental impact of this change in input use has, so far, remained beyond the scope of the economic literature.[4] The present paper therefore aims to partially fill this gap and illustrates a quote from Qaim (2020): "*Improved seeds [...] should never be considered a substitute for good agronomic practice, but should be integrated into sound and locally adapted crop rotations and agricultural systems.*"

The rest of the paper is structured as follows. The following section gives background information on the study area and on the particular agricultural techniques used by its farmers. Section 1.3 explains the data collection process, presents the data and some descriptive statistics. Section 1.4 presents the empirical strategies used to obtain the results, which reported in section 1.5 and discussed in section 1.6. Finally, section 1.7 concludes.

1.2 Background information

This paper is based on data collected on the island of Mindanao, Philippines, in an area locally known as the Upper Pulangi Valley. The main economic activity in this rural area is corn farming, with 50% of the land devoted to this crop according to the 2012 Census of Agriculture and Fisheries (CAF). The production is rainfed, entirely manual and without tillage. Corn growing season lasts four months and there are two production seasons per year: a wet season between April and September and a (relatively) dry one between October and April. Most farmers therefore grow corn twice a year, with little rotation between crops[5], which is compensated by the application of inorganic fertilizer. Some farmers occasionally try to have a third cropping in a year but this remains an exception.

The Upper Pulangi region is characterized by a weak presence of the state, a poverty rate substantially higher than the national average (79% compared to 22.5%) and very poor infrastructure. As a result, few farmers have direct access to markets, agricultural supplies stores and

[3] Brookes and Barfoot (2017) actually attempt to estimate this impact for the US using historical data as well as opinion from extension and industry advisers.

[4] There are two papers investigating the effect of agricultural practice change on health: Brainerd and Menon (2014) exploit the timing of crop planting in different regions of India and show that children exposed to a higher concentration of agrichemicals during their first month experience worse health outcomes. Maertens (2017) uses the introduction of the Renewable Fuel Standard in the US to show that a more intensive use of pesticide sharply increases the probability of perinatal death.

[5] Apart from corn, the common crops in the area include rice, rubber, ginger, hemp and vegetables.

banking facilities and rely on informal traders and money lenders.

For these reasons, the penetration of GM corn seeds is much lower than in the rest of the country. Illegal GM corn seeds are widespread in the region and are cultivated by a large majority of smallholder farmers. These seeds are sold through an underground market and exchanged between peers. Contrary to reports in the media presenting these seeds as a recent phenomenon (Arcalas, 2018), some farmers in the Upper Pulangi claim to have started cultivating them as early as 2005. According to qualitative interviews conducted by the author, those seeds were allegedly created by a former employee of a biotech company who supposedly stole mother seeds and crossed them with a local white corn variety. It still presents some resistance to glyphosate herbicide, allowing the farmers to spray herbicide on their crop, albeit with some crop loss (around 5 to 10%). Moreover, as this resistance appears to be stable across generation, farmers usually save some of their seeds and replant them in the following season (hence the local name of the variety: "*sige-sige*", meaning "follow-follow"). On the other hand, this variety does not exhibit the Bt trait and is therefore exposed to corn borer infestation, the most common pest in the Philippines.[6]

Apart from corn, rice is the second main crop grown in the region, accounting to 20% of cultivated area according to the CAF 2012. It is cultivated on the flat lands in the valley as it needs a substantial amount of water to grow and there is no terracing system in the area. Corn, on the other hand, is sensitive to excess water and is best grown on sloped land from which water can run off. Crop selection is therefore mainly driven by the physical characteristics of the plots.[7] On the contrary, the different varieties of corn (GM and *sige-sige*) are all suited for the same terrains. Qualitative interviews with farmers, extension agents, financiers and input retailers have underscored the important role of financial constraints and risk management in the agricultural decision process. Indeed, biotech seeds are much more expensive than their illegal counterparts and exhibit higher return on fertilizer, which are therefore used more intensively on GM plots. This implies a large upfront cost, and a potentially important loss in case of bad harvest. Biotech seeds are therefore planted by wealthier households, with more productive land. In the analysis that follows, corn varieties are divided in two main categories: GM corn, which refers to branded Bt/Ht corn seeds[8], and the other corn varieties which group the illegal

[6] As in many other developing countries, these counterfeit seeds are less productive than proper biotech seeds. However, farmers are very well aware of this productivity gap and asymmetric information does not seem to be an issue. Indeed,*sige-sige* seeds are never fraudulently sold as branded seeds, as documented in other parts of the world (Ashour et al., 2016; Bold et al., 2017). Buying this variety is therefore a deliberate decision of the farmers and seems to be influenced by financial constraints as many declare that they would prefer to plant proper biotech seeds but cannot afford them.

[7] In our data, only two plots have had both corn and rice over the past ten years.

[8] All the biotech corn cultivated in the region has stacked traits Bt/Ht.

sige-sige and the open-pollinated corn varieties. This grouping is motivated by the fact that open-pollinated varieties had almost disappeared by the time the data was collected.

1.3 Data and Descriptive Statistics

The data was collected between April and August 2018 in 14 villages (*barangays*) from the municipalities of Malaybalay and Cabanglasan in the province of Bukidnon. The survey was part of a larger research project studying the adoption of biotech corn in the region. For the purpose of this project, a lab-in-the-field experiment with farming couples was also conducted in some of the villages. In those, an enumerator went around the village the day before we arrived, informing the farmers of our arrival and inviting them to meet at a specific location the next day. He gave very few details regarding the study except that it was on corn farming, how long it lasted and the selection criteria. We included all those who showed up for the lab-in-the-field into the survey sample. However, in most cases, the turn up was disappointing, and we sent enumerators interviewing people at home, using a random walk selection method. In the villages where the lab-in-the-field was not implemented, only the random walk method was used. A total of 448 households were fully surveyed, 223 of which participated to the lab experiment.

In order to be interviewed, farmers needed to meet two criteria : (i) having cultivated corn at some point over the past ten years and (ii) cultivating less than ten hectares of land. The first condition was imposed because we wanted to study the interplay between corn cultivation methods and the incidence of landslides. We included farmers who did not grow corn anymore but who had in the recent past in order to alleviate the survivor bias.

A significant part of the data consists of recall data regarding the past 10-year history of the farm: land owned and cultivated, crops grown, financing as well as major agricultural shocks such as landslides and crop losses. In a pilot survey, we realized that obtaining reliable recall data was going to be a serious issue, especially over a 10-year span and given the low level of respondents' education. To address this issue, the enumerators started every interview by drawing a time-line of the farm with the help of the respondent. This way, they were able to ensure the internal consistency of answers and mitigate issues related to recall bias.[9] Important events (typhoons) were reported on the time-lines to give farmers time marks and improve the accuracy of their answers. Examples of such time-lines can be found in Appendix A-1. This problem also motivated the decision to exclude large farmers, who control a high number

[9]While the empirical analysis of this paper uses the full 10-year data, robustness checks are run excluding the earliest years.

of plots and would not have been able to recall all the information for every one of them. However, large farms are scarce in the area given that the region was recently deforested and is therefore not characterized by large estates dating back to the Spanish era as in other parts of the country.

With the collected information, an unbalanced panel dataset of 627 plots was constructed, covering the 2008-2017 period and totaling 4,684 plot-year observations. The panel is unbalanced because information was only asked for the years during which the farmer was effectively in charge of the agricultural decisions on the plots. For example, if a farmer started using a new plot in 2012, then we only have information after that date, even if the land was already cultivated by someone else beforehand. Likewise, the questionnaire was focused on the plots that were effectively under the control of the farmer and agricultural information was not collected for the plots rented out or pawned to other households. Additional questions were asked regarding the household's agricultural activity for the twelve preceding months. For corn and rice, the two major cash crops, we collected detailed information regarding input use, costs, harvest, price etc. A few additional questions were asked regarding the 24 preceding months but otherwise, no historical input use information was collected as it would have been very unreliable. This is probably the main limitation of the data as it prevents the inclusion of potentially important time-varying variables in the regressions. As a second-best, I need to use contemporary input use as a proxy of past input use, assuming that temporal variations are either absent or uncorrelated with the outcome variable.

The representativeness of our sample is discussed in Appendix B-1, by comparing it to the National Household Targeting System Data (NHTS), a census conducted in the same villages in order to identify households eligible to the national conditional cash transfer program (4Ps). Interviewed households appear to be representative of the area in terms of size, education and ownership of large assets (fridge, washing machine, electrification).

Table 1.1 presents descriptive statistics of the main variables in the data. The first panel uses the cross-section data, i.e. one observation per household. As expected from the sampling procedure, almost all households have cultivated corn over the past 10 years and 37.3% of them have planted GM seeds. Landslides are very common, with 46.4% of households hit at some point over the past 10 years. This high number can partially be explained by the steepness of cultivated plots, as the mean slope is 46%, corresponding to a 25-degree angle.[10]

[10]Note that the slope information was not collected on the field or through satellite imagery but asked directly to farmers, who were shown a series of pictures representing various angles, between 10% and 100% (respectively 5.7 and 45 degrees). Respondents were not shown the gradient or angles corresponding to the pictures, which can be found in Appendix C-1. While the actual gradient of the slope is certainly prone to measurement error and

Table 1.1: Summary statistics

VARIABLES	N	Mean	Std Dev
PANEL A: Cross-section summary statistics			
Ever corn	448	0.980	0.140
Ever GM corn	448	0.373	0.484
Ever landslide	448	0.464	0.499
Stopped GM corn	167	0.533	0.500
Slope (percent)	445	0.462	0.277
PANEL B: Panel summary statistics			
Corn	3,616	0.845	0.362
GM corn	3,616	0.217	0.413
Other crop	3,616	0.192	0.394
Fallow	3,616	0.113	0.317
Farm size (ha)	3,616	2.258	2.428
Nb of plots owned	3,616	0.923	0.651
Nb of plots used	3,616	1.236	0.605
Landslide	3,616	0.0705	0.256
Landslide area (ha)	250	0.453	0.546
Unusable time after landslide	250	1.035	2.086

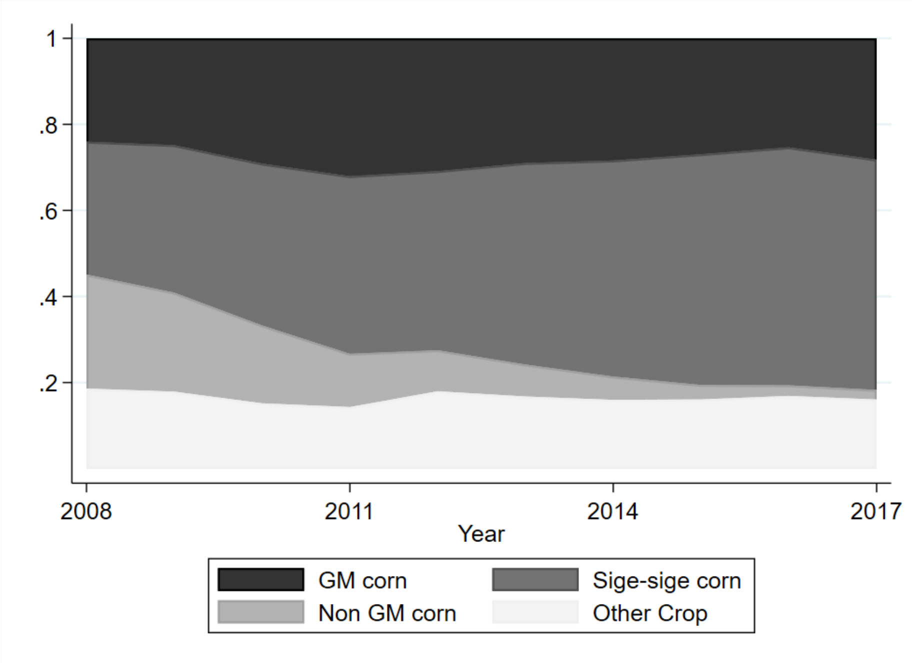
Panel A presents summary statistics using one observation per household. Slope is the mean slope of the farm over the past ten years. Ever corn, Ever GM corn and Ever landslide are dummy variables equal to one if, over the past ten years, the household has grown corn, GM corn or has been affected by a landslide, respectively. Stopped GM corn is a dummy equal to one if the household has stopped growing GM corn.
Panel B uses all household-year observations. Corn, GM corn, Other crop and Fallow are all dummy variables. Landslide area and unusable time were reported by the farmer for each landslide. The unusable time is measured in years.

The descriptive statistics of the second panel are computed using the panel data, one observation per household per year of activity, which explains the large increase in observations. Households planted corn 84.5% of the time, with biotech corn accounting for 21.7%. Other crops were cultivated 19.2% of the time while some plots were left fallow 11.3% of the time. The average farm size is 2.3 ha and the average number of plots cultivated per household is 1.2, with 75% of the respondents cultivating only one plot. The probability that a household experienced a landslide during any single year over the past 10 year was 7%. Following a landslide, farmers wait on average one year before replanting on the affected area. In 72% of the time, they do not wait and replant the following season. The majority of the landslides are

should be used with caution, there is no reason why this measure should be biased in either direction or that the measurement error should be correlated with any variable of interest. No indication was given to the farmers as to whether they should state the slope of the steepest part of the plot, or the average slope. However, given that most plots are relatively small, with a median surface of 1 ha, there is little intra-plot slope variability.

small, with a mean area of 0.45 ha (median = 0.25 ha), as reported by the farmers.[11]

Figure 1.1: Temporal variation of crop repartition



The figure shows the share of cultivated land allocated to specific crop categories. GM corn represents all biotech corn seeds; *sige-sige* corn, the illegal GM corn seeds, with some herbicide resistance and Non GM corn, all other open-pollinated corn varieties.

The evolution of the relative share of land occupied by GM corn, *sige-sige* corn, non-GM (open-pollinated and hybrid) corn and other crops is presented in Figure 1.1. In 2008, the cultivated area was almost equally divided between each category. Over time, the share of biotech corn and other crops remained relatively stable while that of *sige-sige* corn increased at the expense of the non-GM varieties, which had almost disappeared from the fields by the time the data was collected. For the rest of the analysis, these two types of corn will be grouped together and compared to the GM variety.[12]

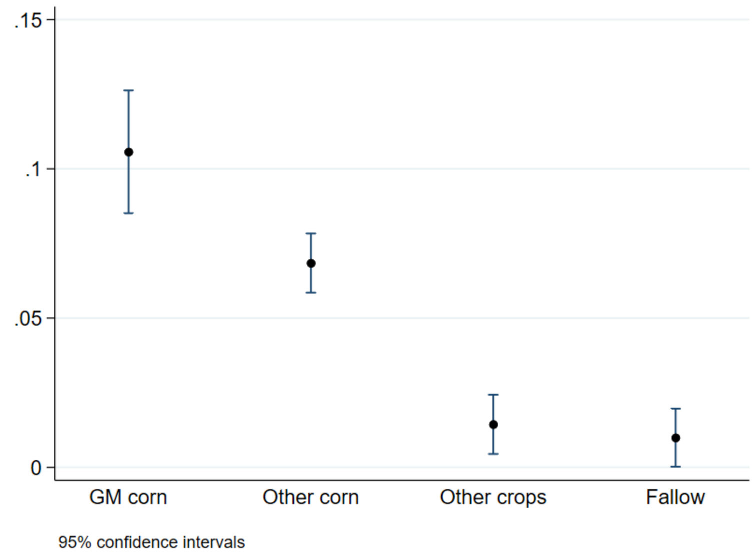
Although the share of land devoted to GM corn appears relatively stable over time, there is substantial movement within the group of farmers cultivating biotech seeds. As reported in the first panel of Table 1.1, more than 50% of the farmers who grow GM corn at some point later

[11]The term landslides covers a set of complex and diverse phenomena that involve the "*movement of a mass or rock, debris or earth down a slope*" (Cruden and Varnes, 1996). According to this classification by Varnes (1978), revised by Cruden and Varnes (1996) and Hungr et al. (2014), the type of landslides relevant for this study are called earth slumps and are characterized by a rotational sliding of earth (see Appendix D-1 for photographic examples). They are associated with slopes ranging between 20 and 40 degrees (between 36% and 83%) and are triggered by intense and/or sustained rainfall leading to the saturation of the soil. See Highland and Bobrowsky (2008) for more details.

[12]It is interesting to note that, in our research area, the spread of *sige-sige* corn did not lead to the disadoption of biotech corn but, instead, drove out the more traditional varieties. This sharply contrasts with the recent spread of illegal seeds documented at the national level as well as with accounts of GM crops driving out traditional varieties.

revert to another crop (*sige-sige* corn in 60% of the cases). Moreover, 15% of those who stop do it twice over the 10-year period. In qualitative interviews, farmers reported bad harvests and expensive inputs as the main reasons for moving away from biotech seeds. Incidentally, the two years with the highest number of disadoptions are 2013 and 2016, which respectively follow Typhoon Pablo and the driest year of the period.

Figure 1.2: Crop-specific landslide incidence



The figure shows the unconditional mean of landslide incidence per crop category.

Figure 1.2 presents the share of plot-year observations that reported a landslide for different crops and land uses. It can therefore be interpreted as the probability of being hit by a landslide during the year that the crop is planted. In line with the agronomy literature showing that row crops induce erosion, the vast majority of landslides occur on plots planted in corn. More surprisingly, plots planted in GM corn are 3.7 percentage points more likely to be hit by a landslide than those planted in other corn varieties. This difference is statistically significant and corresponds to a 55% increase in the probability of experiencing a landslide. Obviously, such a difference might be explained by time variations in weather and in crop cultivation or by differences in location, farm and farmer characteristics. In the rest of the paper, I show that this gap between GM corn and other corn varieties is robust to controlling for both observable and unobservable time-invariant characteristics and aggregate shocks as well as to various model specifications. I then explore two mechanisms: (i) a change in land use and an endogenous allocation of crops on plots and (ii) a shift in agricultural practices inducing an increased use of herbicide which decreases plant cover.

1.4 Empirical methodology

The main empirical strategy used to address this question is a fixed effects linear probability model. More specifically the equation estimated is:

$$landslide_{ijt} = \beta_1 crop_{ijt} + \gamma_{jt} + \theta_i + \epsilon_{ijt} \tag{1}$$

Where $landslide_{ijt}$ is a dummy variable equal to one if the household i from village j experienced a landslide during year t. $crop_{ijt}$ is a vector of dummy variables, each representing a category of crops and equal to one if the crop was cultivated by household i at time t. γ_{jt} and θ_i respectively represent village-year and household fixed effects. The error term ϵ_{ijt} is clustered at the village-year level to take into account correlation between observations.

The inclusion of village-year fixed effects controls for aggregate and village-level time-varying shocks, such as rainfall, extreme weather events, general perception of the GM technology, price of agricultural goods and access to public services and infrastructure. Household fixed effects account for all time-invariant observable and unobservable differences between households, such as location, farmer's age, education and ethnicity. For households who do not change their landholdings over the period, it also controls for the physical characteristics of the farm (area, soil quality, ruggedness, etc.). It is also possible to control linearly for changes in household characteristics using household time trends instead of fixed effects. In that case, households are assumed to have different baseline probabilities of being hit by a landslide and the evolution of this baseline probability is allowed to vary between households over time.

Given the recall nature of the data, it is likely that the quality of the answers decreases with the distance to the time of enumeration. If this recall bias is uniformly distributed among respondents, then it should be absorbed by the year fixed effects and would only add noise to the data. However, if some farmers are more likely to remember accurately than others and this bias is correlated to the crop they were farming at the time, this might bias our estimates. To address this issue, some specifications restrict the estimation to the most recent years and others give observations a weight increasing over time.

The main issue with this model is that there are no clear treatment and control groups, with GM corn being randomly allocated to the earlier. It is possible that time-varying farm-specific unobservable characteristics drive both adoption and landslide incidence. To address this issue, we can interact the crop vector with a dummy variable equal to one if the household has grown

GM corn at some point over the period. An insignificant interaction term implies that adopters are no more likely to be hit by a landslide when they do not grow GM corn, which alleviates the concern that our results are driven by differences between adopters and non-adopters.

The robustness of the results can be further investigated in three different ways. First, I add an extra category in the crop vector in order to distinguish between several corn varieties. Second, I run a series of placebo tests, replacing the crop vector by its lead or its lag. Second, I use a series of alternative models including propensity score matching, survival analysis and Poisson regression. In the matching model, I use a logit regression to predict biotech corn cultivation and control for aggregate time shocks by using exact matching along the time dimension. In order to compare landslide incidence between GM corn and other corn varieties, I exclude years in which corn was not cultivated. For the survival analysis, both Cox proportional hazard model and Weibull models are estimated, allowing for shared frailty at the household level. Finally, the Poisson regression uses the number of landslides over the period as the dependent variable and the explanatory variables count the number of years a specific crop was cultivated.

Genetically modified corn seeds are obviously unlikely to trigger landslides by themselves. Section 1.5.4 explores two important potential mechanisms that are not controlled for in Equation 1: within-farm heterogeneity and time-varying factors. First, the inclusion of household fixed effect or time trend assumes that farms are homogeneous entities when it comes to landslide hazard. This is probably true for the majority of farms that only cultivate one plot of land but not necessarily for the others. Farmers do not decide only which crops to plant but also where to plant them on their farms. The link between GM corn cultivation and landslide incidence might therefore be explained by the fact that this crop is planted on steeper plots, more prone to landslides. To address this issue, we can re-estimate our model at the plot-year level, controlling for plot fixed effects.

Second, Equation 1 does not control for any time-varying characteristics among which agricultural practices. Unfortunately, we only collected this information for each crop for the two seasons preceding the survey and not for the past ten years. The main reason is that, while farmers are likely to recall what they cultivated, the reliability of their answers are likely to be much lower for other agricultural practices, especially input use which involves numerical information. It is therefore impossible to directly link agricultural practices to landslides. However, we can use the recent observations to show suggestive evidence that a change in agricultural use is likely to drive our results. More specifically, the case of three practices will be discussed: erosion control, soil tillage and herbicide use.

1.5 Results

1.5.1 Landslides and GM Corn

The results of the estimation of Equation 1 are presented in Table 1.2. The $crop$ vector is composed of dummy variables for corn, GM corn cultivation as well as fallow land, the omitted category being a combination of all the other crops. A household growing GM corn will have a value of 1 for the variable Corn as well as for GM corn. The GM corn coefficient is therefore to be interpreted as the additional effect of cultivating biotech corn compared to other corn varieties. Without household fixed effect (column 1), the probability of being hit by a landslide is 6.4 percentage points higher when corn is cultivated. Going from non-GM to GM corn further increases this probability by 3.5 percentage points. When adding household fixed effects (column 2), both point estimates increase, especially GM corn. Controlling for all time-invariant farm characteristics, the probability of being hit by a landslide increases by 5.7 percentage points in years in which GM corn is cultivated compared to years with other corn varieties. The point estimates of GM corn in columns 1 and 2 are however not statistically different from each other. In column 3, the sample is restricted to the balanced panel of households for whom we have information over the whole 10-year period and who did not change the area cultivated over that period. In this case, household fixed effects also control for the physical characteristics of the farm. The coefficient of GM corn increases even more, but is not statistically different from that of column 2. Adding household time trends on the whole sample in column 4 yields very similar results.

All these results use data from the entire ten-year recall period. It is however likely that the quality of the answers will decrease with the distance to the time of enumeration. If this recall bias is uniformly distributed among respondents, then it should be absorbed by the year fixed effects and would only add noise to the data. However, if some farmers are more likely to remember accurately than others and this bias is correlated to the crop they were farming at the time, this might bias our estimates. To address this issue, Column 5 shows that the result still holds when restricting the sample to the years 2012-2017, therefore excluding the first four years.[13] Alternatively, column 6 uses the same specification as column 2 but weighs observations linearly as a function of time, giving a higher weight to recent years (1 for 2017) and decreasing linearly with the recall period (0.1 for 2008). The point estimate slightly decreases

[13]The choice of the interval is motivated by the fact that many landslides were reported in 2011 and 2012 and very few in the subsequent two years. Because of the use of fixed effects, we need farmers who have switched to/from GM corn during the period and who have also been hit by a landslide in order to estimate the coefficients. Excluding the year 2012 leads to a sharp reduction in the number of farmers meeting both criteria and estimates the coefficient of GM corn based only on 13 observations.

to 4.9 percentage points but remains statistically significant.

Table 1.2: Landslide occurrence and crop planted

VARIABLES	(1) Village-Year FE	(2) HH FE	(3) Constant land	(4) HH Time Trend	(5) 2012 - 2017	(6) Weighted by year
Corn	0.064***	0.075***	0.060**	0.087***	0.059**	0.071***
	(0.014)	(0.021)	(0.027)	(0.028)	(0.026)	(0.021)
GM corn	0.035**	0.057***	0.101***	0.090**	0.059**	0.049**
	(0.015)	(0.021)	(0.033)	(0.035)	(0.028)	(0.020)
Fallow	0.021*	0.061***	0.067*	0.055*	0.043	0.055**
	(0.012)	(0.023)	(0.038)	(0.031)	(0.031)	(0.026)
Observations	3,616	3,599	2,090	3,599	2,357	3,599
R-squared	0.216	0.313	0.347	0.450	0.368	0.308
Village-Year FE	YES	YES	YES	YES	YES	YES
HH FE	NO	YES	YES	YES	YES	YES
HH Time Trend	NO	NO	NO	YES	NO	NO

Robust standard errors clustered at the village-year level in parentheses.
Linear probability model with dependent variable = 1 if the plot was hit by a landslide in year t. All explanatory variables are dummy variables and the omitted category is any crop except corn.
Column 3 restricts the sample to household with constant landholding over the entire 10-year period. Column 5 only uses observations between 2012 and 2017. Column 6 gives increasing weight according to the year.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

1.5.2 Profitability of Biotech Corn

The previous results establish a strong link between biotech corn cultivation and the probability of landslides, which inevitably leads to crop loss and potentially to a decrease in soil productivity. However, it is clearly established in the literature that biotech crops are more productive and more profitable than other varieties. If this difference in profitability is large enough, it may be completely rational for farmers to plant GM corn despite the increase in landslide risk. To address this issue, Table 1.3 presents a cost-benefit analysis of the two main corn varieties, using the information on recent agricultural activity, including harvest, income and costs over the past growing season[14].

The first row of Table 1.3 shows the average quasi-profit per hectare (excluding labor costs and imputed land prices) for the two varieties, in Philippine peso[15]. This value is computed using the costs and revenue information of the season preceding the survey, for which the most detailed information was collected[16]. The second row presents average gross revenue for each category, again computed with the information from the season preceding the survey. As expected, GM corn is much more productive and its gross revenue per hectare is almost twice

[14]The comparison is between GM and *sige-sige* corn because, at the time of the survey, these were the only two varieties still cultivated in the area.

[15]At the time of survey, one euro was around 63 PHP.

[16]The small difference in quasi-profit between both varieties is surprising and is at odds with the agricultural economics literature on GM crops (Qaim, 2016). While we do find a large difference in yield between GM corn and *sige-sige*, it is mostly offset by more expensive seeds and a more intensive use of chemical fertilizer. Indeed, fertilizer use per hectare of *sige-sige* farmers is on average 50% lower than that of GM corn farmers.

as large as that of *sige-sige*. For each landslide incidence, I then multiply the area affected by the variety-specific average revenue to obtain the direct revenue loss, and present the average in the third row. Plants on the landslide-affected area are usually damaged and stop their growth so nothing can be harvested in these areas, leading to a direct loss in revenue. Since there is little difference in landslide size between varieties, this direct loss is almost twice larger for GM corn than for *sige-sige* corn. However, landslides do not only destroy the harvest when they hit but can also damage the land more permanently. We therefore need to take into account the losses resulting from the impossibility to farm the land for several seasons following a landslide. For each incidence, I add to the direct income loss the average variety-specific profit per hectare multiplied by the area of the landslide and the number of seasons that the land was unusable and report the average values in the fourth row. I use the average quasi-profit reported in the first row to compute losses from subsequent seasons as input costs are not incurred if the area is not planted. In this case, it appears that landslides on *sige-sige* corn plots lead to longer periods without replanting, as the cumulative loss corresponds to 80% that of GM corn[17]. For both varieties, landslides imply significant losses, larger than the quasi-profit for one hectare.

In order to estimate the expected losses for each variety, these revenue losses are multiplied by the probability of landslides, taken from the second column of Table 1.2. Because traditional corn had almost disappeared from the survey area in 2018, the coefficient of corn is imputed to *sige-sige*. The probability of landslides for GM corn is the sum of both corn and GM corn coefficients. The expected cumulative losses represent 19% and 9% of quasi-profit for GM corn and *sige-sige* respectively. The difference between the expected losses is almost equal, in magnitude, to the difference in quasi-profit between both varieties. This implies that the increased risk of GM corn almost completely cancels the profitability advantage of this variety.

This analysis should however be subject to caution for different reasons. First, the average revenue and profitability was only computed for the season preceding the survey. This season was not reported as being particularly good or bad by the respondents and when we compare it with the harvest data of the two preceding years, it is not statistically different. Nonetheless, we cannot entirely rule out the hypothesis that is it not representative. Second, the measurement of the landslide-affected area is not perfect, as the question was asked directly to the farmer and the enumerators did not visit the plots themselves. Even though there is no reason to believe that measurement error differs between GM and non-GM corn, it is possible that the

[17]It is however not clear whether this is due to an objectively larger damage to the land or to differences in farmers' coping strategies inducing farmers to replant on the affected plots despite the damage. This may be the case given that GM corn cultivation incurs much higher costs and a bad harvest implies larger financial losses than with *sige-sige* corn.

Table 1.3: Expected loss of income due to landslides

Mean(PHP)	(1) **GM Corn**	(2) **Sige-sige corn**	(1) - (2)
Quasi-profit per ha	10,993	9,505	1,487
Revenue per ha	31,045	18,303	12,742
Direct revenue loss	12,956	7,170	5,786
Cumulative revenue loss	15,690	12,693	2,997
Probability of landslides	13.2%	7.5%	5.7%
Expected direct revenue loss	1,710	540	1,169
Expected cumulative revenue loss	2,071	957	1,114

All monetary measures are computed using the municipality-specific median price of corn during the harvest preceding the survey. Income per ha is computed by taking the mean of the quantity harvested over the two years preceding the survey multiplied by the price. Direct income loss is the product of the area damaged by the landslide by the mean income per hectare. The cumulative income loss adds to the direct income loss the product of the area damaged in subsequent years by the time it is damaged and the mean quasi-profit per hectare in 2017. Quasi-profit is the farm profit excluding labor expenditures and imputed land prices.

Probability of landslide are taken from the second column of Table 1.2.

farmers systematically over-reported the affected area. In this case, the computed and expected revenue losses would be inflated and the actual difference between GM and *sige-sige* would be smaller. Additionally, if the landslide happens early in the season, the direct revenue loss might be reduced by the fact that some inputs do not need to be used on the affected plots and are saved for the next season. On the other hand, the computation of cumulative losses only takes into account the time during which the plot was not cultivated by the farmer and not the loss in soil fertility following the landslide. It is indeed very likely that the affected area becomes less productive as some of the top soil was washed away, which is not included in our analysis. Moreover, the length of the period during which the land is unusable is underestimated as some plots had still not been replanted at the time of the survey.

1.5.3 Robustness analysis

This section discusses several robustness tests confirming the results of Table 1.2. All the tables are reported in Appendix E-1. First, the differentiation between GM corn and other corn varieties may not be fully convincing as the most common alternative variety is the illegal *sige-sige* corn, which also exhibits some Ht traits. To address this issue, Table E-1.1 replicates Table 1.2 with an additional dummy for *sige-sige* corn. The coefficient of this variable is always insignificant, indicating that there is no statistical difference between non-GM and *sige-sige* corn.

Second, I re-estimate Equation 1 and interact the crop vector with a dummy equal to one if the farmer cultivates GM corn at some point over the past ten years. If the results presented in Table 1.2 are driven by differential trends between adopters and non-adopters that have not been properly controlled for, we should expect that adopters have a higher probability of landslide even when they are not cultivating biotech seeds. Table E-1.2 shows that this is not the case as both interaction coefficients are insignificant (the interaction between adopters and GM corn cannot be estimated and is therefore not reported). Furthermore, the other columns show the result of placebo tests using lags or leads of the cultivated crop vector: Column 2 uses the crop cultivated in t-2; column 3 using that of t-1, column 4 of t+1 and column 5 of t+2. In all those regressions, the coefficients of corn and GM corn are close to zero and insignificant. This shows that landslide occurrence is only correlated with the contemporaneous agricultural practices.

Lagged values of cultivated crops can also be used to investigate whether landslide probability increases with every additional year of GM cultivation or whether the shift is a discrete one, with no cumulative effect. To address this issue, I re-estimate column 3 of Table E-1.2, including the non-lagged variables, and present the results in Table E-1.3 in Appendix. In the first column, the lagged variables have a negative and non-significant coefficient. To get a better understanding of the transition to and from biotech cultivation, we can add an interaction between present and past varieties (column 2). The significant coefficient of GM corn, coupled with a non significant coefficient for the interaction term implies that there are no cumulative effects. Furthermore, the non-significance of the lagged GM coefficient shows that the impact of biotech corn is not persistent in time as landslide probabilities come back to their original level when GM corn cultivation is stopped, in line with the results presented in Table E-1.2.

To further assess the robustness of the results, Tables E-1.4 and E-1.5 in Appendix use propensity score matching and survival models respectively to estimate the impact of GM corn cultivation on landslide occurrence. In Table E-1.4, the probability of cultivating biotech corn is estimated with a logit model using farm size, number of plots, inherited land, slope, education, age, ethnicity and location as predictors. In addition, exact matching is used along the time dimension in order to control for aggregate shocks. As the years in which households did not cultivate corn are excluded from the estimation, and the reported coefficient compare landslide occurrence between GM corn and other corn varieties. They can therefore be interpreted in the same way as the GM corn coefficient of Table 1.2. The positive effect of biotech corn on the probability of landslide is slightly smaller but otherwise similar to that obtained in Table 1.2 and is very robust to using various matching algorithms and different parameter values.

Columns 1 and 2 of Table E-1.5 show the hazard rates obtained from using Cox proportional-hazard model and Weibull survival model, allowing for shared frailty at the household level. Because crop planted can change from year to year, the data is set up such that every observation ends either with a landslide (failure) or with a crop change (censoring). For this reason, the number of observation is higher than the number of households. A hazard ratio higher than one indicates an increase in failure probability, which is the case for GM corn in both specifications. The last two columns present the incidence-rate ratios of Poisson regressions with and without conditional household fixed effects. The dependent variable is the number of landslides over the period and the explanatory variables count the number of years a specific crop was cultivated. As previously, each observation relates to the period in time during which the same crop (or crop mix) was planted, but in this model, a landslide event does not end the observation. Once again, GM crop cultivation is associated with an increase in landslide occurrence, which is even bigger when time-invariant household characteristics are controlled for.

1.5.4 Mechanisms

In order to derive policy recommendations, it is important to identify the mechanisms that could explain the positive correlation between GM corn cultivation and landslide occurrence documented so far. First, I investigate the mediating effects of the two most obvious predictors of landslide occurrence: extreme weather and slope which have, so far, been controlled by the fixed effects. I then move to a more direct explanation of the correlation between landslides and GM corn. A first possibility is that GM corn plants themselves cause this increase in landslides because of physical differences in root structure. Another, more likely, explanation is that this effect is driven by factors that are not controlled for in Equation 1: within-farm heterogeneity leading to endogenous allocation of crops on plots and time-varying variables, especially agricultural practices. This last explanation appears as the most likely candidate to explain our results, even though more agronomic research is needed to firmly confirm it.

Moderating effects of slope and weather

Rainfall and slope gradients are both obvious factors influencing the probability of landslides. So far, they have been controlled for by village-year and household fixed effects. However, it might be interesting to investigate how these determinants interplay with the type of crop cultivated and the probability of landslide.

Froude and Petley (2018) report that 42% of rainfall-triggered landslides in the Philippines are caused by typhoons. Such extreme weather events are frequent in the country, which have been described as the "most storm-exposed country on Earth" (Brown, 2013). Indeed, an average of twenty tropical cyclones enter its Area of Responsibility every year, nine of which actually cross the country (Cinco et al., 2016). Most of these storms affect the northern island of Luzon while the island of Mindanao, situated off the typhoon path, is usually spared. Over the past ten years, only two major storms have hit our study area: Washi in 2011 and Bopha in 2012, locally known as Sendong and Pablo, respectively.

In Appendix F-1, the passage of Washi and Bopha is clearly marked, with the number of landslide-affected households almost ten times higher during the years 2011 and 2012 (24.5% compared to 2.8% on average during non-typhoon years). The dotted line represents the share of days with rainfall above the normalized rainfall Intensity-Duration threshold computed by Guzzetti et al. (2008).[18] 2011 and 2012 are among the years with the highest share but the relationship between this measure and typhoon occurrence is weak.

To examine the differential impact of GM corn on landslide in case of extreme weather, I estimate Equation 1 and interact the crop dummies with two rainfall measures: (i) a dummy variable equal to one for the typhoon years, 2011 and 2012, and (ii) the share of days above the normalized ID threshold. The results of these regressions are presented in columns 1 and 2 of Table 1.4. The probability of landslide increases significantly during typhoon years for plots planted in corn, but there is no significant additional effect of GM corn. Importantly, the difference between GM corn and other corn varieties remains significant during the years without typhoon, even though it decreases slightly, showing that our results are not driven by those specific years. Using the continuous variable for extreme weather yields a slightly different picture as the interaction of biotech corn becomes statistically significant. The differential impact of GM corn is therefore present when considering more common episodes of wet weather but disappears in case of extreme events. The point estimates imply that every day spent above the threshold increases, by 0.1 percentage point, the probability that the household is hit by a landslide over the year if he is cultivating corn, and by an additional 0.12 percentage point if it is GM corn. In this specification, the estimates of Corn and GM corn become insignificant, which clearly shows that wet weather is driving landslides.

In the last column of Table 1.4, the average slope of the farm is interacted with the cultivated crops. The only statistically significant differential effect is that of GM corn. Comparing two farms, which differ by 10 percentage points in slopes, the probability of landslide on the steeper one is 2.2 percentage point higher when both are cultivating GM corn compared to when they are growing another corn variety.

[18]See Appendix F-1 for details on this ID threshold.

Table 1.4: Moderating effects of weather and slope

VARIABLES	(1)	(2)	(3)
Corn	0.038**	-0.092	0.038
	(0.018)	(0.061)	(0.025)
GM corn	0.045**	-0.134	-0.035
	(0.019)	(0.091)	(0.038)
Fallow	0.069***	0.059***	
	(0.022)	(0.021)	
Corn*Typhoon	0.187***		
	(0.046)		
GM Corn*Typhoon	0.060		
	(0.044)		
Corn*Days over threshold		0.356**	
		(0.141)	
GM Corn*Days over threshold		0.432**	
		(0.212)	
Corn*Slope			-0.015
			(0.057)
GM Corn*Slope			0.221**
			(0.085)
Observations	3,466	3,466	3,380
R-squared	0.331	0.323	0.327
Village-Year FE	YES	YES	YES
HH FE	YES	YES	YES

Robust standard errors clustered at the village-year level in parentheses.
Linear probability model with dependent variable = 1 if the plot was hit by a landslide in year t.
Typhoon is a dummy variable = 1 for years 2011 and 2012. Days over threshold is the share of days above the NID threshold from Guzzetti et al. (2008). Slope is the slope of the plot reported by the respondent.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Difference in root structure

The first potential mechanism is that there are physical differences in the root structure of different corn varieties, thus making GM corn intrinsically more prone to landslide. This would be the case if *sige-sige* and traditional varieties have deeper roots than biotech corn. Unfortunately, it is not possible to formally dismiss this hypothesis as *sige-sige* corn remains completely unstudied. However, given that corn cultivation already causes soil erosion, it seems highly unlikely that altering a few genes to get pest and herbicide tolerance traits would induce changes in its root structure leading to the large increase in landslide probability documented in Table 1.2. Moreover, such a difference is completely absent from the literature on GM crops and was never reported by farmers during the qualitative interviews conducted by the author.

Within-farm heterogeneity

Farmers do not decide randomly what crop to plant on their plot, and take into account the physical characteristics of their land when making their decision. So far, the regressions included household fixed effects or time trends which controlled for many confounding factors but did not rule out a possible reallocation of crops within a given farm. It is therefore possible that our results are driven by the fact that biotech corn is planted on plots that are intrinsically more prone to landslides. First, GM corn might be planted on larger plots than other corn varieties. In that case the landslide probability would mechanically increase with no direct connection to the crop itself. Second, given that biotech corn is more profitable, it may be cultivated on more marginal land than other varieties. However, GM corn is also much more costly to cultivate, as these seeds are more expensive and exhibit a higher return on fertilizer, which increases the use of chemical inputs. Rational farmers would therefore prefer to grow it on good land in order to maximize the return on investment (as well as minimize the risk of negative return).

To address this issue, I re-estimate Equation 1 at the plot-year level, this time adding plot fixed effects instead of household fixed effects and thereby controlling for all time-invariant physical characteristics of the plot, even within a given household. Results are presented in Table 1.5 and are very similar to those reported in Table 1.2 the coefficient of GM corn only changes by 0.1 percentage point between the household and the plot fixed effect models.

Table 1.5: Plot fixed effect regressions

VARIABLES	(1) HH FE	(2) Plot FE	(3) Plot Time Trends	(4) Single plots	(5) Ever GM	(6) 2012 - 2017	(7) Weighted by year
Corn	0.075***	0.055***	0.071**	0.047*	0.039	0.061*	0.062**
	(0.021)	(0.020)	(0.031)	(0.027)	(0.038)	(0.035)	(0.025)
GM corn	0.057***	0.058***	0.091***	0.081***	0.063***	0.059**	0.048**
	(0.021)	(0.020)	(0.034)	(0.026)	(0.023)	(0.026)	(0.019)
Fallow	0.061***	0.014	0.014	0.046	0.033	0.009	0.013
	(0.023)	(0.024)	(0.033)	(0.039)	(0.045)	(0.037)	(0.029)
Observations	3,599	4,648	4,648	2,462	1,597	3,045	4,648
R-squared	0.313	0.308	0.450	0.319	0.375	0.377	0.318
Village-Year FE	YES	YES	YES	YES	YES	YES	YES
Plot FE	NO	YES	YES	YES	YES	YES	YES
Plot Time Trends	NO	NO	YES	NO	NO	NO	NO

Robust standard errors clustered at the village-year level in parentheses.
Linear probability model with dependent variable = 1 if the plot was hit by a landslide in year t. All explanatory variables are dummy variables and the omitted category is any crop except corn.
Column 4 restricts the sample to households cultivating at most one plot over the period. Column 5 to plots that have been planted in GM corn at some point over the period. Column 6 only uses observations between 2012 and 2017. Column 7 gives increasing weight according to the year (2008 = 0.1, 2017 = 1).
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Columns 4 and 5 present the additional results for restricted sample analyses, which all confirm the previous findings. First, the sample is restricted to households who farm, at most, one plot over the period and who, therefore do not make a joint crop-plot decision (column 4). Second, our results might be driven by a selection of plots for GM corn that is not appropriately controlled for by the fixed effects. To address this issue, column 5 only keeps plots that have been planted in biotech corn at some point over the past ten years, i.e. those that have been selected into GM corn. The last two columns check for recall bias by restricting the sample to recent years (column 6) and by using year-specific observation weighting (column 7). For all specifications, the effect of GM corn cultivation on landslide incidence is positive and strongly significant. We can therefore reject the hypothesis that the correlation observed in Figure 1.2 is due to an endogenous allocation of crops on plots.

Agricultural practices

In all the results presented so far, the only time-varying explanatory variables were the crop dummies and the village-year fixed effects. However, other important farm-specific factors are likely to vary over time and are potentially correlated to the cultivated crop. When farmers decide to plant a given variety, they decide at the same time where to plant on their farm and which techniques and inputs to use in the cultivation. Of all the different agricultural practices, three are potentially linked to landslide incidence: erosion control, land tillage and herbicide use.

Erosion control techniques, such as tree planting and drainage ditches, are likely to have a large impact on landslide probability. Unfortunately, we only observe them at the time of the survey and do not know when farmers put them in place. Nonetheless, given that GM corn is more productive, investing in erosion control should have a higher return with this variety, and farmers should therefore invest more when they grow GM corn. If anything, this should decrease the correlation between GM corn and landslides and is thus highly unlikely to explain our results. Similarly, soil tillage does not appear as a plausible mechanism as there is very little variation across households and this practice has not changed much over the period.

On the other hand, a decrease in plant cover induced by an increased use of herbicide on GM corn is likely to explain some of the observed correlation. Plant cover is indeed a well-established technique to control erosion in the agronomic literature (Durán Zuazo and Rodríguez Pleguezuelo, 2008). Plants slow the runoff and infiltration of rain water, therefore limiting the risk of runoff erosion and of water saturation, leading to landslides. Moreover, root systems fix the top layer of the soil, further reducing the risk of erosion. Systematic and frequent application of herbicide, however, decreases plant cover and therefore leads to erosion. Multiple studies therefore recommend only partial weeding when cultivating on slopes, as a way to strike a balance between the benefits of weeding - less competition for the crops - and its costs - increased erosion (Lenka et al., 2017; Liu et al., 2019; Utomo and Senge, 2002). These papers, however, only look at runoff erosion and, to the best of my knowledge, no study has examined the impact of weed management on landslide occurrence.

The farm-level recall data collected for this paper does not contain information on herbicide use during the past ten years. However, it was collected for each crop over the two years preceding the survey (i.e. four growing seasons). Glyphosate is, by far, the most common type of herbicide and it is mostly applied on corn and rice fields, either during land preparation or during the growing cycle if the crop exhibits herbicide tolerance. Both GM and *sige-sige* corn have this trait but the resistance is more reliable with the former. Moreover, farmers planting these seeds are richer and therefore more likely to use inputs more intensively.

Table 1.6: Herbicide use per hectare in 2016-2017

VARIABLES	(1)	(2)
Corn	2.543***	1.719*
	(0.606)	(1.025)
GM Corn	1.903***	1.061*
	(0.468)	(0.551)
Observations	826	715
R-squared	0.043	0.938
Growing season FE	YES	YES
Household FE	NO	YES

Robust standard errors clustered at the household level in parentheses.
Farm-level measure of herbicide use in liter per hectare over the 24 months preceding the survey. Genetically Modified corn is the omitted category.
*** p < 0.01, ** p < 0.05, * p < 0.1

This is confirmed by Table 1.6, in which the quantity of herbicide used in liter per hectare is regressed on crop dummies for corn and GM corn. Given that this information was only asked for corn and rice, the omitted category is rice. As expected, farmers use more herbicide when cultivating GM corn. When household fixed effects are included, in column 2, the difference decreases and loses some significance but remains significant at the 10% level. Households cultivating both GM and non-GM corn use on average one liter more of herbicide per hectare on their GM corn compared to other corn varieties (for an average use of 4.3 liters). This difference in herbicide use is therefore not entirely explained by differences in financial constraints between farmers but may be due to a difference in herbicide tolerance between varieties and/or marginal returns of input use.

While data limitation does not allow to estimate directly the correlation between herbicide use and landslide occurrence in any given year, we can look at whether households who use more herbicide in 2016-2017 have been more affected by landslides in the past. This assumes that input use exhibits some serial correlation and that current herbicide use is indicative of past use. Furthermore, to interpret the results as the impact of herbicide on landslide occurrence, we need to assume that past landslide experience does not determine current herbicide use. This reverse causality should, however, play against us as landslides are more likely to decrease herbicide use either because farmers notice the connection between the two or because of an increase in financial constraints following a loss of harvest. Moreover, during all the qualitative interviews conducted in preparation for the survey, no farmer ever stated that herbicide use could lead to landslides and it is therefore unlikely that they would take this risk into account when making agricultural input decisions.

Table 1.7: Herbicide use in 2016-2017 and landslide occurrence

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Standardized herbicide use			Percentile in herbicide use distribution		
Corn	0.065***	0.065***	0.089***	0.063***	0.077***	0.088***
	(0.015)	(0.015)	(0.027)	(0.014)	(0.020)	(0.024)
GM corn	0.041**	0.042**	0.051***	0.036**	-0.011	-0.003
	(0.016)	(0.016)	(0.019)	(0.015)	(0.019)	(0.028)
Fallow	0.027*	0.028*	0.073**	0.022*	0.022*	0.060**
	(0.015)	(0.015)	(0.029)	(0.012)	(0.012)	(0.023)
Herbicide use	0.002	0.003		0.017	0.017	
	(0.005)	(0.009)		(0.013)	(0.019)	
Corn * herbicide use		-0.008	-0.002		-0.034	-0.014
		(0.012)	(0.017)		(0.028)	(0.042)
GM corn * herbicide use		0.027**	0.030		0.113***	0.121**
		(0.013)	(0.018)		(0.041)	(0.055)
Observations	3,136	3,136	3,123	3,568	3,568	3,551
R-squared	0.217	0.218	0.311	0.217	0.220	0.315
Village-Year FE	YES	YES	YES	YES	YES	YES
HH FE	NO	NO	YES	NO	NO	YES

Robust standard errors clustered at the village-year level in parentheses.
Linear probability model with dependent variable = 1 if the plot was hit by a landslide in year t. The first three columns use a household-level crop-specific measure of herbicide use in 2016-2017, standardized by its crop-specific mean and standard deviation. The last three columns use the percentile of the household in the crop-specific distribution of herbicide use in 2016-2017.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 1.7 presents the results of regressing the probability that a farmer experiences a landslide on the crops he cultivates and current herbicide use. Because farmers do not necessarily plant the same crop as they did in the past and different crops lead to a different intensity in herbicide use, herbicide measure is standardized using variety-specific mean and standard deviation[19]. The resulting measure is then averaged at the household level for farmers cultivating different crops during the two years preceding the survey. This transformation is motivated by the fact that we want to distinguish which farmers are heavy herbicide users in 2016-2017, while taking into account differences in herbicide use between crops. Results show that current herbicide use is not correlated with past landslide occurrence. However, a one standard deviation increase in herbicide use in 2016-2017 is associated with a 2.7 percentage point increase in landslide probability during years when GM corn was cultivated. Controlling for household fixed effects, the point estimate increases slightly to 3 pp but loses some significance (p=11.2%).

[19] I exclude observations in the top decile of herbicide use as a few outliers, most certainly incorrectly measured, are likely to have a strong impact on the mean and standard deviation and therefore bias the results.

Using the percentile of the household in the crop-specific standardized herbicide distribution as an alternative measure of herbicide use intensity gives similar results, reported in columns 4-6. Without interaction, the coefficient of herbicide use is very small and insignificant and becomes positive and statistically significant when interacted with the GM corn dummy. Results show that moving up in the distribution by 10 percentage points is associated with an increased probability of landslide of 1.2 percentage points when controlling for household fixed effects. Moreover, when herbicide is interacted with crop dummies, the coefficient of GM corn decreases sharply and becomes statistically insignificant. This result therefore suggests a nonlinear relationship between herbicide use and landslide occurrence, as landslides are more likely only when heavy glyphosate users cultivate the variety that allows for the largest amount of herbicide[20].

1.6 Discussion

This section further discusses the main results of the paper. First, it addresses the potential causal link between herbicide tolerance and herbicide use in the context of the Philippines. Then, it questions the rationality behind the choice of farmers to adopt unsustainable agricultural practices. Finally, it discusses the particularities of the survey area and the external validity of the results.

1.6.1 Herbicide tolerance and herbicide use

Heavy herbicide users in 2016-2017 appear to have experienced higher landslide occurrence during the years in which they were cultivating GM corn. While this does not prove a causal link between herbicide use and landslides, it is consistent with the idea that herbicide tolerant corn has led to a more intensive use of herbicide, which have had adverse effects in terms of environmental degradation.

However, the link between herbicide tolerant crop cultivation and herbicide use is not straightforward. As discussed earlier, the scientific literature finds that herbicide tolerant seeds lead to a substitution from more toxic herbicides to broad-spectrum glyphosate, at least in developed countries. In our survey area, however, herbicide penetration was relatively low in the years preceding the introduction of Ht corn seeds. According to the 1991 Census of Agriculture and Fisheries, only 46.16% of farmers in the Philippines used herbicide in 1991.[21] This proportion

[20]This also explains the insignificant difference between sige-sige corn and non-GM corn in Table E-1.1. However, the fact that heavy herbicide users drive the relationship between GM corn and landslides is not very robust as it is absent when an alternative measure of herbicide use intensity is used in columns 2 and 3.

[21]1991 is the only recent wave of the CAF asking about herbicide use. It is therefore impossible to get a measure closer to the introduction of Ht seeds.

decreases to 26% when focusing on the villages in the Upper Pulangi region. Nowadays, only 7% of the respondents in our survey declared not using any herbicide during the preceding season. It therefore appears that herbicide use increased at the same time as Ht seeds were being adopted by farmers. We can thus reject the hypothesis that glyphosate herbicide simply replaced other narrower chemicals. In addition, herbicide is generally sprayed three times during the growing cycle, once before planting and twice during the growth period. With non-Ht seeds, such an intensive use would simply be impossible. While we do not have a counterfactual to properly address this question, it seems very plausible that herbicide use would be lower in the absence of herbicide tolerant seeds.[22]

Furthermore, Ht seed adopters in developed countries are more likely to practice no-till agriculture or to adopt conservation tillage practices (Fernandez-Cornejo et al., 2014), thereby avoiding land disturbance and potentially reducing landslide risk. However, corn agriculture in the area is still entirely manual and tillage is almost nonexistent. Herbicide use is therefore unlikely to reduce soil erosion through this channel.

1.6.2 Farmers' choice

If a more intensive use of herbicide on plots planted with GM seeds lead to a higher probability of landslide, thereby canceling the gains in productivity, why do farmers keep on adopting this unsustainable practice? Indeed, we would expect rational farmers to take into account the additional risk resulting from the more aggressive weed-control technology and either decrease the use of herbicide or switch to another variety exhibiting lower marginal returns on inputs, such as *sige-sige* corn.

A potential explanation is that learning is slow and complex because crop decisions are only made twice a year and that the probability of landslide is relatively small. Moreover, most of the reported landslides occurred during the typhoon years of 2011 and 2012, making it difficult for farmers to disentangle both effects. Also, while it is costless to observe the occurrence of landslides on neighboring plots, the cultivated variety and the amount of inputs used may be harder to observe. For these reasons, it is possible that farmers have simply not had the time to notice this correlation, given that GM corn was introduced 15 years before the survey. In qualitative interviews, none of the respondents cited herbicide use or corn variety as a factor inducing a landslide.

[22]Ht seeds commercialization are obviously not the only driver behind the global increase in herbicide use. Manual weeding being very labor-intensive, a relative increase in agricultural wages are likely to drive farmers toward chemical weed control solutions, even in the absence of GM technology.

1.6.3 External validity

The data used in this paper was collected in a remote mountainous area in the Philippines, with a high level of poverty, a strong indigenous population and labor-intensive agricultural practices. Generalizing the results to other settings therefore requires a lot of caution as the context appears to play a key role in explaining the observed correlation between Ht corn and landslides. More specifically, our claim is that Ht corn is positively associated with landslides when it is cultivated on steep slope, with no land tillage and limited weed control prior to adoption. While these conditions may appear very restrictive, they are likely to apply to vast regions of developing countries, especially in Asia and Africa, where the adoption of modern agricultural inputs has been slower. Obviously, this only holds for herbicide tolerant corn and does not concern varieties exhibiting other GM traits such as pest tolerance. In qualitative interviews, farmers cited herbicide tolerance as a particularly important trait for them, especially when cultivating steep plots as it decreases labor requirement. Including it in GM seeds commercialized in similar settings is therefore likely to increase adoption.

In addition, the main corn varieties cultivated in the region are Bt/Ht corn and the so-called *sige-sige* variety which presents an attenuated resistance to herbicide. This alternative variety is therefore not the perfect counterfactual when assessing the increased use of herbicide following the adoption of Ht corn. However, these illegal copies have certainly also increased the use of herbicide and, if anything, the resulting bias should go against our results. The magnitude of this bias and the actual change in herbicide use following GM corn adoption in such a context is however left for future research.

Finally, our results need to be put in perspective with the other environmental benefits commonly associated with GM crops, including reduced tillage for Ht crops and decreased pesticide use for Bt crops. Moreover, the increase in productivity allowed by the technology reduces the amount of land required to grow a given amount of food and may therefore contribute to limit land conversion, an issue which is not addressed in this paper.

1.7 Conclusion

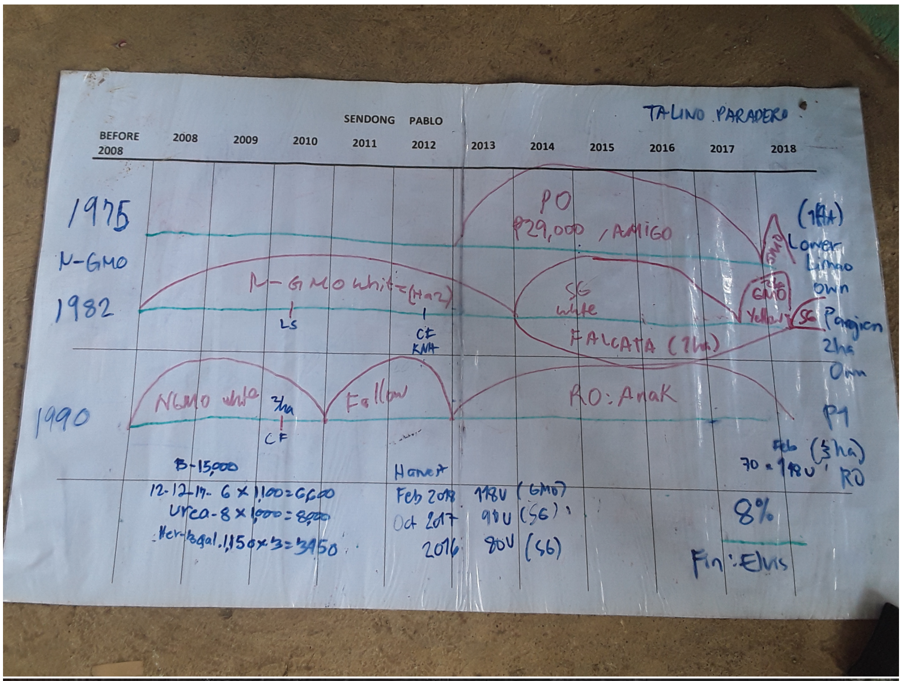
This paper presents a case study in a remote mountainous region of the Philippines and documents a strong, robust and statistically significant positive correlation between Bt/Ht corn cultivation and landslides incidence. The effect is large and cancels the additional profitability of the variety. Suggestive evidence shows that this relationship might be driven by an increased use of herbicide following the adoption of herbicide tolerant seeds. Generalization of these results should however be carried out with extreme caution due to the setting in which the data was collected and the nature of this data. Indeed, the survey area was a particularly poor and remote region and is not representative of the rest of the country, while not being completely unparalleled in an international perspective. Moreover, the data used in this paper is based on recall information, going back as far as ten years. While a specific enumeration method was put into place to maximize its reliability, it is probably of lower quality compared to traditional household surveys. This also strongly limits the type of information that can be gathered as specific numerical answers (e.g. regarding input use) are harder to remember. As a result, the data is insufficient to clearly establish the mechanisms behind the Ht corn-landslide correlation and only provides suggestive evidence.

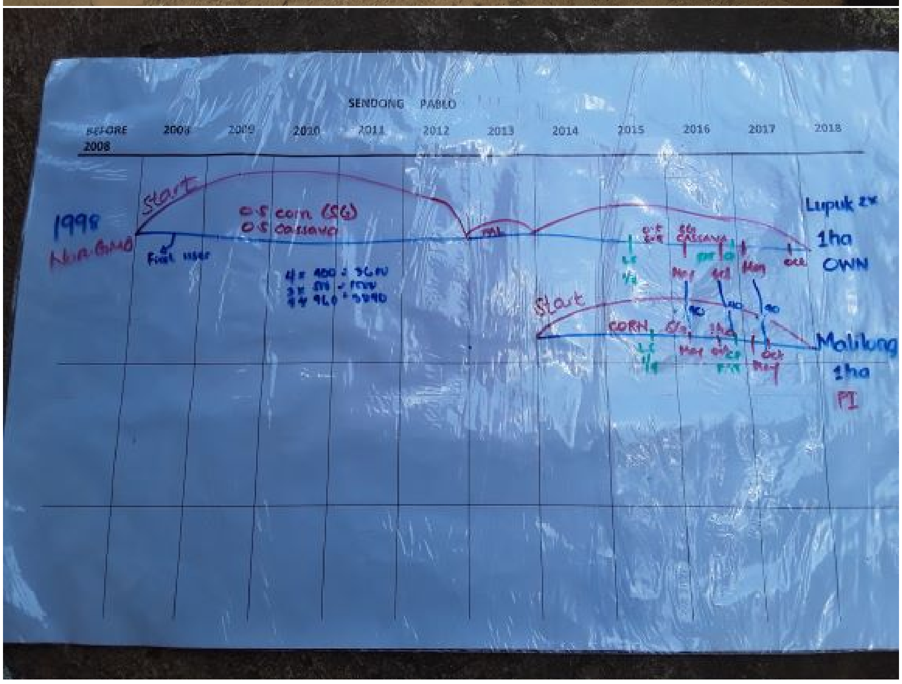
Despite these shortcomings, this paper presents a strong case for taking into account the impact of new agricultural varieties on farming practices. When farmers change their seed variety, they are likely to change the type and mix of inputs they use and this whole system should be the focus of academic research as well as of regulatory agencies. In addition, more agronomic research is needed on the root structure of biotech corn and on the relationship between herbicide use, plant cover and landslide incidence on steep slopes.

From a policy perspective, agricultural extension offices should take a closer look at the environmental impact of new farming practices and promote alternatives that are both environmentally and economically sustainable. Promotion of sustainable land management techniques may indeed be difficult to implement with poor farmers if they have a detrimental effect on yields. Developing poverty alleviating projects and investing in infrastructure therefore appear as important steps toward environmental sustainability. Increasing employment opportunities outside of the agricultural sector could also decrease pressure on the land, and limit the need to cultivate steep marginal lands in mountainous areas. Taking into account the differential impacts of changing agricultural practices by agro-ecological zone and taking appropriate conservation measures is necessary to preserve agricultural productivity and food security in the most marginalized regions of the developing world.

Appendix

Appendix A-1: Timeline photographs





Appendix B-1: Representativeness of the sample

The following table shows the comparison between our sample and the households identified as farmers in the NHTS-PR. Due to data limitation, it is unfortunately not possible to determine whether the landholding or the agricultural practices differ between the two samples. For the rest, households are similar in terms of size, education, access to electricity and ownership of large assets (fridge, washing machine). For most other assets, our sample appears wealthier. Restricting the NHTS-PR data to corn farmers yields the same results. However, since the purpose of NHTS-PR data was to identify poor households, it is likely that respondents under-reported ownership of small assets such as phones, radio or television which are easy to hide. Our interviewed households therefore appear to be relatively representative of the survey area.

Table B-1.1: Representativeness of the surveyed households

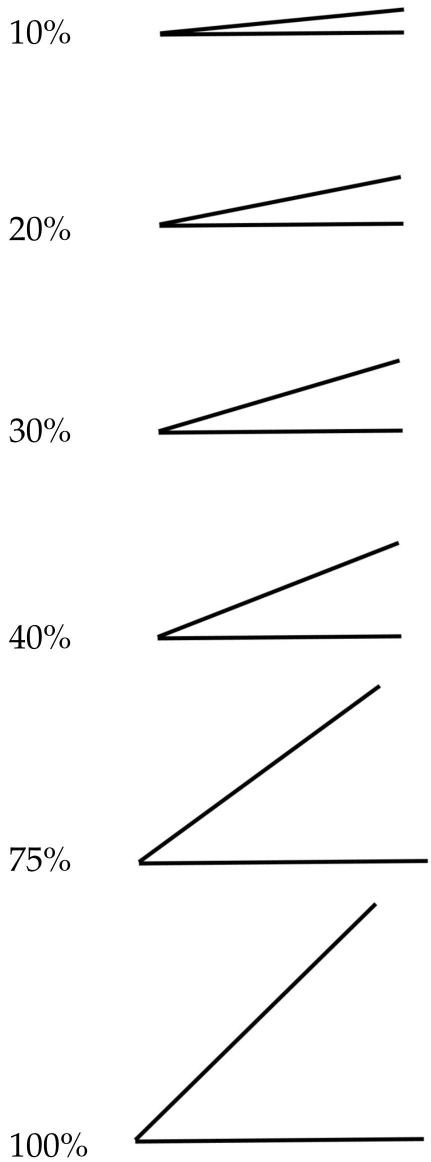
	(1) Survey data		(2) NHTS farmers		T-test P-value
Variable	N	Mean/SE	N	Mean/SE	(1)-(2)
Indigenous	448	0.429	3295	0.509	0.001***
		(0.023)		(0.009)	
Household size	448	5.208	3295	5.008	0.098*
		(0.096)		(0.043)	
Head's education	448	5.243	3295	5.302	0.744
		(0.147)		(0.063)	
Electricity	447	0.566	3295	0.545	0.404
		(0.023)		(0.009)	
Radio	448	0.417	3295	0.329	0.000***
		(0.023)		(0.008)	
Television	448	0.417	3295	0.343	0.002***
		(0.023)		(0.008)	
Stereo	448	0.112	3295	0.076	0.010***
		(0.015)		(0.005)	
Cell phone	448	0.658	3295	0.354	0.000***
		(0.022)		(0.008)	
Computer	448	0.016	3295	0.016	0.942
		(0.006)		(0.002)	
Fridge	448	0.103	3295	0.098	0.772
		(0.014)		(0.005)	
Washing machine	448	0.076	3295	0.059	0.158
		(0.013)		(0.004)	
Car	448	0.007	3295	0.020	0.049**
		(0.004)		(0.002)	
Motorcycle	448	0.315	3295	0.171	0.000***
		(0.022)		(0.007)	

Survey data is the sample of households interviewed for this research. NHTS farmers is the subset of NHTS census data who reported agriculture as the principal activity of the household head.
Indigenous is a dummy variable equal to one if the household head is Lumad. Head's education is the household head's number of years of education. All other variables are dummy variables = 1 if the household owns the asset.

P-values for two-sided t-tests. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Appendix C-1: Pictures Used for Slope Measurement

Question: "In general, what is the slope of your plot?"



Note: Gradients not shown to respondents

Appendix D-1: Landslide photographs

Appendix E-1: Robustness analysis

Table E-1.1: Landslide and crops including sige-sige corn

VARIABLES	(1) Village-Year FE	(2) HH FE	(3) Constant land	(4) HH Time Trend	(5) 2012 - 2017	(6) Weighted by year
Corn	0.062***	0.066**	0.045	0.046	0.070*	0.070**
	(0.018)	(0.027)	(0.033)	(0.043)	(0.042)	(0.031)
GM corn	0.037**	0.065**	0.115***	0.124***	0.049	0.050*
	(0.018)	(0.027)	(0.042)	(0.046)	(0.040)	(0.028)
Sige-sige corn	0.003	0.013	0.020	0.049	-0.013	0.001
	(0.013)	(0.018)	(0.022)	(0.034)	(0.033)	(0.021)
Fallow	0.021*	0.062***	0.068*	0.055*	0.043	0.056**
	(0.012)	(0.023)	(0.038)	(0.031)	(0.031)	(0.026)
Observations	3,616	3,599	2,090	3,599	2,357	3,599
R-squared	0.216	0.313	0.348	0.451	0.368	0.308
Village-Year FE	YES	YES	YES	YES	YES	YES
HH FE	NO	YES	YES	YES	YES	YES
HH Time Trend	NO	NO	NO	YES	NO	NO

Robust standard errors clustered at the village-year level in parentheses.
Linear probability model with dependent variable = 1 if the plot was hit by a landslide in year t. All explanatory variables are dummy variables and the omitted category is any crop except corn.
*** p < 0.01, ** p < 0.05, * p < 0.1

Table E-1.2: Placebo tests

VARIABLES	(1) GM adoption	(2) 2nd lag	(3) 1st lag	(4) 1st lead	(5) 2nd lead
Corn	0.079***	0.007	0.045**	0.036*	0.029
	(0.028)	(0.030)	(0.020)	(0.021)	(0.027)
GM corn	0.059***	-0.023	-0.002	-0.004	-0.012
	(0.022)	(0.025)	(0.021)	(0.020)	(0.018)
Fallow	0.056*	0.048	0.021	0.024	0.061*
	(0.032)	(0.030)	(0.024)	(0.029)	(0.034)
GM adopter * Corn	-0.010				
	(0.040)				
GM adopter * Fallow	0.009				
	(0.056)				
Observations	3,599	2,705	3,143	3,143	2,705
R-squared	0.313	0.325	0.318	0.331	0.366
Village-Year FE	YES	YES	YES	YES	YES
HH FE	YES	YES	YES	YES	YES

Robust standard errors clustered at the village-year level in parentheses.
Linear probability model with dependent variable = 1 if the plot was hit by a landslide in year t.
All explanatory variables are dummy variables and the omitted category is any crop except corn.
*** p < 0.01, ** p < 0.05, * p < 0.1

Table E-1.3: Lagged effects of GM corn on landslides

VARIABLES	(1)	(2)	(3)	(4)
Corn	0.082***	0.094***	0.077***	0.089***
	(0.023)	(0.030)	(0.021)	(0.021)
GM corn	0.069***	0.084***	0.056***	
	(0.025)	(0.030)	(0.020)	
Fallow	0.064**	0.061**	0.063***	0.061***
	(0.026)	(0.026)	(0.023)	(0.023)
Lag Corn	0.009	0.023		
	(0.016)	(0.026)		
Lag GM	-0.032	-0.017		
	(0.023)	(0.027)		
Corn * Lag Corn		-0.024		
		(0.034)		
GM * Lag GM		-0.032		
		(0.036)		
Nb of GM years			0.007	
			(0.005)	
1st year GM				0.051*
				(0.026)
2nd year GM				0.051*
				(0.026)
3rd year GM				-0.007
				(0.037)
4th year GM				0.044
				(0.034)
5th year GM +				0.064**
				(0.032)
Observations	3,143	3,143	3,599	3,599
R-squared	0.325	0.325	0.314	0.313
Year FE	YES	YES	YES	YES
HH FE	YES	YES	YES	YES

Robust standard errors clustered at the village-year level in parentheses. Linear probability model with dependent variable = 1 if the plot was hit by a landslide in year t. All explanatory variables are dummy variables and the omitted category is any crop except corn.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table E-1.4: Propensity score matching - Landslide occurrence and GM corn cultivation

MODEL	PARAMETER	ATT
Nearest-neighbor		0.043 **
		(0.017)
	Trim = 5%	0.047 ***
		(0.018)
	Trim = 10%	0.049 ***
		(0.019)
	Trim = 20%	0.052 **
		(0.021)
Radius	Caliper = 0.001	-0.009
		(0.021)
	Caliper = 0.005	0.035 **
		(0.016)
	Caliper = 0.01	0.026 *
		(0.015)
	Caliper = 0.05	0.037 ***
		(0.014)
Kernel	Bandwidth = 0.01	0.027 *
		(0.015)
	Bandwidth = 0.02	0.032 **
		(0.015)
	Bandwidth = 0.05	0.037 **
		(0.014)
	Bandwidth = 0.1	0.043 ***
		(0.014)
Rosenbaum Bounds	Γ	1.45

ATT coefficients of GM corn cultivation using matching models and excluding non-corn plots.
Matching using exact matching on year and PSM on municipality, remoteness, farm size, number of plots, inherited land area, average slope, household head's education, age and ethnicity.
Γ is log odds of differential assignment to treatment due to unobservables. Value reported is $Gamma$ at which the critical p-value for the estimate implies the effect is insignificantly different from zero at p = 0.10.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table E-1.5: Survival analysis - Landslide occurrence and GM corn cultivation

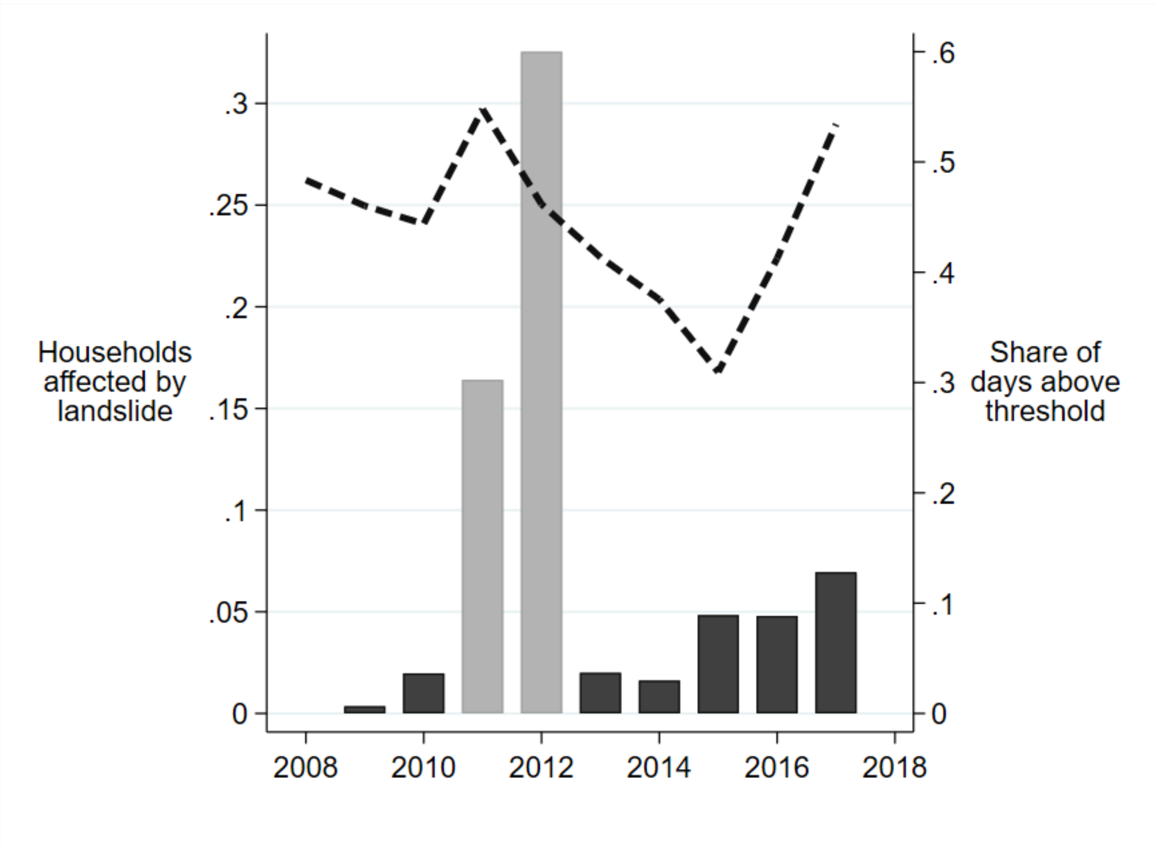
VARIABLES	(1) Cox	(2) Weibull	(3) Poisson	(4) Poisson
Corn	8.562***	7.979***	11.130***	8.303***
	(3.712)	(3.460)	(4.817)	(4.232)
GM corn	1.545***	1.783***	1.356**	2.335***
	(0.203)	(0.234)	(0.178)	(0.632)
Fallow	1.587*	1.682**	1.254	1.900
	(0.377)	(0.401)	(0.298)	(0.949)
Constant		0.002***	0.036***	
		(0.001)	(0.016)	
Observations	989	989	699	205
Number of groups	444	444		
HH RE	YES	YES		
HH FE			NO	YES
Number of hhid				92

Hazard ratios reported for Cox and Weibull models. Incidence-rate ratios reported for Poisson regressions.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Appendix F-1: Share of households affected by landslides and extreme weather

The dotted line represents the share of days with rainfall above the normalized rainfall Intensity-Duration threshold computed by Guzzetti et al. (2008). Following the pioneering work of Caine (1980), an important literature has developed on rainfall thresholds for landslides (the recent literature is reviewed by Segoni et al. (2018)). The most commonly used threshold take into account the fact that landslides can be induced by intense as well as sustained rainfall. Most papers therefore compile slope failure events, cross them with meteorological data and empirically estimate a relationship between rainfall Intensity and Duration above which landslides are likely to occur, known as ID thresholds. In the Philippines, this exercise was carried out by Nolasco-Javier and Kumar (2018) using data from the Baguio district in the north of the country. Unfortunately, it is not possible to apply their threshold to weather data from Mindanao as extremely few days are reported as being landslide-prone. Over the past ten years, this threshold is only surpassed in 2011 and 2014, whereas landslides have been reported every year. This might be due to the fact that Baguio is one of the wettest places of the country. As second-best measure, I use the global threshold computed by Guzzetti et al. (2008) using data from countries all around the world.



Source: Own data and Tropical Rainfall Measuring Mission (TRMM) from Huffman et al. (2012)
Histogram presents the share of plots affected by landslide for every year of the period (Left axis). Dotted line shows the share of days above the ID rainfall threshold from Guzzetti et al. (2008) (Right axis)

CHAPTER 2

AGRICULTURAL PRODUCTIVITY AND LAND INEQUALITY: EVIDENCE FROM THE PHILIPPINES

Ludovic Bequet[1]

Abstract: This paper presents the first detailed empirical evaluation of the effect of agricultural productivity on land inequality using the context of genetically modified (GM) corn seeds introduction in the Philippines. Using three waves of census data covering 21 years and 17 million plots, I identify the effect by exploiting exogenous variations in soil and weather, leading to differences in potential gain from GM corn cultivation. Results show that municipalities that benefited more from the technology experienced an increase in landholding inequality, measured by the area farmed by top decile and by the Gini index. This effect is partly driven by a relative increase in agricultural land and more precisely by a lower contraction in more affected areas. While increased land inequality is associated with a higher level of terrorist activity, it does not seem to have any adverse effect on poverty, household income or expenditure.

***JEL* Classification:** O13, Q12, Q14, Q15

Keywords: Land inequality, Agricultural technology, Land reform, Philippines.

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2.1 Introduction

The structure of a country's agricultural sector is strongly linked to its development level. In low-income countries, it is characterized by a large number of smallholder farmers while in high-income countries, farms tend to be larger and fewer[2]. This difference can be explained by the process of structural transformation, whereby workers move out of agriculture into the industrial and the service sectors. This implies a substantial reallocation of agricultural land between those who leave and those who stay. How this reallocation takes place shapes the land distribution, which has implications for the distribution of income and wealth at the national level.

Gains in agricultural productivity have been identified as a key driver of this structural transformation as they reduce the demand for agricultural labor and increase the demand for manufacturing goods. While there has been an extensive literature studying the impact of agricultural productivity on land expansion (see Villoria et al. (2014) for a review), its effect on land inequality has so far remained unaddressed. This is striking given that modern agricultural technologies are often blamed for favoring large farms, at the expense of smallholder farmers, leading to an increase in land concentration. These claims are especially common for genetically modified (GM) crops but are rarely backed by data or only based on very loose empirical analysis (Catacora-Vargas et al., 2012; Phélinas and Choumert, 2017). Herbicide tolerance and pest resistance - the two main traits in GM crops - are labor saving as they decrease the need of manual weeding and pesticide spraying respectively. As Bustos et al. (2016) show, this kind of labor-augmenting technology can drive structural transformation and is therefore likely to lead to a redistribution of agricultural land. Moreover, the higher return on capital is likely to favor better-off farmers and lead to higher levels of inequality.

This paper presents the first empirical evaluation of the effect of agricultural productivity on land inequality, focusing on the two decades surrounding the introduction of GM corn seeds in the Philippines. Corn is the second most-cultivated crop in the country, mostly by smallholder farmers who rank among the poorest categories of the population (Reyes et al., 2012). GM seeds were introduced in 2003, rapidly adopted by the farmers and can be considered as the most important technical innovation for corn agriculture in the recent decades.

The economic literature on land distribution usually studies the *impacts* of land inequality

[2]Using agricultural census data from 92 countries, Lowder et al. (2016) find that farms smaller than 2 ha account for 30-40% of land in low- and lower-middle-income countries and less than 10% in upper-middle- and high-income countries.

rather than its drivers. The most compelling argument for a more equal land distribution comes from a series of papers, starting with Alesina and Rodrik (1994), showing a negative correlation between inequality - especially land inequality - and economic growth[3]. Historical evidence suggests that this is driven by lower investment in physical and human capital in areas with unequal land distribution[4]. Likewise, land redistribution policies have been shown to decrease poverty in India (Besley and Burgess, 2000), South Africa (Keswell and Carter, 2014) and the Philippines (Reyes, 2002; World Bank, 2009). This may be due to the fact that a more equal distribution generates more employment per hectare (and per unit of output) as small sized farms are more labor intensive and access to land provides a safety net which may encourage non-farm business investment (Binswanger-Mhkize et al., 2009). Furthermore, as agricultural activity in developing countries exhibits diseconomies of scale - the so-called "inverse farm size-productivity" -, redistributing land to smallholder farmers may lead to efficiency gains. This is supported by Vollrath (2007) who finds a negative relationship between land Gini and agricultural productivity using cross-country data. However, this claim has recently been challenged by Foster and Rosenzweig (2017) who show with micro-data that the relationship between farm productivity and size is in fact U-shaped and that large farms are as efficient as small ones, even in developing countries[5].

Land inequality has also been linked with an increased likelihood of conflict (de Luca and Sekeris, 2012; Peters, 2004; Thomson, 2016), environmental degradation (Ceddia, 2019; Sant'Anna, 2016) and reduced resilience against natural disasters (Anbarci et al., 2005)[6]. Despite this large number of studies on the – mostly negative – effects of land inequality, there exists surprisingly little research on its drivers. One notable exception is Bardhan et al. (2014) who use rich panel data from West Bengal to show that household division is a much larger driver of land distribution than land market transactions or the land reform. At a more aggregate level, Lowder et al. (2016) and Jayne et al. (2016) also provide a detailed description of agricultural land distribution, respectively for the whole world and in four African countries. The question of the distributional impacts of agricultural technology is however not new in economics and echoes an old literature studying the distributive effects of the Green Revolution, especially in South Asia[7]. These papers relied on very limited data sources, usually from a few hundred households. Moreover, they only focused on describing the change in inequality and did not rely on causal identification strategies. The present work therefore addresses an old question using

[3]See also Easterly (2007); Fort (2007), Neves et al. (2016) and Cipollina et al. (2018) for meta-analyses

[4]Banerjee and Iyer (2005); Baten and Hippe (2018); Cinnirella and Hornung (2016); Galor et al. (2009)

[5]Similarly, Adamopoulos and Restuccia (2019) find that land redistribution during the agrarian reform in the Philippines led to a 17% decrease in productivity.

[6]See also Guereña and Wegerif (2019) for a recent multi-disciplinary review.

[7]Bardhan (1974); Chaudhry (1982); Freebairn (1995); Otsuka et al. (1992); Prahladachar (1983); Raju (1976)

modern empirical tools. It is also linked to the literature on agricultural productivity and structural transformation, in particular Bustos et al. (2016)[8] and can be seen as a description of the land redistribution process resulting from a more structural change of the economy.

To document the landholding inequality in the Philippines during the decades surrounding the introduction of GM corn in 2003, I use three waves of census data covering 21 years and 17 million plots. First, I show that landholding inequality increased between 2002 and 2012, despite an ongoing land reform aimed at redistributing agricultural land. A Theil's inequality decomposition reveals that within-municipality inequality accounts for 80% of total inequality. Changes in national inequality are therefore highly likely to be driven by changes at the local level and the rest of the empirical analysis takes the municipality as unit of observation[9]. This gives a large enough number of observations to use traditional empirical methods.

As the census data does not distinguish between GM and non-GM corn, it is not possible to correlate the use of the technology with land inequality measures. Moreover, such an empirical strategy would be subject to reverse-causality bias. Indeed, it is not clear whether a positive correlation would mean that higher adoption rates lead to higher land concentration or simply that the technology is adopted in places where land is less equally distributed. To overcome this identification issue, I take advantage of exogenous variations through space and time. First, I compare data collected in 2002 – one year before GM seeds were commercialized – with data from 2012, in a first-difference setting, similar to a municipality fixed effects model. Second, I exploit differences in local soil and weather characteristics to compute an exogenous variation in profitability from GM corn, an approach taken from Bustos et al. (2016)[10]. This allows to compare the change in land inequality between municipalities that benefited substantially from the technology and those that could only benefit marginally. Results show that landholding inequality increased in more impacted municipalities, an effect driven by an increase in the land share of the top decile. This effect can be partially explained by the fact that agricultural

[8]Note that, while the new corn variety described in Bustos et al. (2016) is a land-augmenting technology, the introduction of GM corn in the Philippines was likely labor-augmenting and is more comparable to that of GM soy in their paper.

[9]Agricultural censuses are the most commonly-used data source to investigate land inequality, going back to Deininger and Squire (1998). In a recent paper however, Bauluz et al. (2020) have advocated for the use of household surveys instead. They show that, while both data sources give comparable land Gini coefficients, adjusting for the landless population and the land value – both absent from census data – leads to important changes in inequality measures. While agricultural censuses do have shortcomings, they also offer the extensive coverage needed for the kind of analysis carried out in this paper. Indeed, computing land inequality indicators at the local level (municipality or even village) using household surveys would be highly imprecise given the low number of households typically surveyed in each location. Moreover, household surveys only take into account household farms and therefore systematically miss company-owned farms which tend to be larger. As an extreme example, Lowder et al. (2016) show that in Guatemala, the 2% largest farms from the agricultural census, representing 57% of total land, are absent from the LSMS household survey.

[10]Similar estimation strategies has been used in other related papers such as Dias et al. (2019); Moscona (2019)

land is less likely to decrease in more affected municipalities and that inequality is positively correlated with agricultural area. In addition, heterogeneity analysis reveals some interesting effects. First, it is stronger in municipalities that adopted modern inputs later, i.e. where the potential for yield increase was higher. Second, it is larger in places with more credit penetration ten years before the seeds commercialization. This brings support to claims made by advocacy groups who identify the agricultural financing system as an important mechanism driving land concentration. According to anecdotal evidence, the high input costs associated with the new technology pushes farmers to take usurious loans from informal moneylender, with interest rates as high as 10-15 percent per month. In case of default, they become bankrupt and need to pawn or sell their land, usually to the financier, thereby increasing land concentration (Masipag, 2013). I am however unable to disentangle this effect from a more direct effect of credit availability on treatment intensity as adoption is likely to be higher in places with more financial services. I also find some geographical heterogeneity, with a stronger effect on the southern island of Mindanao. Finally, looking at land *ownership* inequality instead of landholding inequality reveals that this measure follows a similar pattern, although its measurement is more problematic because of data limitation.

To assess to robustness of the results, a series of tests are presented. First, I show that they are unaffected when controlling for the change in population size and composition, thereby ruling out migration as a mechanism. Second, controlling for additional topographical and geographical characteristics does not have a substantial impact on the results. Third, comparing 1991 and 2002 data fails to find a similar effect, showing that, municipalities that benefited more from the technology were not on a different trend. Previous productivity gains therefore did not have the same impact on landholding inequality. Fourth, the results remain significant when spatial correlation is taken into account using Conley standard errors and when standard errors are clustered at the provincial level. Fifth, I run the analysis at the level of the barangay (village) and find the same effect, especially when the sample is restricted to rural areas. Finally, using alternative definition of the treatment variable leads to similar results.

Given the literature showing that GM crops improve farmers' income on the one hand (Qaim, 2016), and the other literature documenting the adverse effects of land inequality on the other, the net effect of the technology appears uncertain, although the inequality effect is unlikely to offset all the productivity gain. In the last part of the paper, I investigate the correlation between land inequality and three sets of downstream outcomes: municipality-level poverty rate; income and expenditure data from household surveys and terrorist activity. Results point to a negative correlation between inequality and poverty but they are not robust to the inclusion of fixed effects and time-varying controls. On the other hand, terrorist activities measured as the number of attacks and the number of casualties are positively correlated with land inequality, especially the attacks perpetrated by communist groups. This suggests that the welfare costs of higher inequality are low on average, but may increase in less politically stable regions. These results however, need to be interpreted with caution as this last section lacks a proper identification strategy and is therefore subject to reverse causality and omitted variable bias.

2.2 Background

The Philippines is an archipelago composed of 7,641 islands, situated in South-East Asia with a total land area of 300,000 square kilometers. During the period analyzed in this paper, 1991-2012, it was considered as a lower-middle income country, with a share of employment in agriculture declining from 45% to 32% (World Bank, 2019). Despite sustained economic growth and a strong decline in overall poverty, poverty incidence remained high in rural areas, as 57% of agricultural households were characterized as poor in 2009, three times the proportion of non-agricultural households (Reyes et al., 2012). The country is also characterized by a high level of income, wealth and land inequality, owing to the legacy of Spanish colonialism which constituted a landed elite class occupying prominent positions in the country political and economic apparatus. This high level of inequality is at the root of the civil conflicts that have beset the country in the past decades, among which the Moro insurgency on the island of Mindanao (McDoom et al., 2019).

In an effort to address the issue of land inequality, the country has undergone a series of land reforms since the beginning of the twentieth century. The most recent one, the Comprehensive Agrarian Reform Program (CARP), started in 1988 with a triple objective of equity/social justice, farm efficiency and poverty reduction. The scope of this reform was extensive as it covered all agricultural land with a few exceptions[11]. Both tenants and regular farm workers were included as recipients, as long as they were landless or smallholder farmers (with less than 3 ha of land). The reform put an upper limit on ownership of agricultural land at 5 ha, plus 3 ha per heir of minimum 15 years at the time of the reform, provided that they were willing to continue tilling or managing the farm. Thirty years after the start of the implementation, the CARP claims to have redistributed 4.8 million hectares to 2.8 million households (Ballesteros et al., 2017). These figures however appear unrealistically high[12]. In addition, several schol-

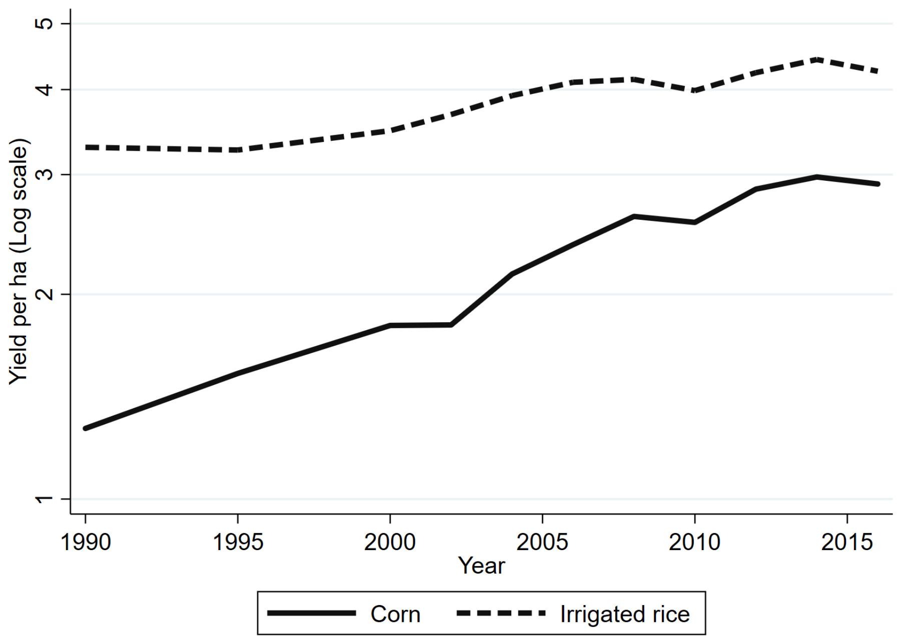
[11]Exceptions include military reservations, penal colonies, educational and research fields, timberlands, undeveloped hills with 18 degrees slope and church areas.

[12]Indeed, according to the agricultural census, there were 3.76 million farmers in the Philippines in 1991 and when we add up the land area under leasehold and tenancy with the area owned in excess of 5 ha, we only reach 4.1 million ha. If the redistribution numbers are true, we would therefore observe a much larger decrease in land

ars have criticized the reform implementation process for being captured by the landed elite and resulting in little distribution of wealth and power to the landless and smallholder farmers (Borras, 2006; Borras et al., 2007; Lanzona, 2019).

Corn is the second most-cultivated crop in the country. It is used both for consumption and sold to the booming animal feeds industry. In 2003, the country approved the commercialization of GM corn seeds. Farmers were fast to adopt this new technology and, by 2014, 62% of the hectarage devoted to corn was planted with GM seeds (ISAAA, 2017). The first generation of biotech corn included the *Bacillus thuringiensis* (Bt) trait, which confers the plant pest tolerance. In 2005, new varieties were commercialized exhibiting herbicide tolerance (Ht) as well. By 2012, the overwhelming majority of GM corn planted in the Philippines had both traits (Bt/Ht)(Aldemita et al., 2014). In addition to the patented GM seeds, illegal open-pollinated varieties (OPVs) containing herbicide-tolerant traits have been reported in the South of the country. These varieties, locally known as *sige-sige* are the result of cross-breeding between traditional cultivars and GM corn seeds. Using qualitative information, De Jonge et al. (2021) estimates that these varieties appeared in Southern Mindanao between 2005 and 2010 and nowadays account for 35 to 50% of maize farm land in Mindanao and the Visayas[13].

Figure 2.1: Temporal evolution of corn and rice yield



Source: Bureau of Agricultural Statistics (2005, 2008, 2013); Philippine Statistics Authority (2018)

inequality than what is found in the subsequent censuses.

[13]Very little is known about the exact characteristics, origin and spread of this *sige-sige* corn. These figures are in line with those found by Bequet (2020) in a case study in Northern Mindanao.

Figure 2.1 shows the evolution of corn and rice yields per hectare between 1990 and 2016, using official data from the Department of Agriculture. In the decade following the introduction of GM corn, corn yield almost doubled. Such a large gain in productivity was not observed in rice, the main crop of the Philippines. In line with the global literature on GM crops (Qaim, 2016), two papers have shown that GM corn has been beneficial to Filipino farmers. Yorobe and Smale (2012) use an instrumental variable strategy to account for adoption and find that it increased net farm income by USD 105 per hectare and monthly off-farm income by USD 49 through a reduction in labor requirements, highlighting the labor-saving effect of the technology. Heterogeneous effects estimated by Mutuc et al. (2013) with propensity score matching show that the farmers benefiting the most are smaller, poorer and less likely to adopt the technology.

2.3 Data

2.3.1 Agricultural census

Data harmonization

The evolution of landholding inequality is computed using the latest three waves of the Census of Agriculture and Fisheries (CAF), collected in 1991, 2002 and 2012 by the Philippine Statistical Agency (PSA), under the supervision of the FAO's World Census of Agriculture. This data provides plot-level information including size, tenure status, main use and the crops cultivated over the past year. Harvest and input information are unfortunately unavailable except for some very coarse measures of input use in 1991. Small differences in the sampling method, farm definition and the type of data collected warrants caution when comparing the three waves. In what follows, I briefly explain the two most important differences and how they are addressed. A more detailed description of the data cleaning process can be found in Appendix A-2.

Farms are defined at the level of the household and in the rest of the paper, farms and farming households are used interchangeably[14]. All farms with a total land area below 0.1 ha are removed from the analysis, a cutoff used in the 2002 census. This ensures that the temporal variations we find in the land distribution are not the result of changing farm definitions and that the households considered devote a significant amount of resources to their farming activity.

The first major difference between CAF waves is that only the last one provides a complete

[14] This implies that several operators working independently from each other but living together (e.g. a father and a son) are considered as one farming unit.

enumeration of all the farms in the country. In 1991 and 2002, a sample of barangays was drawn within each municipality. All farming households living in the sampled barangays were then enumerated. Sampling weights allow the computation of municipality-level statistics and are used in all the empirical analysis.

Another difference between CAF waves is that the location of the plot is reported at the barangay level in 1991 and 2012 and only at the larger, municipality level in 2002. This information is important as we are interested in the distribution of agricultural land, which needs to be computed over a given geographic area. As plots are usually located within walking distance from the place of living, we could run the analysis based on the residence. However, this approach is problematic for two reasons. First, when we speak of land distribution, we are intuitively refering of the distribution of the land located in the area of study, not of the land farmed by households living in that area. Second, farms cultivated by people living far from their plots or extending beyond administrative boundaries, are likely to be systematically different from the others. For example, agricultural land distribution in urban areas is not a relevant issue, whereas absentee landlords living in urban areas may have a non-trivial effect on the land distribution where their farms are located. For this reason, land distribution measures are computed based on the physical location of the plot and not on the residence of its operator. This analysis is carried out at the municipality level as this is the lowest level reported in the three waves[15].

The CAF also reports the land tenure status of each plot, which I divide between ownership (full ownership, owner-like possession and various forms of community ownership) and tenancy (rental, leasehold, rent free occupation). When the farmer is a tenant, we do not have any information regarding the owner of the plot. Indicators of land inequality therefore measure *landholding* inequality and not land *ownership* inequality[16].

Land distribution across farms

The distribution of agricultural landholdings in the Philippines is described in Table 2.1. The total land devoted to agriculture increased over the first decade from 8.6 to 9.6 million ha and then strongly decreased in the second decade to 7.5 million ha. This pattern is driven by a

[15] In addition, the incompleteness of the CAF1991 prevents from computing barangay-level statistics based on plot location. Indeed, we systematically miss the information from households living in non-sample barangays. For non-sample barangays, this means that we only have information on the land cultivated by outsiders. In sampled barangays, we potentially miss many of the outsiders. As farms spreading over administrative boundaries are likely to differ systematically from the others, this would create biases in our land distribution measures. Taking the plot municipality instead solves this problem as all municipalities are enumerated.

[16] As noted by Vollrath (2007), landholding inequality matters for efficiency while land ownership inequality is more relevant from an equity perspective

strong increase in farm number between 1991 and 2002 and a steady decrease in average farm size over the whole period, which was probably driven by the land reform. In addition, total population strongly increased over the period, from 60 to 92 million inhabitants, while the share of rural population remained relatively constant, around 50%. This strong demographic expansion increased the pressure on land and may also explain part of the decline in farm area.

Table 2.1: Summary statistics of national land distribution

	1991	2002	2012
Agricultural area (million ha)	8.57	9.56	7.56
Number of farms	3.76 million	4.8 million	4.55 million
Average farm size (ha)	2.28	1.99	1.64
Landholding Gini	0.590	0.576	0.606
Share top 1%	18.73%	15.34%	19.68%
Share top 10%	46.85%	44.86%	48.02%
Share bottom 50%	13.10%	13.74%	12.32%
Share tenanted land	34.07%	31.19%	27.80%
Share tenanted farms	31.01%	25.30%	25.75%
Population (million)[a]	60.703	75.698	92.100
Share of rural population[a]	51.3%	48.9%	50.9%

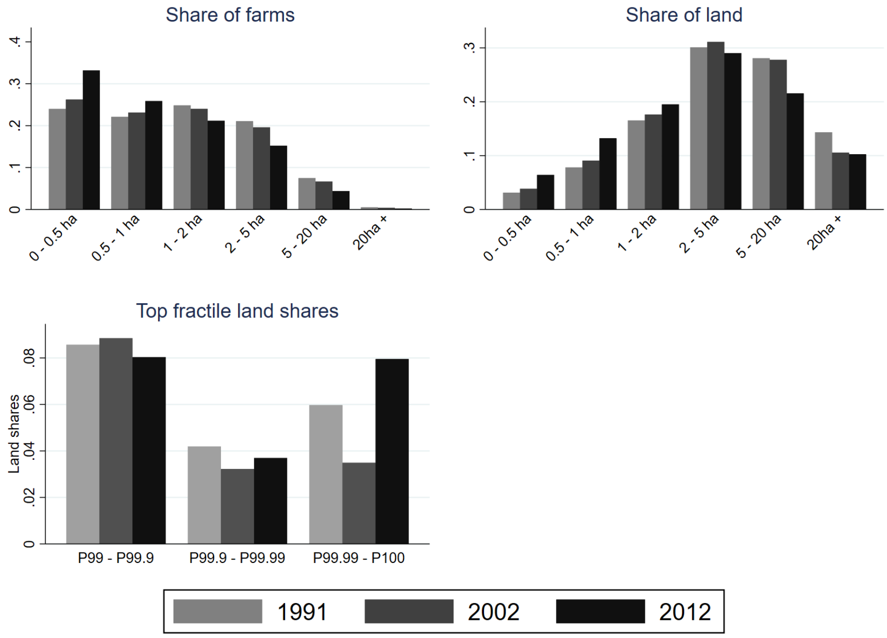
[a] Figures from the Population Censuses of 1990, 2000 and 2010.

Land inequality measures also exhibit a non-linear pattern, decreasing in the first decade and then increasing to levels higher than in 1991. The Gini coefficient – the most commonly-used inequality indicator – is 0.606 in 2012, up from 0.590 in 1991 and 0.576 in 2002. Such levels are high for the ASEAN region but remains below those recorded in Latin American countries (Guereña, 2016). The share of land occupied by different fractiles, shows a very similar pattern of decreasing inequality between 1991 and 2002 which is reversed between 2002 and 2012. At the end of the period, farms in the top percentile (decile) control almost 20% (50%) of the land, a share that has increased by more than 4 pp (3pp) since 2002. At the other end of the distribution, the 50% smallest farms occupy 12.3%, down from 13.74% in 2002.

To illustrate the changes in the landholding distribution, Figure 2.2 presents the temporal evolution in the number of farms and total farm area by land size category. Over time, the share of small farms (< 1ha) increases while the share of farms above 1 ha decreases. The share of land occupied by each category follows a similar pattern except that the decrease only starts after 2 ha. This may be due to the land reform which redistributed land to smallholders.

In the right tail of the distribution, the share of land occupied by farms above 20 ha remains stable between 2002 and 2012, despite a steady decrease in their numbers (from 0.38% of farms in 2002 to 0.21% in 2012), which indicates an increase in the size of very large farms. This is

Figure 2.2: Farm size and land share distribution



confirmed by the last graph which shows the share of land by fractile at the top of the distribution. While it remains relatively stable up to P99.99, the last 0.01% more than doubles its share between 2002 and 2012.

Finally, the share of tenanted land decreases steadily over the two decades while the share of tenanted farms declines sharply between 1991 and 2002 and then remains stable around 25%. This indicates that land ownership inequality exhibit a different pattern than landholding inequality.

Inequality decomposition and municipality-level land inequality

Since land is an immobile asset, it is expected that most of the inequality is to be found at the very local level. Intuitively, farmers need to live close to their farms either because they work in them or because they need to be able to monitor their workers. It is therefore not possible for large farmers to concentrate in specific areas in the same way that wealthy individuals live in the same neighborhoods. In the following, I compute the share of total inequality that can be attributed to within-municipality inequality, using the General Entropy (GE) index (also known as Theil's index - see Appendix B-2 for the technical details of the decomposition).

As expected, the results of this decompositions reported in Table 2.2 show that within-municipality inequality accounts for a very large share, around 80%, of total land inequality. The remaining between-municipality component comes from two sources. First, from differences in area and population density, which might reflect differences in soil fertility as small farms are only likely to be profitable in productive areas. Second, from farms occupying land across municipal boundaries. Indeed, if a farm is located on two municipalities, it will counted as one farm in the national measure but will be split into two in the municipal measure. How land distribution evolves at the local level therefore appears as an important contributor to national land inequality dynamics.

Table 2.2: Landholding inequality decomposition

		1991	2002	2012
Theil's T	Total	0.996	0.804	1.134
	Within municipality	0.785	0.686	0.953
		78.81%	85.32%	84.04%
	Within barangay			0.761
				67.11%
Theil's L	Total	0.672	0.636	0.727
	Within municipality	0.526	0.523	0.588
		78.27%	82.23%	80.88 %
	Within barangay			0.514
				70.70%

Table 2.3: Summary statistics of municipality-level landholding distribution

		(1)		(2)		(3)
		1991		2002		2012
Variable	N	Mean/SD	N	Mean/SD	N	Mean/SD
Total land area	1418	5690.422	1552	5926.297	1545	4828.659
		(6380.557)		(6102.793)		(5580.705)
Nb of farms	1418	2593.834	1552	3051.139	1545	3033.344
		(2153.945)		(2509.451)		(2728.821)
Gini	1418	51.256	1552	51.848	1545	52.285
		(9.689)		(8.933)		(9.971)
Share top 1%	1418	13.648	1552	12.901	1545	12.710
		(11.747)		(9.666)		(11.246)
Share top 10%	1418	40.004	1552	40.239	1545	40.239
		(10.918)		(9.423)		(10.542)
Share bottom 50%	1418	16.752	1552	16.395	1545	16.010
		(4.670)		(4.490)		(5.116)
Share tenanted land	1418	35.640	1552	34.154	1545	31.427
		(16.025)		(15.860)		(16.168)
Share tenanted farms	1418	28.810	1552	24.794	1545	26.564
		(16.126)		(14.979)		(15.008)

Most of the empirical analysis of this paper focuses on the difference in municipality-level inequality between 2002 and 2012. In order to ensure that any difference we find is not driven by the sample composition, I restrict the 2012 data to the barangays enumerated in 2002 when computing municipality-level indicators. In addition, municipalities with less than 50 ha of agricultural land are dropped from the analysis. This restricts the sample to areas where farming is of some importance. Metropolitan Manila (National Capital Region) is also excluded from the analysis, as it is mostly urban. This sample restriction alleviates the issue of outliers driving our results and are applied throughout the rest of the empirical analysis. Table 2.3 reports the descriptive statistics of municipality-level land distribution. Total land area and the number of farms follow similar a pattern on average as at the national level. The inequality measures, on the other hand, behave differently, as the Land Gini increases steadily over time, while it decreased at the national level during the first decade. More surprisingly, the average top 1% share decreases over time and the top 10% share remains remarkably stable. This suggests that the increase at the national level was driven by relatively larger municipalities.

Maps of municipality-level Land Gini for the three waves of data are reported in Appendix C-2. Spatial correlation appears relatively limited, except for some regions characterized by strong land inequality such as the island of Negros in 1991 and central Mindanao in 2012. Temporal persistence, on the other hand, is high as unequal regions in 1991 tend to be more unequal in 2002 and 2012. The increase in land inequality over time is reflected by the darker colors in 2012.

2.3.2 Additional data sources

Aside from the CAF data, the analysis presented in this paper relies on additional data sources. First, the Census of Population (CP), available for the years 2000 and 2010, gives the municipality population and allows me to compute the share of rural population and the share of farming households. Second, GIS data from various sources is used to complement farm- and household-level data.

- Crop suitability measures come from the FAO Global Agro-Ecological Zones (GAEZ) database, which predicts yields for each crop based on soil, climate conditions and agricultural practices at a resolution of 10km per pixel. This measure will be further detailed in the section presenting the empirical strategy[17].
- Net Primary Productivity, obtained from NASA Earth Observatory (NEO), shows the difference between the carbon dioxide taken in by plants through photosynthesis and that released through respiration and is used as a proxy for vegetation growth[18].

[17]The data used in the analysis comes from the v3 of the GAEZ.

[18]It is available at a monthly frequency since 2000 with a pixel size of 10km. Due to strong seasonal variation in the measure, I take the average over the three years surrounding the CAF data collection (2001-2003 for CAF 2002 and 2011-2013 for CAF 2012)

- Geophysical measures such as altitude and ruggedness are computed thanks to the Space Shuttle Radar Topography Mission (SRTM) digital elevation model, which has a pixel size of 90m.
- Tree cover in 2000 and 2010 is obtained from the Hansen et al. (2013) global data which provides the tree cover share for each 30-m pixel.
- Night lights data come from the Defense Meteorological Program Operational Line-Scan System (DMSP-OLS), with a pixel size of 1km.

Each administrative area in the Philippines is uniquely identified by a Philippine Standard Geographic Codes (PSGC). These codes are used to match the different waves of CAF and CP data over time and with GIS data, using administrative boundaries shapefiles, obtained from the UN Office for the Coordination of Humanitarian Affairs (OCHA). Manual matching by names was carried out in order to increase the quality of the match[19]. Finally, the last part of the paper uses additional data on poverty, income, employment and terrorist activity, which is presented in the relevant sections.

2.4 Identification strategy

This paper focuses on the period following the introduction of genetically modified corn in the Philippines, which took place in 2003. We therefore have a first census conducted twelve years before (CAF 1991), another one conducted one year before (CAF 2002) and the last one ten years later (CAF 2012). The main empirical analysis compares the two latest censuses, while using the first one to control for historical differences that may be correlated with the treatment.

Because the data does not distinguish between different corn varieties, we do not directly observe GM corn adoption. It is therefore not possible to look at the direct impact of adoption on land use and distribution, regardless of the endogeneity of technology adoption. To overcome this issue, I use the empirical strategy developed by Bustos et al. (2016) in their paper on structural transformation in Brazil. This strategy exploits the fact that differences in soil and weather characteristics lead to differences in potential gain from adopting the technology, thereby creating exogenous cross-sectional variation in adoption and in treatment intensity. The measure of this exogenous potential gain from GM crop cultivation is obtained from the FAO GAEZ database, which predicts yields for each crop based on soil, climate conditions and agricultural

[19] In case of split/merge between municipalities over the course of the study period, I always aggregate barangays to form the largest stable entities. I am grateful to Andres Ignacio from ESSC for providing me his match between the PSGC 2000 and PSGC 2010.

practices. Crucially for our strategy, those agricultural practices include various degrees of input level intensity. The low level of inputs implies that "*the farming system is largely subsistence based. Production is based on the use of traditional cultivars (...), labour intensive techniques, and no application of nutrients, no use of chemicals for pest and disease control and minimum conservation measures*". The high input level implies that "*[c]ommercial production is a management objective. Production is based on improved or high yielding varieties, is fully mechanized with low labour intensity and uses optimum applications of nutrients and chemical pest, disease and weed control*". The difference in potential yield between high and low levels of inputs therefore serves as a proxy for the profitability gain from improved agricultural technology - i.e. GM corn adoption. Importantly, this measure is only based on exogenous soil and weather characteristics and not on observed yields, which are endogenous to the technology adoption[20]. The variation used to identify the effect is therefore the potential increase in yields, which we assume to be correlated (although not perfectly) with the actual yield gain[21]. Although GM corn introduction is not the only explanation for the increasing corn yields over the period, it is the most important technological change and is therefore likely to have largely contributed to it. For the sake of readability, in the rest of the paper, when we talk about the potential gain from GM corn, we are therefore referring to the overall change in profitability, which is largely driven by the new technology.

Summary statistics of the corn potential yields, with different levels of input, are presented in Table 2.4. They are expressed in tons per hectare, with the last row presenting the difference between high and low levels of inputs. Moving from low to high level of inputs more than triples the potential yield, with some regions gaining as much as four times the average. These values are lower than the average actual yields given that they are computed over the entire country, including the areas not suitable for agriculture. The geographical distribution of the potential gain in corn yield is presented in Figure 2.3.

Table 2.4: Summary statistics of corn potential yield

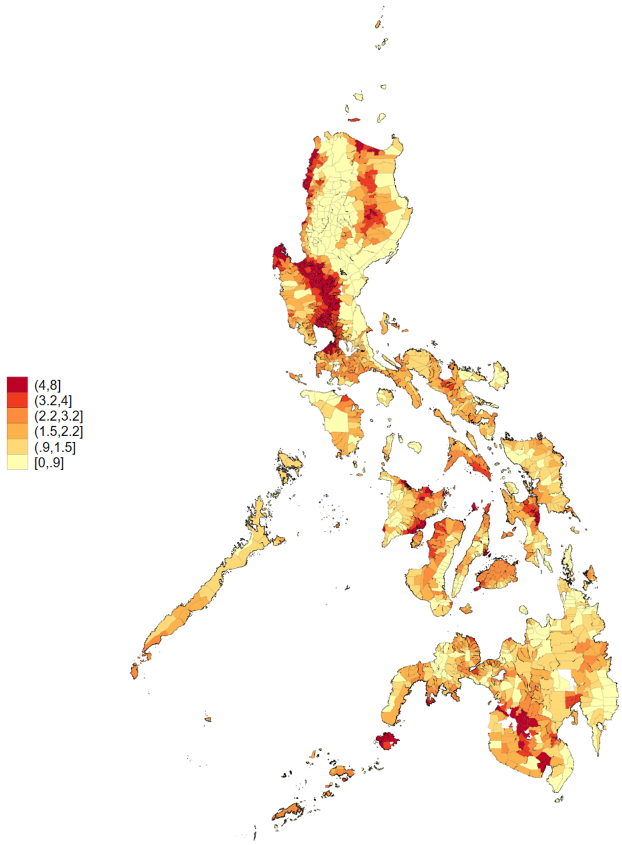
	Mean	Std Dev	Min	Max
Low input level	0.823	0.452	0	2.116
High input level	2.827	1.585	0	9.805
High - Low	2.004	1.268	0	7.997

Source: FAO GAEZ

[20] Given that most of the corn cultivation in the Philippines is rain fed, we use the data under this water source regime.

[21] In a cross-country analysis, Alvarez and Berg (2019) show that potential yield is positively correlated with actual yield, especially so in East Asia and Pacific region (R^2=0.46).

Figure 2.3: Geographical distribution of potential corn yield gain



This estimation strategy can be formalized with the following equation:

$$y_{it} = \delta_i + \delta_t + \beta A_{it} + \epsilon_{it}, \tag{2.1}$$

where y_{it} is an outcome variable that varies across municipality i at time t. δ_i and δ_t are respectively municipality and year fixed effects. A_{it} is the measure of potential corn yield, and takes the value under low level of inputs before 2003 and under high level of input after[22]. In the main specifications, the analysis is restricted to the years 2002 and 2012. In that case, the fixed effect equation is equivalent to the first difference model

$$\Delta y_i = \Delta\delta + \beta\Delta A_i + \gamma_1 X_i + \gamma_2 Z_{i,1991} + \Delta\epsilon_i \tag{2.2}$$

β, our coefficient of interest, reports how the outcome variable changes between two periods following an increase in potential yield due to the introduction of the new agricultural technology. Estimates of β have a causal explanation provided that changes in potential yields are

[22]The agricultural sector obviously did not change from being completely traditional to being fully mechanized with the introduction of GM corn seeds. The results hold when intermediate levels of inputs are used either in the pre- or in the post-adoption period

independently distributed from the outcome variable once we control for all time-invariant characteristics and common shocks. If areas that benefited more from the technology were on different trends from those who benefited less, this assumption would be violated and the estimates would be biased. To alleviate this concern, I include time-invariant geographical controls X_i and socio-economic indicators computed from the CAF 1991, $Z_{i,1991}$.

X_i include the log of municipal area and, in some specifications, elevation, ruggedness, longitude and latitude. Controlling for these last four variables is however problematic as they enter the formula used to compute the potential yield A_i. The interpretation of the coefficient β is therefore going to be different when they are included. On the other hand, excluding them may bias the estimates as they are correlated to other determinants of land inequality trends, such as market access or the occurrence of natural disasters. In a robustness check, I show that the results hold when each variable is added individually.

Trends in land inequality and technology adoption are likely to differ depending on baseline land scarcity. In frontier regions where new land can be cleared, we would expect lower agricultural productivity and different land market dynamics compared to places where all the land is already under cultivation. For this reason, $Z_{i,1991}$ includes the share of total municipal area dedicated to agriculture in 1991. Moreover, over the study period, corn prices have experienced a sharp increase, being multiplied by three between 2002 and 2012 (IMF, 2021). This implies that regions where corn production is more widespread are on a different trend. As these regions are likely to be those with a high suitability, I also control for the share of corn in total agricultural area in 1991. Finally, night light intensity in 1992 controls for a combination of initial population density and economic development[23].

2.5 Results

2.5.1 First-stage effect

The empirical strategy is based on the assumption GM corn introduction had a stronger impact in areas which had higher potential gains. Unfortunately, the agricultural census does not distinguish between different corn varieties and does not provide output information. While

[23] In a recent paper, Gibson et al. (2020) challenge the ability of night lights data to accurately measure economic development in rural areas. They show that this data is particularly unreliable when aggregated over small areas - due to blurring and overglow - and for temporal comparisons - because of satellite change and sensor adjustment to moon light. Given that we aggregate the data at the municipality level and only use one cross-section, these concerns are unlikely to bias our results. Moreover, Gibson et al. (2020) show that night lights are more correlated with economic activity in urban areas, while sparesly populated rural areas remain dark even after electrification. Our municipality-level night lights measure therefore captures the development of the urban center and acts as a proxy for the local market.

it is therefore impossible to provide strong evidence that adoption and yield gains were higher in more suitable areas, the present section, discusses and presents suggestive evidence of such a first stage effect[24]. Note that a strong positive correlation between GM corn adoption and potential yield is actually not needed to identify the effect. As previously explained, the technology was rapidly and widely adopted by the farmers, leading to a strong increase in yields. Assuming that the adoption rate was the same over the entire country - and therefore uncorrelated with crop suitability - we would still expect more suitable regions to be more impacted by the new technology.

Figure 2.4: Geographical distribution of corn cultivation and GM corn adoption in 2014

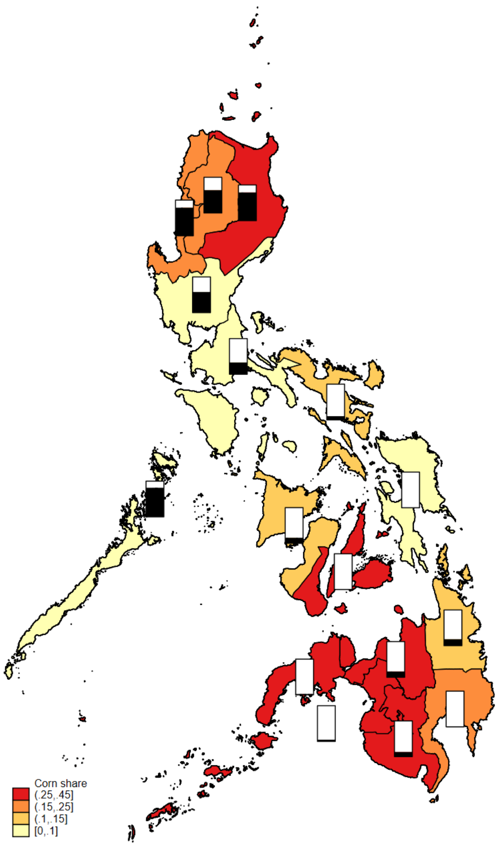


Figure 2.4 presents the share of agricultural area devoted to corn in each region in the 2012 census, along with the share of GM corn in 2014. To the best of my knowledge, this is the most disaggregated data on GM corn adoption, coming from the Department of Agriculture, which is only available at the regional level for the years 2003-2009 and 2014. Adoption is particularly high in Luzon, which coincides with the high potential yield gain documented in Figure 2.3. In the Visayas and Mindanao, adoption is almost inexistant. Official agricultural data however

[24]Bustos et al. (2016) are able to directly address this question and find that the soy potential yield gain is positively correlated with the change in GM soy area share and negatively correlated with the change in non-GM soy area share (Table 6).

understimate the actual adoption of improved corn seeds in these regions as this is precisely where the illegal *sige-sige* seeds can be found. Adoption of those illegal seeds during our study period is likely to be highest in Southern Mindanao, its alleged origin region, which is where potential yield gain is also high.

I now turn to the impact of the new technology on corn cultivation. The results of estimating Equation 2.2 on the importance of corn cultivation are presented in Table 2.5. Columns 1 and 3 document a positive correlation between potential gain and the importance of corn cultivation measured as the difference in the log of corn area and the change in the share of agricultural land devoted to this crop. Adding control variables in columns 2 and 4 does not affect the result and even increases the point estimate for corn area. The magnitude of the coefficients imply that a one-standard deviation increase in potential yield leads to a 0.13-standard deviation increase in corn share, corresponding to an increase in 1.5 percent or 72 hectares for the average municipality. This brings credibility to the estimation strategy as farmers react differently to the technology depending on the soil and weather characteristics of their land.

Table 2.5: Productivity change and corn cultivation

VARIABLES	(1) Δ Corn area (Log)	(2)	(3) Δ Corn share	(4)
Potential gain from GM corn	0.071***	0.120***	0.012***	0.012***
	(0.027)	(0.029)	(0.003)	(0.003)
Municipality area (Log)		-0.028		-0.017***
		(0.041)		(0.004)
1991 Ag area (Share)		-0.402***		-0.073***
		(0.135)		(0.014)
1991 Corn share		-0.054		-0.060***
		(0.112)		(0.013)
1992 Night lights (Log)		-0.089***		-0.005***
		(0.027)		(0.002)
Observations	1,520	1,434	1,520	1,434
R-squared	0.005	0.020	0.019	0.090

Changes in dependent variables are calculated over the years 2002 and 2012. Potential gain from GM corn is the difference between potential rainfed corn yield with high and low levels of inputs from the FAO-GAEZ. The unit of observation is the municipality. Robust standard errors in parentheses.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 2.6 presents the correlation between the potential gain from GM corn and agricultural productivity. Because the CAF do not contain information on output or productivity, I use the the Net Primary Productivity (NPP) as a proxy. This satellite-based indicator measures the difference between the carbon dioxide taken by plants through photosynthesis and the carbon dioxide emitted through respiration. It therefore corresponds to the flow of carbon stocked in plants over a given period and is used as a proxy for vegetation growth, crop yield, forest production etc. The dependent variable is the change in NPP between 2001-03 and 2011-13. Because of to strong seasonal variation in the measure, I take the average value over the three years surrounding the CAF data collection. Column 1 documents a positive relationship between potential yield and productivity when no control variable is included. This positive effect decreases and becomes insignificant when we control for other determinants of NPP, such as the change in tree cover and in crop shares. The interaction between the change in corn share and the potential yield gain, in columns 3 and 5, yield positive and statistically significant coefficients. This provides suggestive evidence that the new technology did lead to an increase in corn production in more suitable areas.

Table 2.6: Productivity change and Net Primary Productivity

VARIABLES	(1)	(2)	(3)	(4)	(5)
Potential gain from GE corn	0.582**	0.127	0.031	0.418	0.334
	(0.251)	(0.294)	(0.310)	(0.315)	(0.330)
Potential gain * Δ Corn share			4.098**		3.999*
			(2.067)		(2.096)
Δ Tree cover (Share)		0.268**	0.277**	0.256**	0.266**
		(0.108)	(0.108)	(0.107)	(0.107)
Δ Corn (share)		-4.618	-14.144**	-3.784	-13.085**
		(3.663)	(5.929)	(3.790)	(6.049)
Observations	1,520	1,520	1,520	1,506	1,506
R-squared	0.003	0.052	0.055	0.066	0.068
Crop controls	NO	YES	YES	YES	YES
Additional controls	NO	NO	NO	YES	YES

Dependent variable is the difference in NPP average over the 2001-03 and the 2011-13 periods. Potential gain from GM corn is the difference between potential rainfed corn yield with high and low levels of inputs from the FAO-GAEZ. The unit of observation is the municipality.
Crop controls include the change in crop share for corn, rice, sugarcane, coconut, banana, other temporary and other permanent crops. Additional controls include log of municipality area, log-change in farm area, number of farms, population, night light intensity and the change in rural population share.
Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

2.5.2 Land inequality

We now turn to the effect of agricultural productivity on the landholding distribution. The first two columns use the percentage point change in landholding Gini as dependent variable and show that this measure is positively correlated with the profitability of the technology. When we control for municipal area and differential trends based on agricultural importance and economic development, the coefficient remains relatively stable but loses some significance. Similar results are obtained in the last two columns which use the land share of the top decile as dependent variable. To improve the readability of the tables, the dependent variables are expressed in percentage points, i.e. ranging from 0 to 100 instead of 0 to 1. Results with control variables imply that a one-standard deviation increase in potential yield leads to a 0.6-point increase in the Gini index and a 0.7-percentage point increase in the top 10% share.

Table 2.7: Productivity change and landholding inequality

	(1)	(2)	(3)	(4)
VARIABLES	Δ Gini		Δ Share top decile	
Potential gain from GM corn	0.531***	0.459**	0.583***	0.554**
	(0.191)	(0.210)	(0.214)	(0.239)
Municipality area (Log)		1.074***		1.212***
		(0.301)		(0.346)
1991 Ag area (Share)		3.624***		2.737**
		(0.964)		(1.104)
1991 Corn share		0.540		1.436
		(1.044)		(1.191)
1992 Night lights (Log)		0.362**		0.418**
		(0.183)		(0.203)
Observations	1,520	1,434	1,520	1,434
R-squared	0.006	0.025	0.006	0.023

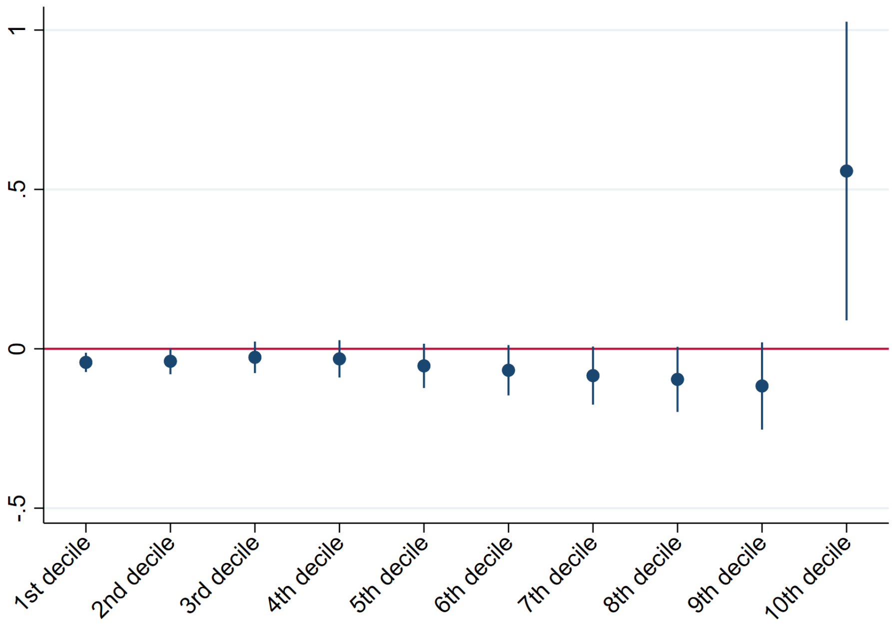
Changes in dependent variables are calculated over the years 2002 and 2012. Potential gain from GM corn is the difference between potential rainfed corn yield with high and low levels of inputs from the FAO-GAEZ. The unit of observation is the municipality. Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

The impact of the new technology on the landholding distribution is presented in Figure 2.5, which replicates the last column of Table 2.7 using each decile land share as outcome variable. The change in inequality appears to be driven by the increase in the land share of the top decile and a decrease of all the other deciles, although this last effect is not always statistically significant.

2.5.3 Mechanisms

A change in the land distribution can be explained by three potential mechanisms : (i) a reallocation of the previously-farmed land between farmers, (ii) an expansion (or contraction) of the farm area and (iii) an increase (or decrease) in the number of farms. These mechanisms are not mutually exclusive as a new farm can encroach on new land, thereby also increasing

Figure 2.5: Impact of productivity change on land share for each decile



Each point represents the coefficient of potential gain in GM corn from a different regression, using the change in land share devoted to each decile as dependent variables, similar to column 4 of Table 2.7.

agricultural area.

To disentangle the different mechanisms, Table 2.8 first documents the correlation between agricultural productivity and the change in farm area and in farm number. Column 1 shows a weakly significant, positive correlation between the potential gain from GM corn and agricultural area. The magnitude of the coefficient implies that a one-standard deviation increase in potential productivity leads to a 3.17% increase in cultivated area, corresponding to 153ha for an average municipality. This however does not necessarily imply agricultural land *expansion* in more affected municipalities as this effect is a relative one, comparing places more and less affected by the technology. As the general trend over the period is a contraction in agricultural land, it is possible that the positive effect corresponds to a smaller decrease in farm area. Column 2 shows that the farm number does not react to the change in agricultural productivity and is therefore not driving the relative expansion.

The rest of the table uses the change in Land Gini as dependent variable, with column 3 replicating the result from Table 2.7. Columns 4 and 5 respectively control for the change in farm area and that in farm number and column 6 includes both. The coefficient of potential gain from GM corn decreases and becomes insignificant when controling for the change in agricultural area. On the other hand, it does not change when controling for the change in farm number, which was expected given the non significant result in column 2. Adding both controls together further reduce the point estimate, which becomes statistically different from that of column 3 at the 10% level. This indicates that land reallocation between existing farmers does not play an important role and that the increase in land inequality is driven by municipalities that experienced a relative increase in agricultural land and a relative decrease in the number of farms. Using the share of top decile instead of the Gini index as dependent variable leads to very similar results (Table D-2.1 in the Appendix).

Table 2.8: Productivity change and landholding inequality - Mechanisms

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Δ Farm area (Log)	Δ Farm nb (Log)		Δ Gini		
Potential gain from GM corn	0.026*	-0.011	0.459**	0.317	0.467**	0.101
	(0.013)	(0.013)	(0.210)	(0.205)	(0.210)	(0.192)
Municipality area (Log)	0.076***	0.025	1.074***	0.660**	1.058***	0.462*
	(0.019)	(0.018)	(0.301)	(0.302)	(0.303)	(0.280)
1991 Ag area (Share)	0.133**	0.105*	3.624***	2.891***	3.554***	2.995***
	(0.062)	(0.061)	(0.964)	(0.912)	(0.970)	(0.866)
1991 Corn share	-0.133**	-0.049	0.540	1.270	0.574	1.575*
	(0.052)	(0.047)	(1.044)	(0.982)	(1.048)	(0.899)
1992 Night lights (Log)	-0.067***	-0.051***	0.362**	0.728***	0.396**	0.687***
	(0.012)	(0.012)	(0.183)	(0.180)	(0.187)	(0.176)
Δ Farm area (Log)				5.491***		10.553***
				(0.690)		(0.889)
Δ Nb farms (Log)					0.671	-7.439***
					(0.586)	(0.879)
Observations	1,434	1,434	1,434	1,434	1,434	1,434
R-squared	0.047	0.029	0.025	0.132	0.026	0.215

Changes in dependent variables are calculated over the years 2002 and 2012. Columns 3-6 use the change in landholding Gini index as dependent variable. Potential gain from GM corn is the difference between potential rainfed corn yield with high and low levels of inputs from the FAO-GAEZ. The unit of observation is the municipality.
Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Understanding whether this relative increase in farm area corresponds to an actual farmland expansion or to a smaller contraction is an important question from an environmental perspective. To address this issue, I re-estimate column 4 of Table 2.8, transforming the change in farm area from a continuous variable to a set of binary variables, each one corresponding to a different quintile of the distribution. Since 77% of municipalities experience a decrease over the decade, only the last quintile is associated with an increase in agricultural area as[25]. As Table D-2.2 in Appendix shows, the potential gain coefficient decreases strongly when we only control for the first two quintile categories, i.e. when we differentiate municipalities that experienced a strong decrease in agricultural land from the rest. In the opposite, controlling for the last two quintiles - those where there was no change or an increase - does not affect the coefficient of interest. This indicates that the positive correlation between agricultural productivity and land inequality is not driven by an actual expansion of agricultural land, but by a smaller contraction.

[25] The distribution of the change in agricultural area is presented in Figure D-2.1 in Appendix.

2.5.4 Heterogeneous effects

Modern input and credit penetration

A common story in anti-GMO advocacy is that of predatory lending resulting in farmers taking on too much debt and eventually defaulting. Their lands are then confiscated by the moneylender or they are forced to sell them (Masipag, 2013). As a result, moneylenders or other better-off households are able to increase their landholding, resulting in an increase in land inequality[26]. The CAF data does not provide enough information to precisely test this story but can still give us some suggestive evidence. Indeed, the CAF 1991 asked farming households whether they contracted a credit (formal or informal) over the preceding year. Aggregated at the municipality level, this question gives us a measure of credit penetration 10 years before GM corn was introduced[27]. If such claims were true, we would expect to see a stronger effect in municipalities where credit availability is higher. The second column of Table 2.9 repeats the analysis of the Land Gini, controlling for the degree of credit penetration in 1991 and interacting it with our potential gain measure. None of the additional coefficients are significant, implying that credit may not be an important mechanism.

However, credit penetration is potentially correlated with other agricultural development measures, which may also play a role in our story. The CAF 1991 also asked farmers whether they were cultivating high-yield varieties (HYV) over the past year. Aggregating these responses at the municipality level gives us an indicator of the modernity of agricultural practices ten years before treatment. As Column 3 shows, the effect of potential gain on the Land Gini is highest in municipalities with low HYV use in 1991 and is equal to zero in areas where improved seeds were already widely adopted.

This result first suggests that our main result is driven by municipalities that were lagging behind in the modernization of their agriculture, and therefore where the potential for yield improvement was the largest. Second, since credit and HYV are positively correlated, the results presented in Column 2 might be biased downwards (and those of Column 3 upwards). Indeed, when we allow for different trends depending on both credit and HYV penetration, we respectively find a positive and negative significant coefficient for the interaction terms (Col-

[26]This claim is not contradicted by Figure 2.5 which shows little effect of GM corn at the bottom of the distribution. Indeed, if farmers sell their entire farm, they are removed from the land distribution.

[27]Note that the effect of financial development is a priori not clear. When it is inexistant, only a few wealthy farmers will have the opportunity to adopt the technology and reap its benefits, which should worsen inequality. A high level of credit availability therefore implies that more farmers have access to the technology and its higher yields. In this case, we would expect to see a low level of inequality in municipalities with better access to financial services.

Table 2.9: Landholding Gini and productivity change - Historical cultivation practices

VARIABLES	(1)	(2)	(3)	(4)	(5)
Potential gain from GM corn	0.459**	0.340	1.028**	0.796*	0.846*
	(0.210)	(0.410)	(0.441)	(0.459)	(0.434)
Credit 1991		-0.249		-3.030*	-3.048*
		(1.473)		(1.755)	(1.733)
Pot. yield * Credit 1991		0.225		1.956***	1.616**
		(0.623)		(0.729)	(0.727)
HYV 1991			2.328	4.318**	2.800
			(1.530)	(1.839)	(1.814)
Pot. yield * HYV 1991			-1.165*	-2.524***	-2.271***
			(0.670)	(0.809)	(0.781)
Municipality area (Log)	1.079***	1.071***	1.053***	1.021***	0.673**
	(0.302)	(0.306)	(0.302)	(0.304)	(0.304)
1991 Ag area (Share)	3.673***	3.655***	3.580***	3.242***	2.428***
	(0.965)	(0.966)	(0.972)	(0.973)	(0.933)
1991 Night lights (Log)	0.357**	0.360**	0.353*	0.361**	0.702***
	(0.180)	(0.181)	(0.182)	(0.182)	(0.179)
1991 Corn share	0.567	0.632	0.529	0.654	0.945
	(1.044)	(1.066)	(1.057)	(1.058)	(0.992)
Δ Farm area (Log)					5.562***
					(0.706)
Observations	1,435	1,435	1,435	1,435	1,435
R-squared	0.025	0.026	0.028	0.032	0.140

Dependent variable is the change in landholding Gini index, calculated over the years 2002 and 2012. Potential gain from GM corn is the difference between potential rainfed corn yield with high and low levels of inputs from the FAO-GAEZ. The unit of observation is the municipality.
Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

umn 4). Moreover, this mechanism remains significant when controlling for the change in farm area (Column 5). The positive effect of agricultural productivity on land inequality is therefore higher in municipalities with better access to financial services. However, this only brings weak supportive evidence to the "default and confiscation" narrative as credit availability is likely to increase adoption and therefore act as proxy for treatment intensity. I am therefore unable to rule out alternative mechanisms linking credit, productivity and inequality.

Geographical heterogeneity

I now look at heterogeneous effects based on the location of municipalities in order to get a better understanding of the geographical distribution of our main effect. The first three columns of Table 2.10 allow for differential effects between coastal and interior municipalities. This is motivated by the fact that coastal municipalities are likely to be different from the rest on many levels (exposure to climate events, transportation, communication etc.). The correlation between agricultural productivity and land inequality is only significant for coastal municipalities, and disappears when controling for the change in farm area and in farm number. However, the coefficient is not statistically different from the coefficient for Potential gain * Interior municipalities.

Table 2.10: Landholding Gini and productivity change - Geographical heterogeneous effects

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Potential gain * Coastal municipality	0.625**	0.605**	0.329			
	(0.269)	(0.283)	(0.248)			
Potential gain * Interior municipality	0.401	0.173	-0.255			
	(0.273)	(0.277)	(0.268)			
Potential gain * Visayas				0.799**	0.609	0.327
				(0.388)	(0.413)	(0.350)
Potential gain * Mindanao				1.169**	1.097**	1.049**
				(0.500)	(0.510)	(0.420)
Potential gain * Luzon				0.401	0.252	-0.131
				(0.251)	(0.261)	(0.247)
Municipality area (Log)		1.037***	0.453		0.923***	0.310
		(0.301)	(0.281)		(0.302)	(0.283)
1991 Ag area (Share)		3.976***	3.338***		2.795***	1.625*
		(0.956)	(0.864)		(0.977)	(0.887)
1991 Corn share		0.148	1.276		-0.240	0.491
		(1.025)	(0.894)		(1.112)	(0.935)
1992 Night lights (Log)		0.364**	0.684***		0.455**	0.833***
		(0.182)	(0.176)		(0.183)	(0.177)
Δ Farm area (Log)			10.476***			10.678***
			(0.889)			(0.897)
Δ Nb farms (Log)			-7.460***			-7.408***
			(0.876)			(0.876)
Coastal municipality	-1.866**	-2.460***	-1.935**			
	(0.946)	(0.934)	(0.852)			
Visayas				-0.619	-0.993	-0.072
				(1.046)	(1.090)	(0.987)
Mindanao				0.865	0.120	0.018
				(1.218)	(1.223)	(1.099)
Observations	1,520	1,434	1,434	1,520	1,434	1,434
R-squared	0.012	0.034	0.218	0.020	0.033	0.225

Dependent variable is the change in landholding Gini index, calculated over the years 2002 and 2012. Potential gain from GM corn is the difference between potential rainfed corn yield with high and low levels of inputs from the FAO-GAEZ. The unit of observation is the municipality.
Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

The last three columns presents heterogeneous effect by island group: Luzon (North), the Visayas (center) and Mindanao (South). Without additional controls, the positive effect of agricultural productivity on land inequality is significant for the Visayas and Mindanao (although none is statistically different from the Luzon coefficient). Adding control variables decrease the point estimate for the Visayas but not for Mindanao which remains positive and significant even after controlling for the change in farm area[28]. The increase in inequality due to changes in agricultural productivity is therefore driven by the island of Mindanao and by coastal municipalities.

Figure D-2.2 presents the results obtained when column 5 of Table 2.10 is replicated, allowing a differential effect for each region. These regional heterogeneous effects are then mapped in Figure D-2.3. The results confirm the previous analysis as the four regions with the largest point estimates are located on the island of Mindanao, the effect being strongly different from zero in three of them.

2.5.5 Land ownership inequality

The analysis so far has focused on landholding inequality, i.e. computing the land distribution using operated farm as the basic unit. However, land *ownership* inequality is also an important measure as it is more closely linked to wealth and poverty. Due to data constraints, it is impossible to repeat the analysis using the same inequality measures for land ownership. Instead, we can look at the share of land that is not owned by the household cultivating it. An increase in that measure indicates an increase in land ownership inequality given that land ownership tends to be less equally distributed than landholding. Similarly, an increase in the share of tenanted farms also indicates more ownership inequality. Table 2.11 presents the results obtained by estimating Equation 2.2 using the two aforementioned land ownership measures as dependent variables. The share of tenanted land decreases in municipalities that benefited more from the technology, although this effect loses some significance once we add the control variables (p-value = 0.14). The share of tenanted farms shows similar results, with a positive correlation with the potential gain that becomes insignificant once the control variables are added (p-value = 0.19). Overall this suggests that the increase in landholding inequality is reflected in the land ownership distribution as a smaller proportion of farms own a larger (or similar) share of the land. This may be driven by the land expansion in the last decile of the landholding distribution.

2.6 Robustness tests

2.6.1 Crops, population and economic development

The positive effect of agricultural productivity on land inequality might be the result of a move towards more land intensive crops in municipalities that benefited more from the new tech-

[28]The coefficient for Mindanao also becomes statistically different from the Luzon coefficient, but not from the Visayas coefficient.

Table 2.11: Productivity change and land ownership inequality

	(1)	(2)	(3)	(4)
VARIABLES	Δ Tenanted land		Δ Tenanted farms	
Potential gain from GM corn	-0.613**	-0.465	0.606*	0.464
	(0.282)	(0.315)	(0.314)	(0.353)
Municipality area (Log)		-1.383***		-2.408***
		(0.448)		(0.418)
1991 Ag area (Share)		-5.242***		-8.212***
		(1.577)		(1.533)
1991 Corn share		0.567		-3.251**
		(1.483)		(1.426)
1992 Night lights (Log)		-0.284		-0.047
		(0.291)		(0.286)
Observations	1,520	1,434	1,520	1,434
R-squared	0.003	0.016	0.003	0.053

Changes in dependent variables are calculated over the years 2002 and 2012. Potential gain from GM corn is the difference between potential rainfed corn yield with high and low levels of inputs from the FAO-GAEZ. The unit of observation is the municipality. Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

nology. Corn, however, does not fit this description as it is mostly cultivated by smallholder farmers. As column 2 of Table E-2.1 in the Appendix shows, land inequality decreases when the corn share increases and adding this control increases (not significantly) the potential gain coefficient. Adding the change in land share for other common crops such as rice, sugarcane, coconut and banana does not have a significant impact (column 3).

Another potential explanation might be that people migrated from low to high productivity municipalities. Such a mechanisms is however unable to explain our results as controlling for the change in population in column 4 does not affect our coefficient of interest. Similarly, the effect of agricultural productivity on land inequality is not driven by differential trends in rural-urban migration as controlling for the share of rural population leads to similar results (column 5). Finally, column 6 controls for the change in night light intensity between 2002 and 2012 and shows that the potential gain coefficient remains unchanged. Adding all the additional controls in a single regression leads to similar results. Changes in crop mix, internal migration patterns or economic development are therefore not driving the relationship between productivity and inequality.

2.6.2 Topo-geographical characteristics

The empirical strategy used in this paper relies on a measure of potential yield gain, which is computed using soil and weather characteristics. However, these characteristics may affect the trend in land inequality through other channels than land productivity. For example, elevation and ruggedness determine the availability of transport infrastructure and therefore input availability and market access. Similarly, extreme weather patterns affect the accumulation of physical capital, with consequences for the trend in economic development. On the one hand, omitting these variables from the regression, as has been the case so far, might bias our estimates. On the other hand, if we control for them, the potential gain variable loses part of its substance and it is not clear how to interpret the coefficients.

To address this issue, I re-estimate the main regression for the landholding Gini, adding topo-geographical control variables and present the results in Table E-2.2 in the Appendix. In order to keep some informational value in the potential gain variable, the controls are added individually in each regression. Columns 2 and 3 control for average elevation and ruggedness index. In both cases, the point estimate becomes larger and more significant, indicating that, if anything, the omitted variable bias was pushing our coefficient downwards. Column 4 controls for longitude and latitude, which is strongly correlated with weather patterns, especially extreme weather since tropical cyclones hit the northern half of the country on a yearly basis while missing almost systematically the southern part. The inclusion of these variables does not impact our result. Finally, the last column assumes that trends in land inequality differ at the provincial level and therefore allows for province fixed effects. While the value of the coefficient does not change much, its significance decreases (p-value = 0.156).

2.6.3 Pre-treatment trends

One of the key identifying assumptions in our estimation strategy is that trends in land inequality are uncorrelated with the potential yield gain once we control for municipal area and pre-determined variables. This would be violated if previous productivity growth had already put more profitable areas on different trends. One way to test this hypothesis is to run the same analysis, comparing data from 1991 and 2002, i.e. before the introduction of GM corn. Results of this placebo test are presented in Table E-2.3. Note that, contrary to what we have done so far, municipality-level measures of land inequality are not computed from the same set of barangays given the sampling method of the CAF 1991 and 2002. It is therefore impossible to rule out the fact that the results presented in this table are partly due to sampling differences[29].

[29] The use of sampling weights should however largely alleviate this issue.

When no controls are included, we find an insignificant, negative, correlation between potential yield gain and the change in Gini index or in the top decile land share. This effect slightly increases but remains insignificant when we control for municipal area, agricultural land share, corn share and night light intensity. Similar results are obtained with the land share of the top decile, giving little support for potential different trends before GM seeds introduction.

Table E-2.4 pools the three waves of CAF data into a single regression, therefore combining the results of Table 2.8 and Table E-2.3. The results are in line with those previously reported, with a non significant effect of potential gain between 1991 and 2002 and a positive and significant effect between 2002 and 2012. Pooling all the data also allows to control for different trends at the municipality level through municipality fixed effects. When adding those (columns 3 and 6), the effect of potential gain in the second period remains positive and statistically significant.

2.6.4 Spatial correlation

Given that soil and weather characteristics are not distributed randomly over the country, potential corn yield is likely to exhibit some level of spatial auto-correlation. Not taking this into account leads to an underestimation of standard errors, thereby increasing the probability of excluding the null hypothesis when we should not. For this reason, Table E-2.5 reports the p-value obtained when re-estimating our main results with alternative clustering techniques. The first row shows the p-values obtained from the robust standard errors that we have used so far. The second and third rows presents p-values after the correction suggested by Conley (1999) using a 25-km and a 50-km radius and the last row when standard errors are clustered at the provincial level. When control variables are not included, the coefficients remain below the 5% threshold with the 25-km radius and below the 10% with the 50-km radius. When controls are included, p-values are larger but always remain below 15%. Provincial-level clustering yields standard errors somewhere between the two radius values.

2.6.5 Barangay-level analysis

Due to the geographic characteristics of the country, the level of within-municipality heterogeneity in the Philippines tends to be high. For example, the median municipality area is equal to 119 sq km and the median elevation range(difference between highest and lowest altitude) is 543m, reflecting the hilliness of the country. Similarly, the within-municipality standard deviation in potential yield is equal to 0.65 on average, which correspond to half of the standard deviation computed between municipalities. Given this heterogeneity, we cannot be sure that the increase in land inequality is actually observed in areas that became more productive or is the result of spill-over effects coming from nearby areas.

To address this issue, I repeat the analysis using barangay-level data and present the results in Table E-2.6. Before interpreting the results, it is important to remind the differences between barangay- and municipality-level data. First, the plot physical location is only available at the municipality-level. Barangay land inequality measures are therefore computed on the total land cultivated by people living in the barangay, not on the land located within its boundaries. While both sets are the same in most cases, large farms straddling administrative boundaries and absentee landlords will create a wedge between them. It is therefore possible to have a value of agricultural area larger than the total barangay area, which was not the case in the municipality data. Second, due to the sampling method used in the successive rounds of the CAF, the number of observations will vary depending on the variables included in the analysis. More specifically, when controlling for 1991 variables, the observation number will strongly decline as we only use the balanced sample over the three waves[30]. Third, while municipalities with less than 50 ha of agricultural land were excluded from the analysis, this threshold is decreased to 10 ha for barangays. Once again, this avoids taking into account areas where farming is a marginal activity. Finally, while most municipalities comprise both urban and rural areas, barangays usually fall in only one of those categories. Given that agricultural land inequality is not a relevant issue in urban areas, it makes sense to restrict the sample to rural barangays only .

Results from Table E-2.6 are remarkably similar to those from Table 2.8, especially when we restrict the analysis to rural barangays (Columns 3 and 6). In those barangays, a one-standard deviation increase in potential yield leads to a 1.1-point increase in Gini coefficient and a 0.6-percentage point increase in the top decile land share. The results obtained at the municipality level are therefore unlikely to be driven by spill-over effects.

2.6.6 Alternative measures of inequality and productivity

The measure of potential gain from GM corn that we have used so far was defined as the difference between the potential corn yield with high and low levels of input. The high level corresponds to optimal modern agricultural practices while the low level corresponds to traditional practices with no external inputs. The agricultural sector in the Philippines, however, did not change from being completely traditional to being fully mechanized over the decade 2002-2012 and the introduction of GM seeds can certainly not account for such a drastic change.

[30]See Appendix A-2.5. for the details regarding the sampling structure and the weights recomputation.

As an additional robustness test, I use alternative measures of potential gain from GM corn, recomputing it using the potential yield with intermediate levels of inputs either in the pre- or in the post-adoption period. The first four columns of Table E-2.7 presents the results when it is defined as the difference between intermediate and low levels of inputs; the last four columns when it is defined as the difference between high and intermediate levels of inputs. Results are in line with those presented in the rest of the paper. When using the difference in yield between intermediate and low levels of inputs, however, the effect is much less precisely estimated and becomes insignificant. This is the result of the lower variation in potential gain with this definition: the standard deviation is 0.35 compared to 1.27 when we take the difference between high and low levels of inputs. This decreases the statistical power of the analysis, leading to a non rejection of the null hypothesis although the point estimates are twice larger than in the baseline regressions.

2.7 Land inequality and socio-economic outcomes

Results presented in this paper document an increase in landholding inequality following the introduction of GM corn in the Philippines. Since land inequality has been shown to have adverse effect on welfare and economic development, the question of the net effect of the technology needs to be addressed. In other words, is the increased inequality a small price to pay given the gain in agricultural productivity? To investigate this question, the present section focuses on three types of indicators: (i) Municipality-level poverty rates, (ii) income and expenditure data from a representative household survey and (iii) terrorist activity. The following results are only correlational and potentially subject to reverse causality as they are not identified on any exogenous variation in the land distribution.

2.7.1 Poverty incidence

The first socio-economic outcome investigated is poverty incidence, measured at the municipality level by Philippines Statistics Authority (2016) using the methodology developed by Elbers et al. (2003). This methodology combines census data, providing comprehensive coverage but limited information, with survey data, which provides extensive information for a smaller sample. This allows the computation of small area statistics, including poverty rates. For the Philippines, such measures are available for the years 2000, 2003, 2006, 2009 and 2012. However, a change in methodology in 2006 makes the 2000 and 2003 estimations impossible to compare with the later ones.

Table 2.12 presents the correlation between the 2012 poverty level and land inequality. Because the dependent variable is an estimation, the standard errors of all regressions are bootstrapped. In order to improve readability, all variables are expressed as percentage points - i.e. between 0 and 100 instead of 0 and 1. The first column shows that municipalities with a more unequal land distribution tend to have a lower poverty level as both contemporaneous and 10-year lagged inequality are negatively correlated with poverty. The coefficients size imply that poverty increases by 2.8 and 1.6 percentage points when the lagged and contemporaneous land inequality respectively increase by one standard deviation. Using our measure of potential gain from GM corn, Column 2 shows that municipalities with a higher potential gain also have a lower poverty rate. A one-standard deviation increase in potential gain is associated with a 5.4 percentage point decrease in poverty.

Table 2.12: Municipality-level poverty rate

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2012 Land Gini	-0.152**		-0.120**	-0.097***	-0.198***		-0.039	-0.001
	(0.061)		(0.053)	(0.034)	(0.062)		(0.051)	(0.041)
2002 Land Gini	-0.311***		-0.099	-0.086**	-0.159***		-0.035	-0.045
	(0.057)		(0.062)	(0.042)	(0.046)		(0.042)	(0.042)
Potential gain from GM corn		-4.224***	-3.175***	-1.582***		-2.830***	-1.152***	-0.378
		(0.264)	(0.298)	(0.236)		(0.321)	(0.420)	(0.330)
2006 Poverty rate				0.636***				0.598***
				(0.019)				(0.029)
Observations	1,520	1,574	1,518	1,518	1,520	1,574	1,518	1,518
R-squared	0.052	0.102	0.350	0.588	0.056	0.091	0.313	0.584
Province FE	NO	NO	NO	NO	YES	YES	YES	YES
Controls	NO	NO	YES	YES	NO	NO	YES	YES

Dependent variable is an estimation of municipality poverty rate in 2012, using the methodology developed by Elbers et al. (2003). Control variables included in columns 3, 4, 7 and 8 are population (log), share of rural population, share of farming households and share of agricultural land. These variables are computed using the 2010 Census of Population and the 2012 Census of Agriculture and Fisheries. Standard errors are bootstrapped.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Column 3 combines land inequality and corn productivity in the same regression and adds demographic and economic controls (log of population, share of rural population, share of farming households and share of agricultural land). All coefficients slightly decrease and the 10-year lagged land inequality becomes insignificant. Adding the 2006 poverty rate in column 4 allows us to investigate the correlation between land inequality and the *change* in poverty. The results are remarkably similar to those previously reported: the change in poverty rate is negatively correlated both with the 10-year lagged and with contemporary land inequality. This implies that places that became more unequal over the decade experienced a stronger decrease (or smaller increase) in poverty. However, when provice fixed effects are added in Columns 5-8, this correlation strongly decreases and becomes insignificant, indicating that it was largely driven by unobserved heterogeneity.

2.7.2 Household survey data

The Family Income and Expenditure Survey (FIES), carried out by the Philippine Statistical Authority every three years, collects repeated cross-sectional data on income and expenditure from a representative sample of the Philippine population. The sample size varies from 20,000 in the 1990s to around 40,000 after 2000. The analysis below uses the closest data from the agricultural census, namely the FIES 2003 and 2012. Investigated outcome variables include the logarithm of per capita income and expenditure and dummy variables equal to one if the household head is employed and is a farmer. I also use the national poverty lines at the time of survey to categorize households as poor and non-poor[31]. Finally, I create two additional variables, indicating whether the household is in the bottom quintile or in the top decile of the national per capita income distribution. In contrast with the rest of the paper, the analysis is run at the level of the household and not the municipality. The estimated equation is given by

$$y_{ijt} = \delta_j + \delta_t + \beta_1 Gini_{jt-1} + \beta_2 Gini_{jt} + \gamma_1 X_{ijt} + \gamma_2 Zjt + \epsilon_{ijt}, \quad (2.3)$$

where y_{ijt} is the outcome variable of household i, living in municipality j at time t. δ_j and δ_t are respectively municipality and year fixed effects. X_{ijt} and Z_{jt} control for household characteristics (family size, head's gender, age and education) and for time-varying municipality characteristics (log of farm number, log of farm area and potential corn yield[32]) respectively. β_1 gives the conditional correlation between the 10-year lag in landholding inequality and the dependent variable. This variable is included because we expect land inequality to have a lagged effect on income and expenditure. As the past land inequality is included in the regressions, β_2 gives the conditional correlation between the change in land inequality and the dependent variables[33]. The error term ϵ_{ijt} is clustered at the municipality level. The equation is estimated using OLS for all the outcome variables.

The first panel of Table 2.13 shows the results when only year fixed effects and household characteristics are included. Households living in municipalities where land was more unequally distributed in the past are more likely to be employed and less likely to have agriculture as their main occupation. Contemporaneous land inequality is positively correlated with income, expenditure and employment and negatively correlated with the probability of being a farmer and of being poor. Coefficient sizes imply that an increase in past inequality by one standard

[31] Households are categorized as poor if their per capita income is lower than PHP 12,267 in 2003 and lower than 18,395 in 2012.

[32] This variable takes the value of the potential yield with low inputs in 2002 and with high inputs in 2012.

[33] Contrary to other tables in this paper, the Land Gini variable is not expressed as percentage points and therefore takes values between 0 and 1.

deviation is associated with an incresed probability of being employed of 2.3 percentage points. An increase in contemporaneous inequality by one standard deviation is associated with an increase in income of 4.4% and a decrease in the probability of being poor by 2 percentage points.

Panel B reports the results when we include municipality fixed effects and time-varying control variables. The inclusion of these variables strongly decrease the coefficients of present and past land inequality, which all become insignificant. Interestingly, households living in municipalities that experienced a stronger increase in potential corn yield have lower income and expenditure and are more likely to be farmers and poor. An increase of potential gain by one standard deviations is associated with a decrease in income by 2.6% and an increase in the probability of being poor by 1.5 percentage points.

Table 2.13: Income, expenditure and employment

VARIABLES	(1) Income	(2) Expenditure	(3) Head employed	(4) Head farmer	(5) Poor	(6) Bottom quintile	(7) Top decile
PANEL A - WITHOUT MUNICIPALITY CONTROLS							
Past Land Gini	0.054	0.117	0.251***	-0.207***	-0.001	-0.014	0.002
	(0.124)	(0.122)	(0.052)	(0.076)	(0.058)	(0.053)	(0.027)
Land Gini	0.467***	0.524***	0.374***	-0.286***	-0.217***	-0.195***	0.083***
	(0.114)	(0.108)	(0.052)	(0.071)	(0.054)	(0.051)	(0.024)
Observations	66,939	66,939	66,939	66,939	66,939	66,939	66,939
R-squared	0.480	0.511	0.134	0.154	0.220	0.208	0.182
HH controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality controls & FE	No	No	No	No	No	No	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
PANEL B - WITH MUNICIPALITY CONTROLS							
Past Land Gini	0.003	0.021	0.047	0.134	0.019	-0.001	-0.021
	(0.107)	(0.093)	(0.082)	(0.104)	(0.063)	(0.059)	(0.031)
Land Gini	-0.084	-0.017	-0.002	0.145	0.020	0.003	-0.035
	(0.116)	(0.098)	(0.073)	(0.095)	(0.074)	(0.066)	(0.029)
Potential corn yield	-0.020***	-0.012**	-0.002	0.019***	0.011***	0.005*	-0.004**
	(0.006)	(0.005)	(0.004)	(0.005)	(0.003)	(0.003)	(0.002)
Observations	66,939	66,939	66,939	66,939	66,939	66,939	66,939
R-squared	0.593	0.640	0.190	0.238	0.347	0.337	0.214
HH controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality controls & FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Data from the FIES 2003 and FIES 2012. For households observed in 2003 and 2012, past land Gini corresponds to the landholding Gini index computed at the municipality level in 1991 and 2002 respectively. Land Gini corresponds to the landholding Gini index computed at the municipality level in 2002 and 2012 respectively.
Columns 1 and 2 use per capita log income or expenditure. Columns 3-7 use dummy variables as dependent variables.
Household control variables include household head's gender, age, education level and household size. Municipality control variables include the log of farm number and of agricultural area.
Robust standard errors clustered at the municipality level in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Similar results are obtained when the sample is restricted to households for whom farming is the main occupation (see Table F-2.1 in Appendix). Without municipality controls, past land inequality is positively correlated with the probability of being employed. Contemporaneous land inequality is positively correlated with income, employment and negatively correlated with poverty. When municipality controls are added, all correlations become insignificant. Once again, potential gain in corn productivity is negatively correlated with income and positively correlated with poverty. This might reflect the fact that corn farming - even with improved inputs - is mostly carried out by poor smallholder farmers. Although those results are only correlational, they do not provide any evidence suggesting a strong negative impact of land inequality on socio-economic indicators.

2.7.3 Terrorist activity

Since the beginning of the 21st century, the Philippines have been faced with an increase in terrorist activities, perpetrated by left-wing guerilla and islamist insurgency groups. While part of this increase can be attributed to geopolitical events, such as the rise of islamist terrorism, some scholars have attributed this to the unequal distribution of assets between ethnic groups, especially in the South of the country (McDoom et al., 2019). The present section investigates potential links between land inequality and terrorist attacks reported in the Global Terrorism Database (GTD). This database was created by the National Consortium for the Study of Terrorism and Responses to Terrorism (START) from the University of Maryland and compiles newspaper reports of terrorist activities across the world.

Figure 2.6 reports the yearly number of attacks and casualties, between 1990 and 2018. Over the entire period, 24.5% of attacks are attributed to islamist terrorism while 46.4% are attributed to communists[34]. Following a decrease in the 1990s, the number of attacks, especially involving communist groups, and the number of casualties sharply rise between 2005 and 2015. The geographical distribution of the attacks is reported in Figure G-2.1 in the Appendix. Most of the events occur on the island of Mindanao. Islamist attacks are concentrated in the West and the South of the island while communist attacks are more common in the East of Mindanao and also happen in other parts of the country.

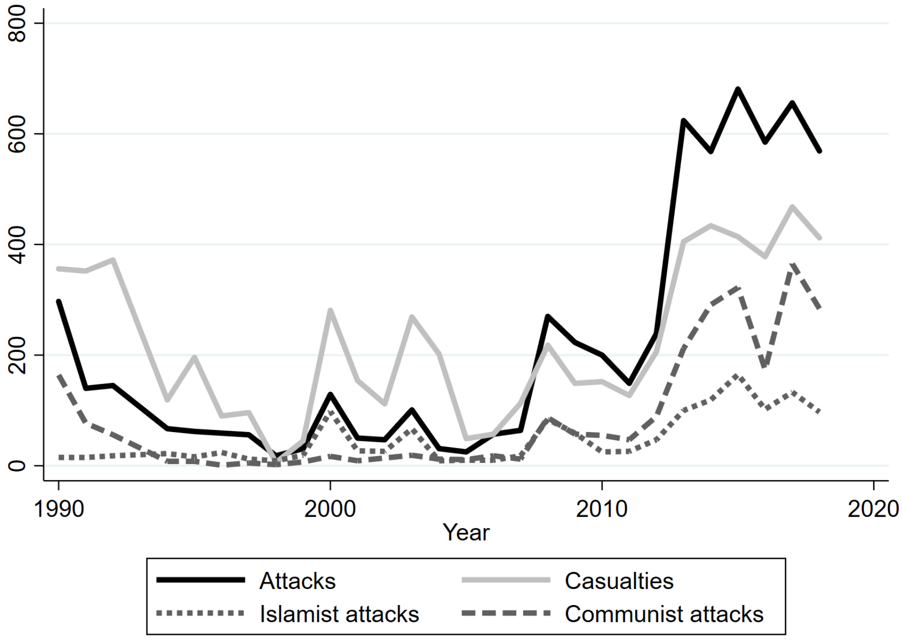
In order to test the correlation between land inequality and terrorist activity, I use the data provided by the GTD aggregated at the municipality-year level. While previous regressions in this paper were always comparing two data points ten years apart per municipality, the model estimated here is different:

$$y_{it} = \beta Gini_{it} + \gamma X_{it} + \delta_i + \delta_t + \epsilon_{it}, \tag{2.4}$$

Where y_{it} is the number of terrorist attacks or of casualties in municipality i in year t, comprised between 1991 and 2012. Control variables in X_{it} include the log of agricultural area and of night light intensity, which control for changes in the size and sectoral composition of the local

[34] Note that the perpetrator is categorized as Unknown in 34.9% of the cases

Figure 2.6: Temporal variation in terrorist activity at the national level



economy. Yearly values for the land Gini and control variables are computed from the CAF data using linear interpolation. As a result, the number of observation strongly increases, from 3 to 22 per municipality. δ_i and δ_t represent municipality and year fixed effects and account for any unobservable time-invariant and aggregate shocks, such as geographical characteristics, geopolitical situation and methodological changes in terrorism data collection. As terrorist attacks are relatively rare events, including municipality fixed effects strongly decrease the number of observations. This also leads to a sample selection issue as municipalities that have not been affected by an attack are excluded from the estimation. As a result, municipality fixed effects are replaced in some regression by province time trends. Finally, the error term ϵ_{it} is clustered at the provincial level to take into account the spatial correlation in terrorist activity. Due to the high number of zero values in the dependent variables (96% of municipality-year cells do not experience an attack), the equation is estimated using pseudo-Poisson maximum likelihood, which is the most appropriate estimator for panel count data with excess zeros.

The first two columns of Table 2.14 show that land inequality is positively correlated with terrorist attacks when either province time trends or municipality fixed effects are included. When we add economic control variables, the point estimate only remains significant in the municipality fixed effect regression (Column 2). A similar effect can be found when distinguishing between islamist and communist attacks. However, when controls are included, the correlation only remains significant for communist attacks and with municipality fixed effects. This indicates that land inequality is associated with a higher intensity of attacks in areas where ter-

Table 2.14: Terrorist attacks

VARIABLES	(1) All	(2)	(3) Islamist	(4)	(5) Communist	(6)
Land Gini	3.901***	2.560**	4.582**	1.984	1.258	1.985
	(1.203)	(1.147)	(1.792)	(2.773)	(0.925)	(1.218)
Observations	29,206	10,102	8,820	2,131	26,002	5,612
Year FE	YES	YES	YES	YES	YES	YES
Province time trend	YES	NO	YES	NO	YES	NO
Municipality FE	NO	YES	NO	YES	NO	YES
Land Gini	0.821	2.566***	1.095	1.801	-0.019	2.571*
	(1.394)	(0.883)	(2.182)	(2.287)	(0.882)	(1.418)
Log Agricultural land	0.532***	-0.226***	0.564**	-0.628***	0.630***	-0.174
	(0.130)	(0.083)	(0.283)	(0.231)	(0.103)	(0.169)
Log Night light	0.619***	-0.385***	0.644***	-0.388	0.220***	-0.399**
	(0.068)	(0.126)	(0.164)	(0.313)	(0.064)	(0.159)
Observations	29,197	10,102	8,818	2,131	25,994	5,612
Year FE	YES	YES	YES	YES	YES	YES
Province time trend	YES	NO	YES	NO	YES	NO
Municipality FE	NO	YES	NO	YES	NO	YES

Poisson pseudo-maximum likelihood with fixed effects regressions. Unit of observation is the municipality, each municipality is observed every year between 1991 and 2012.
Robust standard errors clustered at the provincial level in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

rorist groups were already operating rather than in regions that were previously spared. Table G-2.1 in the Appendix presents similar results, using the number of casualties as dependent variable. Although these results may be subject to reverse causality and omitted variable bias, this provides some suggestive evidence that political instability in the Philippines feeds of the unequal distribution of land.

2.8 Discussion

Municipalities that benefited more from improved agricultural productivity experienced an increase in landholding inequality over the decade 2002-2012. According to our main results from Table 2.7, gains in productivity induce, on average, an increase in land Gini of 0.9 percentage points. Over the period, the municipality-level Gini index increased by an average of 0.45 percentage points, which implies that, without productivity gain, landholding inequality would have actually decreased by 0.5 percentage points on average. Further analysis documents that this effect strongly decreases when we control for the change in agricultural land. More precisely, municipalities that experienced larger yield gains are less likely to decrease their land devoted to agriculture, which is negatively correlated with land inequality. The main effect is therefore not mediated by an *increase* in agricultural land in more affected municipalities but by a *smaller decrease*, thereby alleviating environmental concern surrounding land encroachment on the remaining forests of the Philippines.

Heterogeneity analysis reveals that the positive relationship between productivity and inequality is not equally present across time and space. More specifically, it does not hold for the 1991-2002 period, the decade preceding the introduction of GM seeds, which nonetheless experienced some gains in corn yields. The nature of the technological change therefore appears to matter. In addition, spatial heterogeneity analysis reveals that the effect is only statistically significant at the 10% level in 7 out of the 16 regions of the Philippines. Unfortunately, the agricultural census lacks detailed information on input and output, preventing us from linking the productivity increase to changes in the agricultural production function which could explain the movements observed in the landholding distribution.

A priori, given that seeds and other inputs can easily be divided, GM corn technology appears to be scale neutral. There are, however, two reasons to believe this may not be entirely true. First, large farmers can buy their inputs in bulk and pay a lower price on them. Second, switching to the new technology entails a higher level of risk and poor farmers are less able to insure against it. Indeed, GM corn cultivation offers higher yields than alternative varieties thanks to its better weed and pest management, which increases the gross return on land. At the same time, input costs also increase as seeds are more expensive and herbicide and fertilizer are used more intensively . These higher input costs imply larger potential losses in case of crop failure, which increase the riskiness of agricultural production. In a country exposed to many natural hazards like the Philippines (tropical cyclones, drought, flooding etc.), the probability of an adverse event destroying the harvest is not negligible. This is especially the case for smallholder farmers, who have limited options to insure against such shocks, either because they lack access to the formal financial sector or because their farm size restricts diversification options. Indeed, 45% of farms in the CAF 2012 only farm one plot, and an additional 33% only two. Moreover, heavy use of herbicide on GM corn prevents intercropping. As a result, large farmers who have easier access to financial institutions and alternative income sources are more able to insure against the increase in risk and therefore to reap the benefits from the new technology. In addition, the labor-saving characteristics of GM seeds favor the capital-rich individuals, which can increase income inequality between farmers.

While GM corn adoption was high at the end of our period, it was still not universal, especially in some parts of the country. In addition, the agricultural land market is likely to be slow to react to exogenous shocks given that farmers typically farm the same land every year. As a result, we may not be observing the full effect of the new technology, which does not necessarily imply that we only have a lower-bound effect. Indeed, if the optimal farm size becomes larger following the increase in productivity, adopters will expand their landholding compared to non-adopters, thus increasing land inequality. As adoption increases, new adopters also expand and we may therefore expect a decrease in inequality in a second time. Such a mechanism is, however, highly speculative and would need to be backed by empirical evidence.

One potentially important aspect that is overlooked in this paper is the implementation of the CARP land reform, which took place over the entire study period. This omission is the result of a complete lack of data regarding the amount of land redistributed at a disaggregated level. Given the high level of redistribution reported by the government, this may pose a threat to the validity of our results if landlords' opposition to the process was stronger in regions that benefited more from the new technology. However, given that the CARP started in the 90s, landlords would have needed to anticipate the arrival of the technology in order to keep their land until 2002. If this was the case, we would observe a similar effect between 1991 and 2002, which is not the case as reported in Table E-2.3. Such a political economy explanation is therefore unlikely to be driving our results. Moreover, the actual amount of land redistributed by the policy remains largely uncertain given that official statistics appear unrealistically high.

2.9 Conclusion

This paper shows that gains in corn productivity are an important factor explaining the evolution of land inequality in the Philippines during the first decade of the 21st century, following the introduction of genetically modified corn seeds. Our results show that municipalities that benefited more from this technology experienced an increase in landholding Gini and in the share of land occupied by the farms in the top decile. Several mechanisms and heterogeneous effects have been identified. First, the increase in land inequality appears to be driven by a smaller contraction of agricultural land in municipalities that were more affected. Second, the effect is stronger in places where agricultural credit transactions were widespread and improved seeds were less used in 1991. Third, the effect is heterogeneous across regions, although it is present on all major island groups. Fourth, it does not appear to be driven by migration between muncipalities or by rural-urban migration within municipalities. Fifth, it is not present in the decade preceding the introduction of GM corn.

This paper, however, is not meant to present any sort of welfare evaluation of GM corn. While land inequality is associated with a higher occurrence of terrorist activity, it is also positively correlated with income or expenditure data from household surveys and negatively correlated with poverty, although these correlations are not very robust. If the increased inequality has any welfare costs – which is not entirely supported by the data - , they are unlikely to outweigh the large benefits reported elsewhere on farm profits and household income.

While the empirical analysis uses an exogenous variation in profitability to identify the effect of the new technology, I lack agricultural data to go beyond the reduced-form equations and identify the mechanisms through which productivity affects the landholding distribution. Likewise, the agricultural land market is likely to be slow to react to exogenous shocks given that farmers typically farm the same land every year. As a result, we might only be observing the short-term effect of the commercialization of GM corn seeds. The identification of the mechanisms linking productivity to landholding inequality in the short and the long run offer an interesting avenue for future research.

Appendix

A-2. Appendix A-2: Data cleaning details

A-2.1. Farm definition

The definition of a farm varies between the census waves. In 1991 and 2002, enumeration was limited to farms satisfying one of two conditions: (i) using at least 1000 square meters to raise crops, livestock or poultry and (ii) raising at least 20 heads of livestock or 100 heads of poultry. In 2012, however, this rule was lifted and any agricultural operation, regardless of land or herd size, was enumerated. Moreover, the rule does not appear to have been properly followed in 1991 as over one million farms report an area below 0.1 ha compared to only 8,355 in 2002. To make sure that temporal variations we find in the land distribution are not the result of changing farm definitions, farms with a total land area of less than 0.1 ha are excluded from the data. This implies dropping around 820,000 households in 2012. Through this restriction, we also make sure that the households considered devote a significant amount of resources to their farming activity, and we do not take into account all those who only tend a small plot of vegetables for their own consumption.

A-2.2. Use of PSGC

Tracking geographical units through time can be challenging if administrative boundaries change. The CAF raw data identifies the barangays (and the municipalities they are part of) using Philippine Standard Geographic Codes (PSGC). As administrative boundaries change, these codes are regularly updated, on average every two years. Unfortunately, the CAF documentation does not state clearly which version of the PSGC is used for each wave. In addition, the Philippine Statistics Authority was not able to provide a list of codes prior to 1998. I therefore use the version of PSGC that offers the highest number of matches, i.e. PSGC 1998 for the CAF 1991, the PSGC 2002 for the CAF 2002 and the PSGC 2018 for the CAF 2012. I was however unable to link 54 municipalities from the CAF 1991 to the rest of the data (representing 4.7% of the total agricultural area). Similarly, 3 and 1 municipalities had to be dropped from the CAF 2002 and CAF 2012 respectively.

To match municipalities across time, I use the PSGC 2002 version in order to minimize the distance with the other two. When municipalities merge or split between waves, I always use the larger entity for the analysis. Details of the PSGC matches are available upon request.

A-2.3. Crop area

In 1991 and 2002, the area planted in each crop is collected, along with the number of times that crop was planted. In 2012, however, we only know which crops were planted in each growing season. When several crops are cultivated on the same plot, we therefore do not know the area allocated to each one. In order to have consistent measures between years, I assume that when corn, rice or sugarcane are cultivated, they are planted on the entire plot. Given that they are rarely intercropped, this only leads to a slight overestimation of their prevalence. In addition, each crop is counted once, regardless of how many times it was harvested during the year. If a farmer grows rice during the wet season and corn during the dry season, his farm is included in the rice area as well as in the corn area. This implies that when we add the shares of land devoted to each crop, the result is likely to exceed one. Double counting of crops cultivated twice a year would lead to a stronger overestimation of their presence given that permanent crops such as coconut or banana are only counted once. Moreover, this measure is only used as a control variable in some regressions and the mismeasurement is unlikely to invalidate our main results.

For permanent crops such as coconut and banana, their dedicated area is very poorly reported and often missing. As many households own only a couple of trees, and they are much more likely to be intercropped, we would largely overestimate their presence by assuming that they cover the entire plot. The number of trees is however reported more reliably. I therefore use this information to recompute planted area by taking into account planting distance recommended by the Philippine Department of Agriculture. More specifically, I take planting densities of 123 plants/ha for coconut and 500 for banana (the median density in the 1991 data which contains both area and number of plants). In addition, the planted area is replaced by the plot area whenever it was larger.

A-2.4. Identification variables in CAF 2012

Respondents identification in the CAF 1991 and 2002 data are coherent and appear reliable, in the sense that it is possible to merge the different datasets with very limited loss of observations (only 20 unmatched plots in 1991 and less than 0.1% in 2002).

In the 2012 data, however, more cleaning is necessary in order to correclty match the different datasets. This is especially the case for the dataset containing plot-level tenure and use information. These variables are key to creating the land ownership inequality indicators used presented in Table 2.11. Agricultural operators are identified thanks to a series of ten identification variables (region, province, municipality, barangay, enumeration area, segment number, building serial number, housing unit serial number, household serial number and operator line). Manual inspection of those variables revealed that the last character of each entry was actually the first character of the following variable. For example, the farms located in the province of Abra report being in the region number 40 and the province number 10, while this province has the number 1 according to the PSGC. The same applies for all the subsequent identification variables. Correcting for this allows the matching of 98% of the observations. Removing the last digit of the household serial number to the unmatched variables increases the share of matched observations.

In addition to this problem with the id variables, the plotsizes reported in this dataset are rounded, for a reason that the PSA is not able to explain. As a result, 48% of the plots have a value of 0ha, which is problematic when computing land inequality indicators. This problem is solved using two methods. First, when the plots have a match in another dataset (for example, containing crop information), the plotsize is taken from there. This allows me to confirm that the problematic values were indeed rounded. Second, for plots that cannot be matched, for example because they are left fallow or contain pasture land, the rounded value is kept and the 0 values are replaced by 0.1 ha, which is the average size of the matched plots that reported this value.

A-2.5. Sampling and weights recomputation

The sampling procedures for CAF 1991 and 2002 were the following:

1. Four provinces were fully enumerated (Laguna, Isabela, Bukidnon and Batanes). The province of Marinduque was also fully enumerated in 1991 only.
2. In the remaining provinces, the barangay with the largest farm area according to the previous census was enumerated with certainty.
3. In 1991, 50% of the remaining barangays were enumerated.
4. In 2002, the remaining barangays were divided into two groups: those sampled in 1991 and the others. 25% of each stratum was selected.

Comparing the last two waves is straighforward as we only keep data from the barangays surveyed in 2002 and use their weight on both waves.

When combining all three waves, or when comparing the 1991 and 2002 data, we need to take the sampling procedure into account in order to recompute the weights. Indeed, weights can change between census wave and the probability of being part of the full balanced panel depends on the weights in both waves. More specifically, we should not increase the weight given to certainty barangays since they were not randomly selected and therefore only represent themselves. The recomputed weight is therefore the average of the initial weights corrected by a factor γ_{ijt}:

$$w_{ij} = \frac{1}{2}\left(w_{ij91}\gamma_{ij91} + w_{ij02}\gamma_{ij02}\right),$$

with the correction factor γ_{ijt} equal to 1 for the certainty barangays and to $\frac{N_{j91}}{\Sigma_i w_{ij91}}$ otherwise, where N_{jt} corresponds to the number of barangays enumerated in municipality j in year t.

Appendix B-2: Inequality decomposition

The general formula of GE measures is given by

$$GE(\alpha) = \frac{1}{\alpha(\alpha-1)}\left[\frac{1}{N}\sum_{i=1}^{N}\left(\frac{x_i}{\bar{x}}\right)^{\alpha} - 1\right],$$

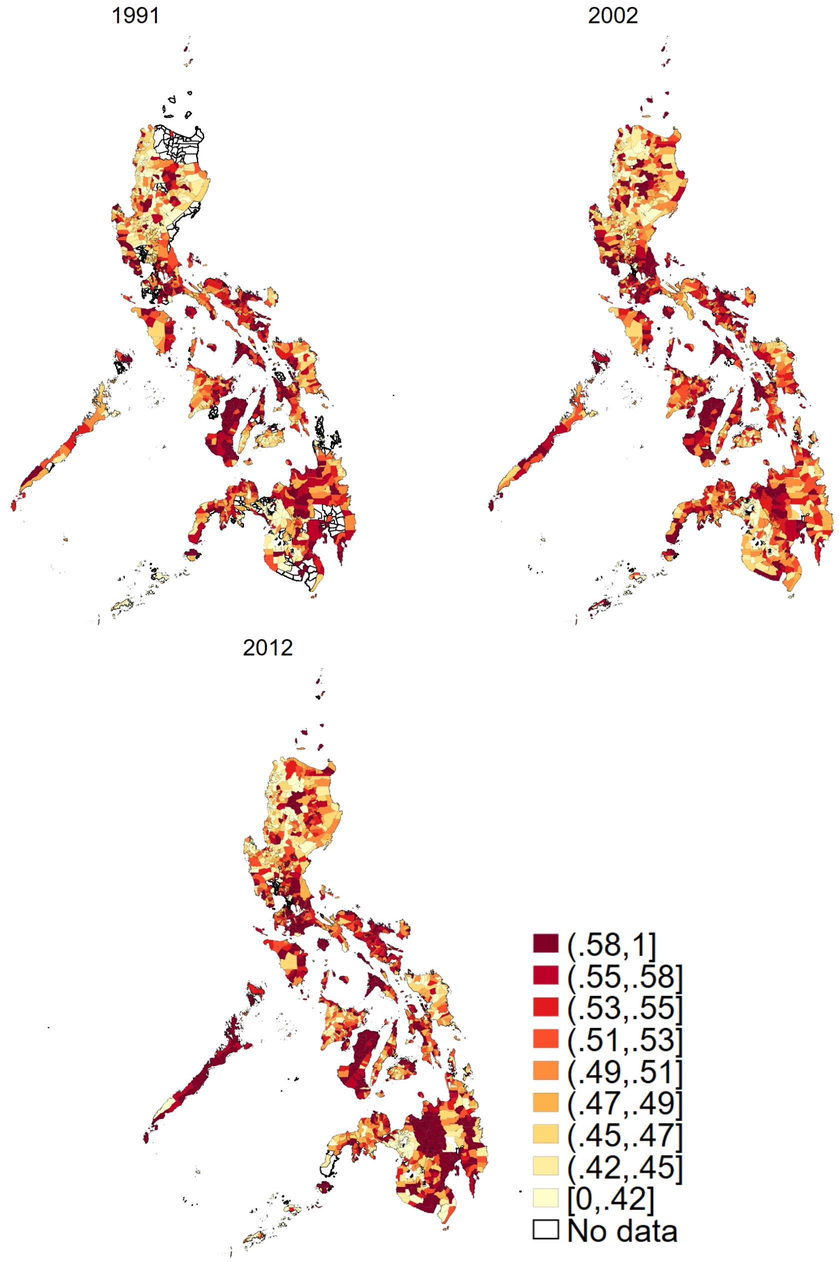
where x_i is the landholding size and $\bar{x}$ the mean farm size. The parameter α represents the weight given to land size differences along the farm size distribution, a low value giving more weight to the left tail of the distribution while a high value giving more weight to the right tail. The two most used values are 0 and 1, respectively giving Theil's L and Theil's T indices. These indicators can then be decomposed into two additive components, measuring between-municipality and within-municipality inequality. For Theil's T, this first decomposition is given by

$$\begin{aligned} T &= \frac{1}{N}\sum_{i=1}^{N}\frac{x_i}{\bar{x}} ln\left(\frac{x_i}{\bar{x}}\right) \\ &= \sum_{i=1}^{N}\frac{x_i}{X} ln\left(\frac{x_i N}{X}\right) \\ &= \sum_{j}\left(\frac{X_j}{X}\right)T_j + \sum_{j}\left(\frac{X_j}{X}\right) ln\left(\frac{X_j/X}{N_j/N}\right), \end{aligned}$$

where municipalities are indexed by j and T_j is the value of Theil's T index computed for municipality j[35]. It is also possible to decompose this measure along more than one level, provided that each level is nested within the other. This analysis is only possible for 2012 as it requires information on the full census of barangays. Following Akita (2003), I therefore decompose national inequality into three components: between municipality, between barangay and within barangay and report the results in Table 2.2.

[35] Theil's L index decomposes similarly, using the number of farms N as weights. For more information, see Haughton and Khandker (2009).

Appendix C-2: Spatial distribution of landholding Gini



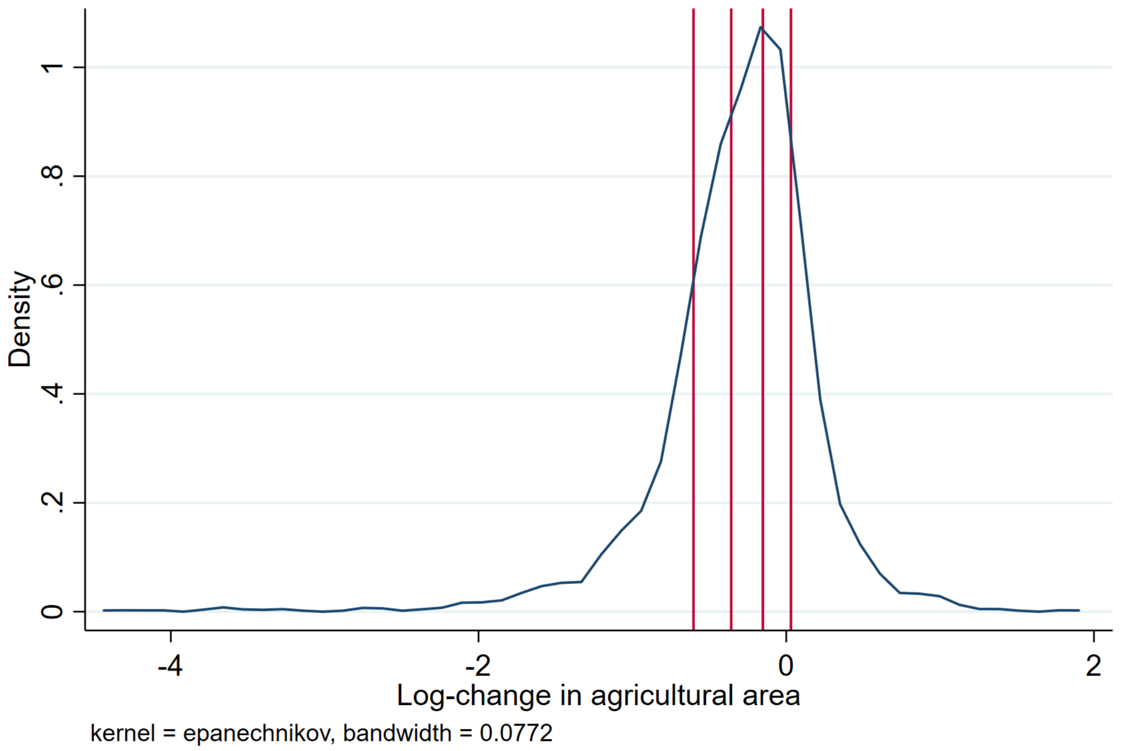
Appendix D-2: Supplementary material - Results

Table D-2.1: Top decile share and productivity change - Mechanisms

VARIABLES	(1)	(2)	(3)	(4)
Potential gain from GM corn	0.554**	0.435*	0.535**	0.117
	(0.239)	(0.239)	(0.234)	(0.209)
Municipality area (Log)	1.212***	0.865**	1.255***	0.573*
	(0.346)	(0.356)	(0.346)	(0.310)
1991 Ag area (Share)	2.737**	2.122**	2.915***	2.275**
	(1.104)	(1.071)	(1.109)	(0.975)
1991 Corn share	1.436	2.048*	1.352	2.498**
	(1.191)	(1.154)	(1.185)	(1.013)
1992 Night lights (Log)	0.418**	0.725***	0.332	0.665***
	(0.203)	(0.205)	(0.210)	(0.202)
Δ Farm area (Log)		4.604***		12.075***
		(0.897)		(1.123)
Δ Nb farms (Log)			-1.699**	-10.978***
			(0.765)	(1.142)
Observations	1,434	1,434	1,434	1,434
R-squared	0.023	0.084	0.030	0.230

Dependent variable is the change in land share occupied by the top decile of the landholding distribution, between 2002 and 2012. Potential gain from GM corn is the difference between potential rainfed corn yield with high and low leve and ls of inputs from the FAO-GAEZ. The unit of observation is the municipality.
Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Figure D-2.1: Distribution of the change in agricultural area (Log)



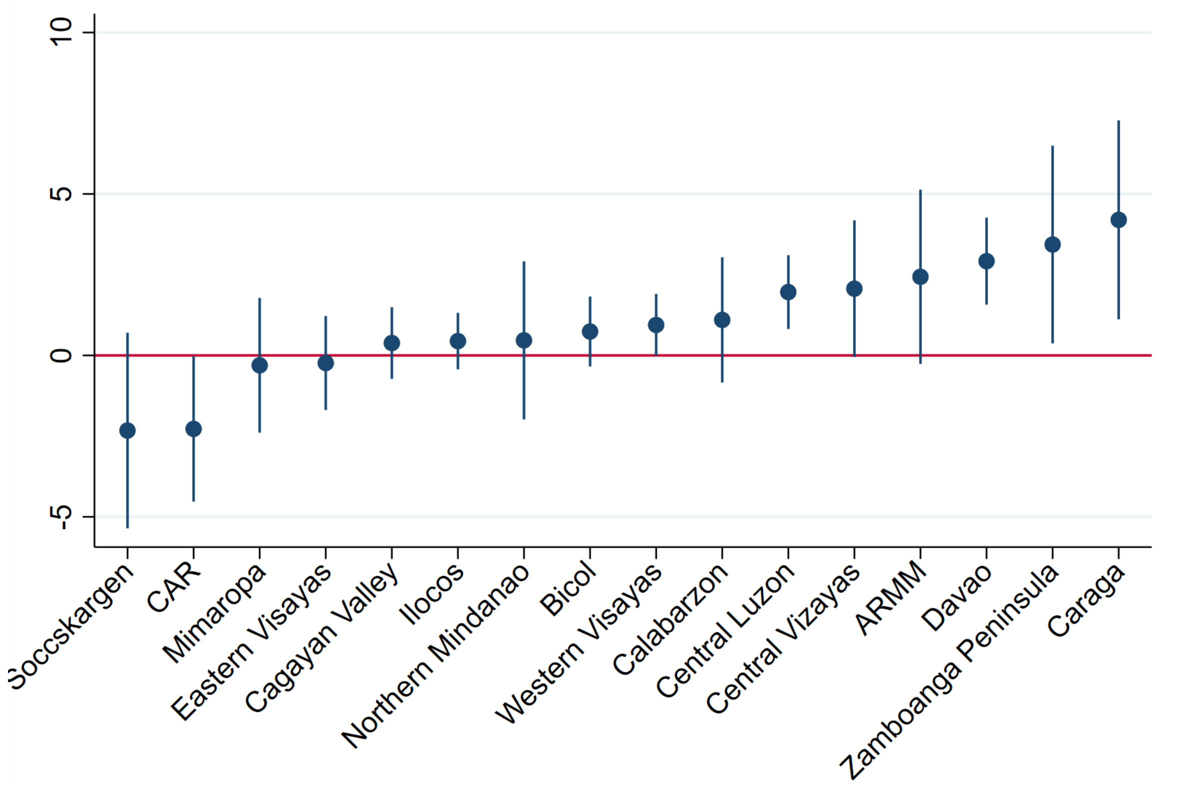
Vertical lines indicate quintiles

Table D-2.2: Effect of agricultural area on the productivity-inequality relationship

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Potential gain from GM corn	0.457**	0.314	0.168	0.168	0.259	0.260	0.347*	0.464**
	(0.208)	(0.207)	(0.207)	(0.205)	(0.204)	(0.205)	(0.203)	(0.202)
Municipality area (Log)	1.080***	0.648**	0.547*	0.480	0.598**	0.686**	0.790***	0.993***
	(0.301)	(0.304)	(0.303)	(0.297)	(0.297)	(0.293)	(0.290)	(0.291)
1991 Ag area (Share)	3.676***	3.080***	3.544***	3.529***	3.536***	3.805***	3.758***	3.733***
	(0.965)	(0.950)	(0.959)	(0.919)	(0.910)	(0.916)	(0.900)	(0.914)
1991 Corn share	0.553	1.024	1.286	1.514	1.617	1.559	1.462	1.227
	(1.037)	(1.025)	(1.018)	(1.000)	(0.987)	(0.988)	(0.987)	(0.996)
1992 Night lights (Log)	0.358**	0.546***	0.606***	0.603***	0.615***	0.581***	0.515***	0.470***
	(0.180)	(0.180)	(0.179)	(0.177)	(0.176)	(0.176)	(0.174)	(0.175)
Quintile 1 Δ Ag area (Log)		-4.867***	-5.898***	-7.126***	-9.293***			
		(0.639)	(0.659)	(0.699)	(0.825)			
Quintile 2 Δ Ag area (Log)			-3.920***	-5.134***	-7.318***			
			(0.498)	(0.550)	(0.705)			
Quintile 3 Δ Ag area (Log)				-3.540***	-5.745***	2.537***		
				(0.522)	(0.685)	(0.530)		
Quintile 4 Δ Ag area (Log)					-4.396***	3.877***	2.962***	
					(0.695)	(0.548)	(0.489)	
Quintile 5 Δ Ag area (Log)						8.280***	7.388***	6.627***
						(0.679)	(0.633)	(0.613)
Observations	1,436	1,436	1,436	1,436	1,436	1,436	1,436	1,436
R-squared	0.025	0.073	0.104	0.126	0.152	0.147	0.135	0.118

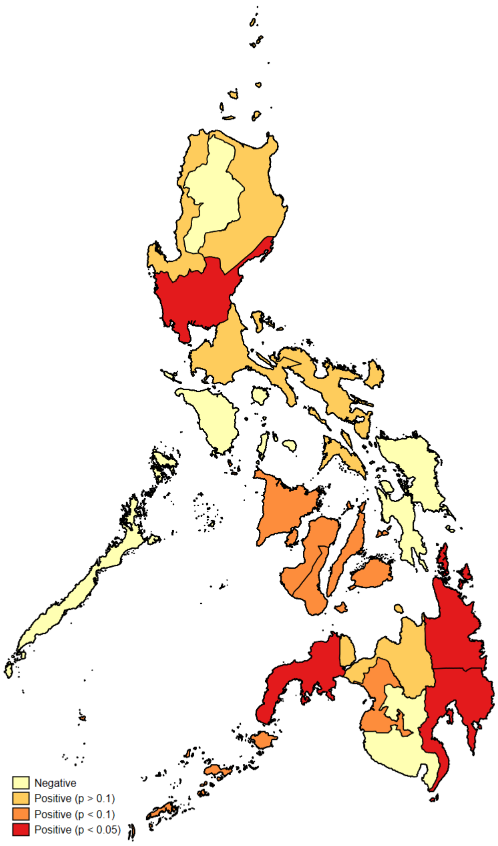
Dependent variable is the change in landholding Gini between 2002 and 2012. Potential gain from GM corn is the difference between potential rainfed corn yield with high and low levels of inputs from the FAO-GAEZ. The unit of observation is the municipality.
Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Figure D-2.2: Effect of agricultural productivity on land inequality at the regional level



Each point represents the coefficient of the interaction between the potential gain from GM corn and the region dummy, using the change in landholding Gini as dependent variable.

Figure D-2.3: Effect of agricultural productivity on land inequality at the regional level



Map color reflects the sign and significance of the coefficients reported in Figure D-2.2.

Appendix E-2: Supplementary material - Robustness tests

Table E-2.1: Landholding Gini and productivity change - controlling for population and economic development

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Potential gain from GM corn	0.459**	0.640***	0.488**	0.430**	0.426**	0.414**	0.430**
	(0.210)	(0.212)	(0.198)	(0.207)	(0.208)	(0.208)	(0.193)
Municipality area (Log)	1.074***	0.819***	0.868***	1.057***	1.047***	1.099***	0.917***
	(0.301)	(0.302)	(0.295)	(0.302)	(0.301)	(0.300)	(0.296)
1991 Ag area (Share)	3.624***	2.551***	2.913***	3.606***	3.634***	3.475***	2.807***
	(0.964)	(0.967)	(0.916)	(0.974)	(0.971)	(0.936)	(0.923)
1991 Corn share	0.540	-0.336	-1.516	0.600	0.557	0.680	-1.408
	(1.044)	(1.020)	(0.935)	(1.046)	(1.052)	(1.045)	(0.940)
1992 Night lights (Log)	0.362**	0.282	0.446**	0.388**	0.373**	0.371**	0.512***
	(0.183)	(0.181)	(0.176)	(0.196)	(0.186)	(0.182)	(0.190)
Δ Corn (share)		-14.706***	-9.695***				-10.054***
		(3.001)	(2.774)				(2.780)
Δ Population (Log)				-0.845			-2.379
				(2.357)			(2.162)
Δ Rural pop (Share)					-2.043		-3.201
					(9.620)		(8.909)
Δ Night light (Log)						0.885*	0.793*
						(0.469)	(0.420)
Observations	1,434	1,434	1,434	1,424	1,424	1,433	1,423
R-squared	0.025	0.058	0.223	0.025	0.025	0.028	0.226
Crop shares	NO	NO	YES	NO	NO	NO	YES

Dependent variable is the change in landholding Gini coefficient between 2002 and 2012. Potential gain from GM corn is the difference between potential rainfed corn yield with high and low levels of inputs from the FAO-GAEZ. Crop shares include the change in agricultural land share of rice, sugarcane, coconut, banana, other temporary and other permanent crops. The unit of observation is the municipality.
Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table E-2.2: Landholding Gini and productivity change - Topo-geographical controls

VARIABLES	(1)	(2)	(3)	(4)	(5)
Potential gain from GM corn	0.459**	0.794***	0.828**	0.612***	0.403
	(0.210)	(0.238)	(0.372)	(0.216)	(0.284)
Municipality area (Log)	1.074***	0.959***	1.023***	1.044***	-0.418
	(0.301)	(0.307)	(0.304)	(0.302)	(0.409)
1991 Ag area (Share)	3.624***	3.955***	3.901***	2.603***	1.560
	(0.964)	(0.952)	(0.965)	(0.980)	(1.338)
1991 Corn share	0.540	0.066	0.439	-0.327	0.743
	(1.044)	(1.033)	(1.040)	(1.121)	(1.539)
1992 Night lights (Log)	0.362**	0.348*	0.373**	0.404**	0.166
	(0.183)	(0.184)	(0.182)	(0.184)	(0.232)
Elevation		0.003**			
		(0.001)			
Ruggedness			0.027		
			(0.021)		
Longitude				0.364*	
				(0.197)	
Latitude				-0.059	
				(0.121)	
Observations	1,434	1,434	1,434	1,434	1,432
R-squared	0.025	0.032	0.027	0.031	0.186
Province FE	NO	NO	NO	NO	YES

Dependent variable is the change in landholding Gini coefficient between 2002 and 2012. Potential gain from GM corn is the difference between potential rainfed corn yield with high and low levels of inputs from the FAO-GAEZ. The unit of observation is the municipality.
Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table E-2.3: Placebo test using 1991 and 2002 data

VARIABLES	(1)	(2)	(3)	(4)
	Δ Gini		Δ Top 10%	
Potential gain from GM corn	-0.228	0.128	-0.289	-0.014
	(0.174)	(0.199)	(0.190)	(0.227)
Municipality area (Log)		-1.205***		-1.298***
		(0.295)		(0.345)
1991 Ag area (Share)		-8.918***		-6.725***
		(1.405)		(1.737)
1991 Corn share		3.723***		4.405***
		(0.901)		(0.953)
1992 Night lights (Log)		-0.265		-0.343
		(0.198)		(0.225)
Observations	1,350	1,341	1,350	1,341
R-squared	0.001	0.051	0.002	0.033

Changes in dependent variables are calculated over the years 1991 and 2002. Potential gain from GM corn is the difference between potential rainfed corn yield with high and low levels of inputs from the FAO-GAEZ. The unit of observation is the municipality. Robust standard errors in parentheses.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table E-2.4: Productivity change and landholding inequality - Including CAF 1991

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
		Δ Gini			Δ Top 10%	
Potential gain from GM corn	-0.228	-0.077		-0.289	-0.119	
	(0.174)	(0.185)		(0.190)	(0.206)	
Potential gain from GM corn * 2012	0.758***	0.651**	0.750**	0.872***	0.722**	0.861**
	(0.259)	(0.260)	(0.310)	(0.286)	(0.286)	(0.345)
Municipality area (Log)		-0.001			0.015	
		(0.216)			(0.250)	
1991 Ag area (Share)		-1.248			-0.996	
		(0.817)			(0.954)	
1991 Corn share		2.052***			2.851***	
		(0.706)			(0.782)	
1992 Night lights (Log)		0.053			0.045	
		(0.137)			(0.153)	
Observations	2,870	2,775	2,674	2,870	2,775	2,674
R-squared	0.004	0.007	0.315	0.004	0.008	0.315
Year FE	YES	YES	YES	YES	YES	YES
Municipality FE	NO	NO	YES	NO	NO	YES

Changes in dependent variables are calculated over the years 1991, 2002 and 2012. Potential gain from GM corn is the difference between potential rainfed corn yield with high and low levels of inputs from the FAO-GAEZ. The unit of observation is the municipality.
Robust standard errors in parentheses.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table E-2.5: Spatial correlation correction

		(1)	(2)	(3)	(4)
		Δ Gini		Δ Top 10%	
Potential gain from GM corn		0.526	0.442	0.591	0.520
	Robust SE	[0.006]	[0.029]	[0.007]	[0.020]
	Conley 25-km radius	[0.026]	[0.073]	[0.039]	[0.078]
	Conley 50-km radius	[0.053]	[0.113]	[0.080]	[0.124]
	Province cluster	[0.044]	[0.096]	[0.061]	[0.084]
Observations		1,520	1,434	1,520	1,434
R-squared		0.006	0.026	0.006	0.025
Controls		NO	YES	NO	YES

Changes in dependent variables are calculated over the years 2002 and 2012. Potential gain from GM corn is the difference between potential rainfed corn yield with high and low levels of inputs from the FAO-GAEZ. The unit of observation is the municipality.
P-values between brackets.

Controls include log of municipality area, change in the share of land devoted to agriculture, change in the share of agricultural land devoted to corn and log change of night light intensity.

Table E-2.6: Barangay-level analysis

	(1)	(2)	(3)	(4)	(5)	(6)
		Δ Gini			Δ Top 10%	
VARIABLES	All barangays	Balanced panel	Rural barangays	All barangays	Balanced panel	Rural barangays
Potential gain from GM corn	0.610***	0.626***	0.819***	0.368***	0.209	0.409**
	(0.120)	(0.174)	(0.186)	(0.108)	(0.164)	(0.170)
Barangay area (Log)		0.347	0.473**		-0.215	-0.042
		(0.215)	(0.239)		(0.210)	(0.231)
1991 Ag area (Share)		-0.020	-0.026**		0.005	0.009
		(0.015)	(0.012)		(0.006)	(0.006)
1991 Corn share		0.302	0.395		1.071	1.187*
		(0.729)	(0.725)		(0.698)	(0.711)
1991 Night lights (Log)		0.604	1.149		0.746	0.779
		(0.980)	(1.163)		(0.680)	(0.970)
Observations	11,905	6,767	5,439	11,905	6,767	5,439
R-squared	0.004	0.005	0.009	0.002	0.003	0.003

Changes in dependent variables are calculated over the years 2002 and 2012. Potential gain from GM corn is the difference between potential rainfed corn yield with high and low levels of inputs from the FAO-GAEZ. The unit of observation is the barangay.
Robust standard errors clustered at the municipality-level in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table E-2.7: Alternative measures of potential gain from GM corn

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Intermediate - Low Inputs				High - Intermediate Inputs			
VARIABLES	Δ Gini		Δ Top 10%		Δ Gini		Δ Top 10%	
Potential gain from GM corn	1.304*	0.831	1.500*	1.173	0.742***	0.679***	0.806***	0.796***
	(0.762)	(0.827)	(0.892)	(1.002)	(0.241)	(0.263)	(0.267)	(0.294)
Municipality area (Log)		0.983***		1.116***		1.095***		1.231***
		(0.301)		(0.348)		(0.301)		(0.345)
1991 Ag area (Share)		3.898***		3.027***		3.560***		2.679**
		(0.963)		(1.103)		(0.961)		(1.101)
1991 Corn share		0.412		1.298		0.573		1.466
		(1.040)		(1.185)		(1.044)		(1.193)
1992 Night lights (Log)		0.440**		0.505**		0.338*		0.395*
		(0.180)		(0.200)		(0.182)		(0.202)
Observations	1,520	1,434	1,520	1,434	1,520	1,434	1,520	1,434
R-squared	0.003	0.023	0.003	0.020	0.007	0.026	0.006	0.024

Dependent variable is the change in landholding Gini coefficient between 2002 and 2012. Potential gain from GM corn is the difference between potential rainfed corn yield with intermediate and low levels of inputs in columns 1-4 and between high and intermediate in columns 5-8. The unit of observation is the municipality.
Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Appendix F-2: Supplementary material - Socio-economic outcomes

Table F-2.1: Income, expenditure and employment for farming sample

VARIABLES	(1) Income	(2) Expenditure	(3) Head employed	(4) Poor	(5) Bottom quintile	(6) Top decile
PANEL A - WITHOUT MUNICIPALITY CONTROLS						
Past Land Gini	0.063	0.121	0.275***	0.040	0.036	0.031
	(0.115)	(0.109)	(0.075)	(0.070)	(0.069)	(0.024)
Land Gini	0.254**	0.278***	0.474***	-0.170***	-0.162**	0.020
	(0.103)	(0.098)	(0.064)	(0.063)	(0.063)	(0.016)
Observations	38,624	38,624	38,624	38,624	38,624	38,624
R-squared	0.489	0.528	0.111	0.228	0.211	0.121
HH controls	Yes	Yes	Yes	Yes	Yes	Yes
Municipality controls & FE	No	No	No	No	No	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
PANEL B - WITH MUNICIPALITY CONTROLS						
Past Land Gini	0.043	0.057	0.030	0.039	0.046	0.024
	(0.132)	(0.119)	(0.120)	(0.096)	(0.089)	(0.030)
Land Gini	-0.023	0.071	0.010	-0.007	0.025	-0.010
	(0.141)	(0.123)	(0.105)	(0.114)	(0.105)	(0.028)
Potential corn yield	-0.015*	-0.011	-0.017***	0.011**	0.008	0.000
	(0.008)	(0.007)	(0.006)	(0.005)	(0.005)	(0.002)
Observations	38,623	38,623	38,623	38,623	38,623	38,623
R-squared	0.610	0.659	0.215	0.362	0.351	0.161
HH controls	Yes	Yes	Yes	Yes	Yes	Yes
Municipality controls & FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Data from the FIES 2003 and FIES 2012. For households observed in 2003 and 2012, past land Gini corresponds to the landholding Gini index computed at the municipality level in 1991 and 2002 respectively. Land Gini corresponds to the landholding Gini index computed at the municipality level in 2002 and 2012 respectively.
Columns 1 and 2 use per capita log income or expenditure. Columns 3-6 use dummy variables as dependent variables.
Household control variables include household head's gender, age, education level and household size. Municipality control variables include the log of farm number and of agricultural area.
Robust standard errors clustered at the municipality level in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Appendix G-2: Supplementary material - Terrorist activities

Figure G-2.1: Spatial distribution of terrorist activity between 1991 and 2018

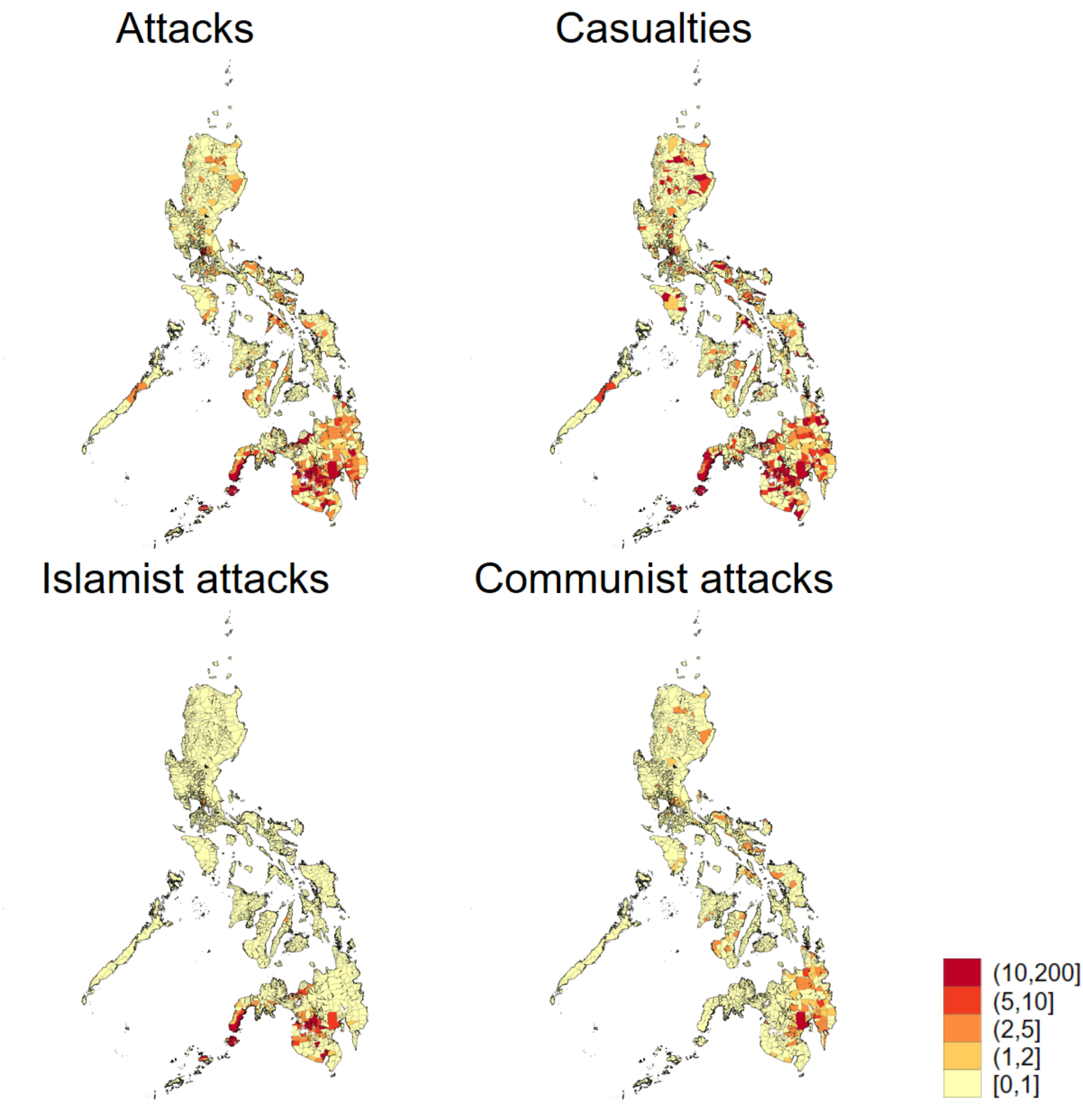


Table G-2.1: Terrorist attack casualties

VARIABLES	(1) All	(2)	(3) Islamist	(4)	(5) Communist	(6)
Land Gini	4.204**	3.523**	5.050*	7.268**	2.184	2.785
	(1.789)	(1.602)	(2.862)	(2.925)	(1.969)	(2.296)
Observations	28,857	7,454	7,002	1,423	23,351	3,596
Year FE	YES	YES	YES	YES	YES	YES
Province time trend	YES	NO	YES	NO	YES	NO
Municipality FE	NO	YES	NO	YES	NO	YES
Land Gini	2.162	3.325***	2.658	4.485	1.228	3.273
	(2.088)	(1.079)	(3.123)	(2.805)	(2.007)	(2.612)
Log Agricultural land	0.344*	-0.406***	0.248	-1.143***	0.313	0.066
	(0.190)	(0.152)	(0.323)	(0.386)	(0.216)	(0.297)
Log Night light	0.425***	-0.293**	0.491***	-0.369	0.102	-0.357*
	(0.082)	(0.137)	(0.152)	(0.293)	(0.102)	(0.192)
Observations	28,848	7,454	7,000	1,423	23,343	3,596
Year FE	YES	YES	YES	YES	YES	YES
Province time trend	YES	NO	YES	NO	YES	NO
Municipality FE	NO	YES	NO	YES	NO	YES

Poisson pseudo-maximum likelihood with fixed effects regressions. Unit of observation is the municipality, each municipality is observed every year between 1991 and 2012.
Robust standard errors clustered at the provincial level in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

CHAPTER 3

SHARING NORM, HOUSEHOLD EFFICIENCY AND FEMALE DEMAND FOR AGENCY IN THE PHILIPPINES

Joint with Jean-Marie Baland, Catherine Guirkinger and Clarice Manuel (UNamur) [1]

Abstract: Households in the Philippines are characterized by durable unions and a relatively high status of women who are entrusted with the management of household finances, a context conducive to intra-household cooperation. We run experimental games with couples in the rural Philippines. We first find the prevalence of a strong sharing norm whereby women secure about two thirds of the total payoffs, in line with their prominent role in the family. Despite a favourable setting, couples incur large efficiency losses of about 46% of potential gains. We interpret this finding as revealing a strong, latent demand for agency by women who express a strong preference for hidden money over (larger) transfers from their husband as the latter involve an implicit control over their use. These findings challenge a naive view of female empowerment that solely focuses on the apparent control over household resources.

***JEL* Classification:** D13, C90, O12, N35

Keywords: Household efficiency, Female empowerment, Lab-in-the-field, Philippines.

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3.1 Introduction

Classical models of household decisions such as the Unitary and the Collective Models assume efficiency (Alderman et al., 1995). A growing empirical literature has called this assumption into question, in particular in the context of developing countries (see for instance Udry (1996), Duflo and Udry (2004), Goldstein (2004), Jakiela and Ozier (2016), Kazianga and Wahhaj (2017), and Rossi (2019)). Baland and Ziparo (2017) summarize the various mechanisms that may undermine household efficiency in poor countries and point in particular to the instability of marital relationships and the low level of female bargaining power. Marital instability pushes individuals to take actions to secure themselves in case of marital breakdown, while low bargaining power may prompt women to adopt passive and non-cooperative behaviors as the potential gains from cooperation are fully captured by husbands.

In this context, the Philippines provide an interesting setting to investigate cooperation in the household as (i) households are overwhelmingly nuclear and couples are remarkably stable (divorce is illegal) and (ii) women enjoy a high relative status, including a prominent role in household finances. In this paper, we present a series of lab-in-the-field experimental games conducted with rural households in the Philippines. Spouses played with each other a standard Dictator game, a Dictator game with multiplier and a Trust game. Our first result highlights large inefficiencies within couples which goes against a cooperative approach of the household. On average, households forego 46% of their potential gains in the games. Similar levels of inefficiency have been observed in similar games in several settings such as India (Castilla, 2015) or Kenya (Hoel, 2015); see in particular the review by Munro (2018).[2] Our second result highlights a pattern of transfers revealing the prevalence of a surprisingly strong sharing norm, whereby women secure about 60% of the pay-offs, regardless of the game played. This is consistent with their traditional role as financial managers of the household.

Finally, we explore possible mechanisms underlying household inefficiency. We interpret our main findings as a demand for agency, whereby women in particular express a preference for money under their direct control. For instance, given the return behavior of the spouse in the trust games, wives forego 1.74 dollars and husbands 1.14 dollars for every dollar they decide to keep. This suggests that transfers from husbands appear as less valuable than money wives keep for themselves, as if transfers carry "strings attached". This is in line with a recent exper-

[2]Moreover, as shown by Hoel (2015), couple behaviors in experiments have strong predictive power for real life decisions (see also Munro (2018)).

imental literature highlighting a demand for secrecy within couples (see for instance, Ashraf (2009); Boltz et al. (2019); Hoel (2015); Jakiela and Ozier (2016); Kebede et al. (2014)). What our evidence highlights is that, in the Filipino context, entrusting women with the nominal charge of household finance does not confer them a full control over its use. This suggests a more nuanced view of female empowerment than a self-declared participation to household financial decisions.

The rest of the paper is structured as follows. Section 2 describes the context of marital relationships in the Philippines, Section 3 discusses the data and the design of our experiment. Section 4 presents the results of the games, highlighting the prevalence of a sharing norm and large levels of inefficiency. Section 5 discusses the mechanisms underlying these inefficiencies. Section 6 concludes.

3.2 Institutional Context

Households in the Philippines feature two characteristics that should further cooperation and promote efficiency: (i) the permanence of the couple and (ii) the apparent gender equality. In addition, women play a prominent role in household finances. We discuss these three points below.

First, divorce remains illegal in the Philippines and Filipinos strongly believe that marriages are permanent (Abalos, 2017; Medina, 2001). Given a strong sigma on separation, the society expects women to keep the relationship intact through "her submission, patience and virtues" (Alcantara, 1994). She would typically be the one to be blamed or publicly shamed for letting the relationship break down (Angeles and Hill, 2009).

Nevertheless, compared to other developing countries, Filipina women are more empowered and experience better living conditions. The Philippines receives a score of 0.784 (17th rank) on the gender equality index of the Human Development Report and outranks by far its neighbors of the East Asia and Pacific Region (0.688)[3]. Husband and wife are said to have equal roles in making decisions involving property, income, agricultural decisions or the education of children (Gerpacio et al., 2004; Ramirez, 1984). In rural areas, farming couples work side by side, with the woman typically responsible for transplanting, weeding, fertilization, harvesting and threshing (Illo and Lee, 1991; Pineda, 1981). We observe this in our sample where about 85% of households have both husband and wife working on the household plot in the most recent cropping season.

[3] The index is computed based on four dimensions: educational attainment, health and survival, political empowerment, and economic participation and opportunity (WEF, 2020).

Despite this apparent equality, gender roles are highly differentiated: "In the ideology of the Filipino family, [...] the wife/mother [is] cast as manager, nurturer and moral pillar, and husband as resource provider and titular head" (Chen, 2005: 70, cited by Chant (2007)). Filipina women play a central role in domestic affairs, "often being referred to as [...] the light of the home, or even as [...] the 'commander' " (Angeles, 2001). They are typically entrusted with financial responsibilities on household expenditures and are given control over household spending from the pooled income of household members (Stoodley (1957); Ramirez (1971) as cited in Church (1986); Illo (1989); Eder (2006); Alcantara (1994); Vancio (1980)). Thus, in our sample, wives declare that they are in charge of the household's money in 92% of the households[4].

Filipinos generally believe that men are incompetent in managing money. Husbands are supposed to turn over their earning to their wives who, in turn, provide them with a daily allowance or pocket money to spend on their vices (Angeles and Hill, 2009; Eder, 2006). "Men often spend a disproportionate amount of time and money (including that of their wives) on extra-domestic activities, including socializing with their [...] gang, and/or engaging in [...] vices such as betting on cockfights, drinking and taking [...] mistresses" (Chant, 2007). In a study of Ifugao women, Kwiatkowski (2019) reports that "men tended to spend money on themselves more often than women spent money on themselves".

While on the surface women have high status, some scholars argue that family relationships remain highly hierarchical with men keeping a leadership role in the household: Wives relations to economic assets are typically "indirect and mediated through her husband" (Eder, 2006). Women's active management of money signifies women's responsibility for managing family finances rather than control over how the cash is spent (Aguilar, 1988; Errington, 1990). As pointed out by Kwiatkowski (2019), this form of delegation introduces a critical difference between the money a wife receives from her husband and the money she earns herself: "Within the household, although Ifugao women usually managed all of their family's cash resources, women were highly conscious of the money they themselves had earned versus the money earned by their husbands. Some did not always feel they could freely spend the money that their husband had earned. [...] One woman stated that she was often reticent to ask her husband for money that he had earned for items or services that she felt she needed, or that she would have liked to give to her relatives in crisis."

In addition, even if a woman has control, the money she manages may just cover basic house-

[4]On the other hand, only 36% of husbands claimed to be in charge of the money. The question was part of the post-game questionnaire where each participating member of the couple was asked independently "Are you in charge of the household's money?".

hold needs and it is not clear that the husband turns over all his earnings, taking advantage of her ignorance of how much he actually earns. Ashraf (2009) highlights that husbands may be tempted to withhold money and not turn all of it over to their wives. As she writes, "this behavior is so widespread that there is a word in the Tagalog language that is applied to men not handing over all of their income to their wives: kupit. Kupit literally means to pilfer, to filch, to steal in small quantities".

The combination of low divorce rate and high gender equality makes Filipino context a particular and relevant place to investigate cooperation in the household. Yet, power relations underlying stereotyped gender roles and a culture of secrecy and separate budgets for personal spending poses obvious challenges to collective efficiency.

3.3 Experimental Design and Data

Sample selection and survey

The data was collected from April to August 2018 from a sample of farming households living in the uplands of Bukidnon in Northern Mindanao. As this research was part of a larger research project on smallholder corn farmers, respondent households were selected based on the following criteria: they farmed corn at least once in the last 10 years, and cultivate less than 10 hectares of land.[5]. Each household spent about three hours answering the household survey and participating in the experiment. Overall, we were able to gather information from 212 farming households from 14 villages[6].

We collected detailed information on the household, spousal trust, and household decision making, through separate interviews with each spouse. We asked which spouse takes decisions when it comes to household expenditures, agricultural credit, or crop choice. We also included questions about the level of trust the participant has in her spouse when it comes to handling household finances. Table 3.1 reports some descriptive statistics. About half of the respondents belong to an indigenous community, the others originate from migrant communities in the region or other islands. On average, women are slightly more educated than their husbands and have been married to each other for more than 20 years. A third of the couples are matrilocal as the couple lived, at some point after marriage, close to the bride's family. Within households the level of trust is generally high even though 25% of the wives declare that they

[5] Information about the survey and the experiment was given to the villagers one day in advance by one of our enumerators.

[6] Data collection and the experiment were conducted in the native languages of the area, Pulangiyen and Bisayan in particular

do not fully trust their husband for financial decisions. In terms of decision making, about half of household decisions are taken jointly. According to both members of the couple, husbands take slightly more individual decisions than their wife.

Table 3.1: Descriptive statistics

Variable	N	Male Mean/SD	Female Mean/SD
Age (self)	212	43.571	39.500
		(12.337)	(12.419)
Education (self)	212	5.052	5.995
		(3.107)	(3.448)
Indigenous (self)	212	0.547	0.585
		(0.499)	(0.494)
No trust	212	0.075	0.250
		(0.265)	(0.434)
Reported joint decision share	212	0.490	0.518
		(0.332)	(0.348)
Decision share (self)	212	0.302	0.223
		(0.248)	(0.238)
Decision share (spouse)	212	0.208	0.260
		(0.208)	(0.232)
Years of marriage	212	20.528	
		(12.810)	
Matrilocality	212	0.358	
		(0.481)	
HH owns land	212	0.774	
		(0.420)	
Wife owns land	212	0.217	
		(0.413)	

Experimental games

The lab-in-the-field experiment involved both spouses who played with each other a series of games derived from the standard literature, namely two variants of the Dictator Game and a Trust game in which all respondents played both roles. Although players made decisions that influenced the payoffs of their spouse, the game set-up prevented the spouse to infer how much money the player kept for herself. At the beginning of each session, the enumerator grouped together the husbands (wives) and placed them in a location away from the view of their spouse's group in order to ensure privacy. We also provided each player a makeshift booth to conceal her decisions.

To avoid systematic biases, games were played in one of four pre-determined orders[7]. The games were incentivized and the compensations were determined by the payoffs resulting from one randomly chosen game. We made sure that players could not infer the decisions made by their spouse from this compensations. In practice, participants received either individual vouchers, handed out individually, or a couple voucher.[8] Vouchers could be exchanged for a variety of household and personal items in a small shop run by the enumerating team directly after the session.

In the standard Dictator Game, each participant received two envelopes, one of which contained 200 pesos[9] as endowment. Players had to decide how to share the received endowment with their spouse by filling in the second envelope. The physical manipulation of the bills and envelopes was meant to help participant visualise the stakes. In the "multiplier" version of the Dictator Game, the money given to the spouse was tripled before reaching her. After explaining the game, the enumerators always provided examples to clearly illustrate the multiplication of the money sent.

The Trust Game used the same set-up as the Dictator Game with multiplier, but allowed the receiving spouse to send back part of what she received. To capture the return strategy while ensuring privacy, we asked, for each possible amount sent, the amount they were willing to send back.[10] To create a single measure of return behaviour from the return strategy, we compute the average amount returned for each dollar received (after tripling the amount)[11]. This is the main measure of trust game return that is used in the rest of the paper. A limitation to this approach is that it is based on hypothetical returns which are not equally plausible as participants have expectations on the amounts likely to be sent by their spouse. In Appendix B-3, we present our main results using as an alternative measure the return amount corresponding to the transfer actually sent by the spouse (instead of the average over all possible transfers). Results are left unchanged by this alternative definition.

Two features of our games mitigate the "undoing problem", whereby spouses make ex-post transfers unknown to the experimenter (Munro, 2018). First, we chose to distribute vouchers to be exchanged against goods by the recipient, immediately after the experiment, thereby

[7]We have prepared four scenarios that changes the sequence in which the games are played. These are available in Appendix C-3

[8]The value of the couple voucher was based on a separate section of the interview, not presented in this paper. The choice between individual and couple voucher was randomized at the session level and unknown to the participants before the end of the games.

[9]This is equivalent to a day's wage in this area. The exchange rate is roughly 50 PhP $\approx$ 1 USD.

[10]In order to avoid redundancy, we asked the amount returned in case the amount sent was 50, 100, 150 and 200. The response sheet showed both the amount sent and the amount received after tripling.

[11]In practice, we compute the ratio of the total amount returned divided by the sum of all possible transfers received.

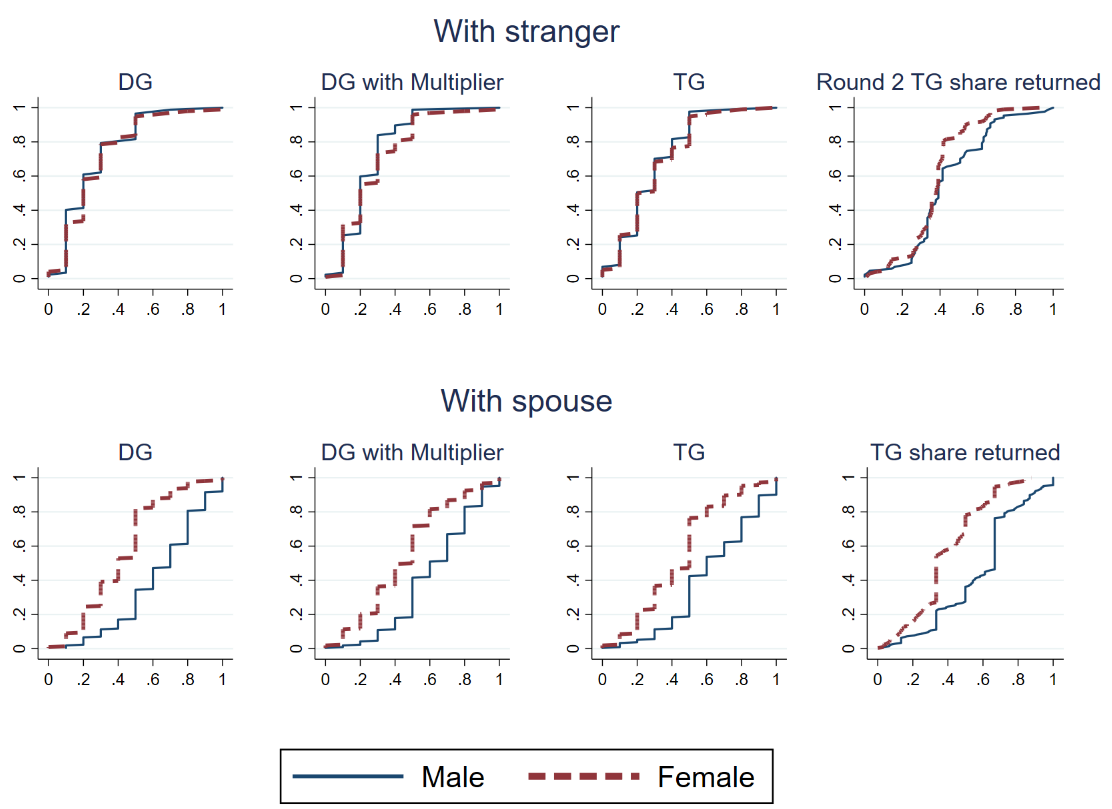
discouraging post-game transfers. Second, the compensations, when individuals, were kept private.

To provide a benchmark for intrahousehold cooperation, we revisited two months later some of the villages and asked former participants to play the same set of games with an anonymous player from their community. Overall 185 individuals participated in these additional games.

3.4 Norm and Efficiency in the Household

We first present the behaviors of husbands and wives when they played with an anonymous recipient in the relevant subsample of players. Figure 3.1 reports the cumulative distributions of the share sent for each decision taken. As can be seen, men and women behave in a surprisingly similar manner, as the distribution are almost identical across gender. On average the amount sent is about 25% and never exceeds 50% of their endowment. Unsurprisingly, when return transfers are allowed, the amount sent is slightly larger as the cumulative distribution of the share sent in the trust game dominates the share sent in the dictator game with multiplier.

Figure 3.1: Cumulative density of amounts sent



As expected, when playing with their spouse, the amounts sent in each decision are larger.

However, husbands and wives play very differently, as husbands transfer systematically larger amounts. For instance, in the dictator game, husbands send 65% of their endowment while wives send only 42% (see Table 3.2). A similar differential is observed for each of the four decisions presented in Table 2. In addition, for decisions that involve a pure transfer (DG and TG Return), the shares sent by husbands and wives approximately sum to 1.[12] In other words, in those games, the share of the initial endowment that accrues to women (men) is independent of the gender of the sender. Interestingly, the same pattern obtains in the distribution of the final payoffs of the trust game: the wife secures the same share of the final payoff whether she or her husband makes the first transfer. Figure 3.2 plots the cumulative distributions of the wife's payoff share when husbands or wives play first (and the difference in these payoffs), illustrating the irrelevance of the identity of the first player. Overall, these two findings suggest the existence of a strong sharing norm that systematically favors women in intra-household transfers, in line with the anthropological evidence.

Table 3.2: Endowment share sent in the games

		(1)		(2)	T-test
		Male		Female	Difference
Variable	N	Mean/SE	N	Mean/SE	(1)-(2)
Dictator Game	212	0.649 (0.016)	212	0.415 (0.014)	0.234***
Dictator Game with Multiplier	212	0.627 (0.015)	212	0.451 (0.016)	0.176***
Trust Game - Player 1	212	0.636 (0.016)	212	0.442 (0.015)	0.194***
Trust Game - Player 2	212	0.581 (0.017)	212	0.383 (0.012)	0.198***

We now analyze whether this gender differential holds once we control for various household and individual characteristics in the dictator game. The latter corresponds to a simple cake sharing between spouses and may thus be the most direct evidence of a sharing agreement.

Table 3.3 reports the results of various alternative specifications of OLS estimations for the amount sent in the Dictator Game (as measured by the share of the initial endowment). We control in particular for bargaining power and trust. Indeed, bargaining power, as measured by the share of household decisions taken by each partner, may be critical for the allocation of household resources and mutual trust is typically considered as necessary for successful

[12]The average of the sum of husband and wife transfers is 1.058, which, while statistically different, is very close to one.

Figure 3.2: Trust game final payoff

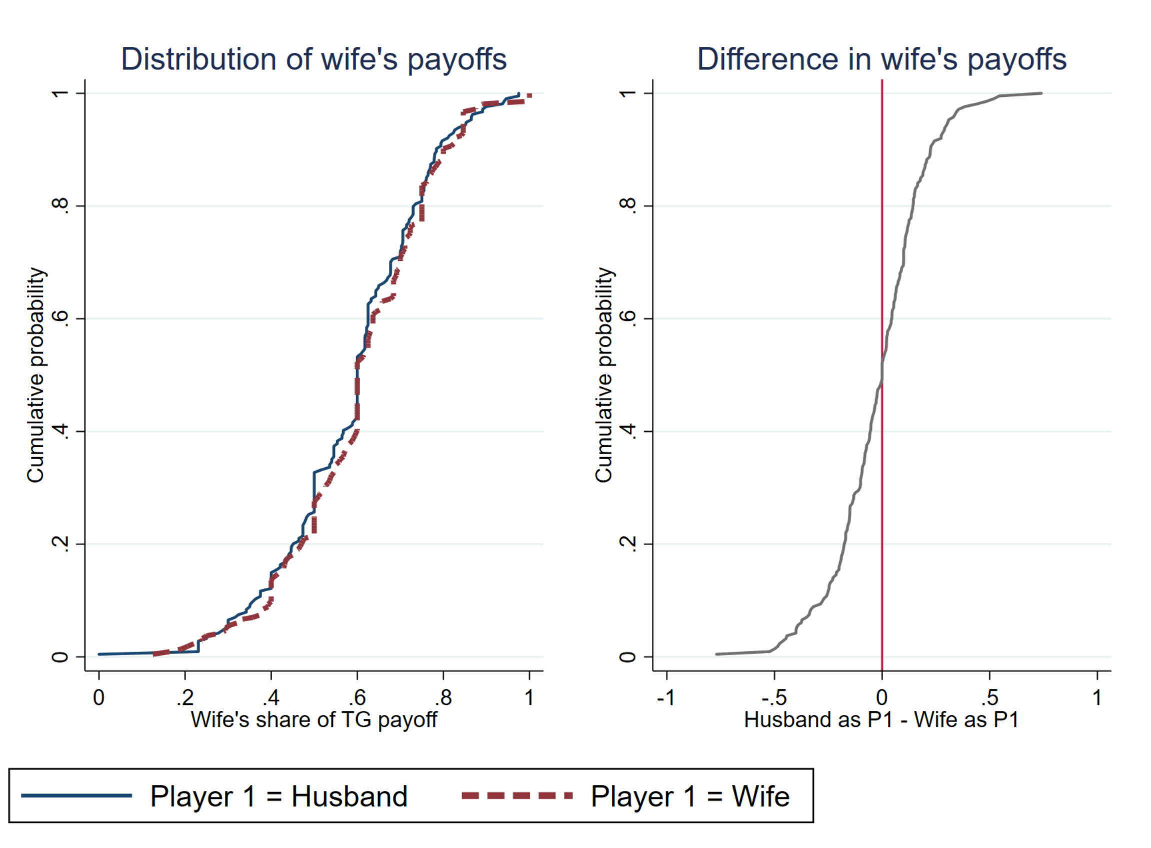


Table 3.3: Endowment share sent in Dictator Game

VARIABLES	(1)	(2)	(3)	(4)
Female	-0.241***	-0.240***	-0.243***	-0.248***
	(0.033)	(0.032)	(0.033)	(0.039)
No trust	0.011		0.012	0.032
	(0.029)		(0.030)	(0.033)
Decision share (self)		0.005	0.003	-0.054
		(0.046)	(0.046)	(0.063)
Decision share (spouse)		0.025	0.027	0.026
		(0.046)	(0.047)	(0.073)
Observations	424	424	424	420
R-squared	0.249	0.249	0.250	0.632
Controls	YES	YES	YES	YES
HH FE	NO	NO	NO	YES

cooperation. Column 4 includes household fixed effects. All regressions are clustered at the session level, where a session is defined by the group of (same gender) individuals who played the games at the same time and place.

The results confirm a strong and stable gender differential in the amount sent. Across all specifications, women send 24 percentage points less than their husband and this coefficient is very precisely estimated. A F-test of the joint significance of all the other control variables fails to reject the null hypothesis at standard levels of significance. In particular, the structure of the household decision making appears irrelevant. In Appendix A-3, we further probe into the role of female bargaining power by investigating two alternative measures of women empowerment: matrilocality and individual land ownership. The corresponding coefficients are small and insignificant while the coefficient on "Female" remains unaffected.

This systematic gender differential supports the hypothesis of a sharing norm in favor of women who end up with a larger share of household resources. This norm should in principle allow spouses to maximize their collective gains, since they have clear expectations of their respective payoffs. We designed a dictator game with multiplier to investigate this conjecture. This game departs from a pure cake sharing structure by allowing the household to secure large payoffs, as the amount sent is multiplied by three. Household efficiency requires the first player to send her/his full endowment.

As shown in Table 3.2, this is not what we observe: on average, men send 63% and women only 45% of their endowment. This implies large losses for the households who forgo, on average, 46% of the potential gains. We report the estimation results in Table 3.4, following the specifications presented in Table 3.3. The female coefficient is again large and very stable around 17 percentage points. This indicates that households are inefficient, as if spouses would not pool their resources but keep separate budgets.

A major difference with the results of the dictator game is the role of trust. Trust towards one's spouse matters for collective efficiency, as mistrustful spouses send 11 percentage points less, regardless of the specification chosen (Table 3.4). In a way, the amount sent can be viewed as an investment, the returns of which are in the hands of the spouse. The trust variable can thus be interpreted as indicating to what extent the recipient will use the augmented transfers in a way that suits the sender's purpose, through some joint decision-making process (this dimension is arguably less relevant in a zero-sum game, such as the dictator game.) Finally, as above, none of the other controls is significant.

3.5 Interpreting household inefficiency

Given the stability of the average transfers across games, one may question the level of understanding of the games by the players. We took great care in ensuring that participants saw the differences between the different games and the critical role of the multiplier. They system-

Table 3.4: Endowment share sent in Dictator Game with multiplier

VARIABLES	(1)	(2)	(3)	(4)
Female	-0.164***	-0.186***	-0.164***	-0.162***
	(0.037)	(0.037)	(0.038)	(0.044)
No trust	-0.110***		-0.111***	-0.117***
	(0.029)		(0.028)	(0.036)
Decision share (self)		-0.058	-0.044	-0.041
		(0.046)	(0.044)	(0.083)
Decision share (spouse)		-0.037	-0.055	-0.033
		(0.050)	(0.046)	(0.063)
Observations	424	424	424	420
R-squared	0.176	0.156	0.181	0.562
Controls	YES	YES	YES	YES
HH FE	NO	NO	NO	YES

atically played mock games with a detailed analysis of the payoffs by enumerators recruited locally and extensively trained by the research team which accompanied them in all the research sites. Second, decisions systematically differ when playing with a stranger rather than with the spouse. Third, when playing with a stranger, the amounts sent in the trust game are larger than in the dictator game with multiplier, indicating an understanding of a possible reciprocation. Moreover, in line with our expectation, trust in one's spouse does not play a role in simple transfer game but becomes critical in games involving a multiplier. Finally, as we show below, the amount sent in the trust game does depend on the expected return strategy of the partner, again revealing some comprehension of the most complex of the three games played.

3.5.1 Collective inefficiency, ex post transfers and trust

The large inefficiencies highlighted in the dictator game with multiplier may result from the inability of the spouses to share their gains ex post.[13] One expects therefore that explicitly allowing for return transfers would help restore efficiency: couples could increase their collective gains and share these gains ex post according to the sharing norm. To investigate this conjecture, we implement a standard trust game, by adding the possibility of return transfers to the dictator game with multiplier.

We start by investigating the determinants of return transfers in the last stage of the game. We elicited the amount each player would send back for various possible transfer received. We

[13]With respect to the undoing problem in intra-household games, these inefficiencies reveal the difficulties in sharing ex-post across spouses. The Trust Game can be viewed as a way to elicit the importance of these ex-post transfers.

compute the average amount returned for each dollar received (after tripling the amount)[14]. The decision to return part of the amount received is essentially equivalent to a simple dictator game. On average, husbands send back 0.58 while wives send back 0.38 of each dollar received (Table 3.2). Table 3.5 presents the results of our estimations. As in the analysis of the simple dictator game, the only significant coefficient is the one attached to female. Wives send back about 20 percentage points less than their husbands. The sharing norm therefore also applies to return transfers.

Table 3.5: Endowment share returned in Trust Game

VARIABLES	(1)	(2)	(3)	(4)
Female	-0.193***	-0.199***	-0.193***	-0.185***
	(0.029)	(0.029)	(0.029)	(0.030)
No trust	-0.032		-0.033	-0.055
	(0.029)		(0.029)	(0.044)
Decision share (self)		-0.024	-0.020	-0.016
		(0.044)	(0.044)	(0.057)
Decision share (spouse)		-0.025	-0.031	-0.061
		(0.043)	(0.042)	(0.058)
Observations	424	424	424	420
R-squared	0.208	0.206	0.209	0.657
Controls	YES	YES	YES	YES
HH FE	NO	NO	NO	YES

Table 3.6: Endowment share sent in Trust Game

VARIABLES	(1)	(2)	(3)	(4)
Female	-0.197***	-0.212***	-0.197***	-0.194***
	(0.037)	(0.036)	(0.037)	(0.041)
No trust	-0.073**		-0.074**	-0.087**
	(0.029)		(0.029)	(0.037)
Decision share (self)		-0.074	-0.065	-0.032
		(0.052)	(0.052)	(0.054)
Decision share (spouse)		-0.063	-0.075	-0.019
		(0.048)	(0.047)	(0.076)
Observations	424	424	424	420
R-squared	0.182	0.180	0.191	0.631
Controls	YES	YES	YES	YES
HH FE	NO	NO	NO	YES

We now turn to the first decision of the trust game. As shown in Table 3.2, the possibility of

[14]In practice, we compute the ratio of the total amount returned divided by the sum of all possible transfers received.

return transfer does not change substantially players' behavior. The average amounts sent are essentially identical to those of the dictator game with multiplier: men send on average 63% and women 44% of their endowment. Allowing return transfers does not reduce inefficiency. The latter does not therefore result from the spouses' inability to make transfers ex post. On average households still loose 46% of their potential gains.

Table 3.6 reports regression results for the amount sent in the first stage of the game, using the same specifications as above. Again two coefficients stand out. Female players systematically send 20 percentage points less than male players and the lack of trust towards the partner reduces the amount sent by 7 to 9 percentage points. These effects are of a similar magnitude as those reported for the dictator game with multiplier.

Table 3.7: Share sent in Trust Game and spouse's return behavior

VARIABLES	(1)	(2)	(3)
Female	-0.228***	-0.216***	-0.222***
	(0.038)	(0.039)	(0.040)
Spouse's TG return (average)	0.091	0.096*	0.133**
	(0.056)	(0.055)	(0.062)
No trust		-0.075**	0.014
		(0.030)	(0.070)
Spouse's TG return (average) * No trust			-0.166
			(0.117)
Observations	424	424	424
R-squared	0.177	0.188	0.192
Controls	YES	YES	YES
HH FE	NO	NO	NO

As discussed above, the lack of trust may imply that the spouse limits as much as s/he can the budget available to his or her partner. The lack of trust may also imply that one systematically underestimates the return transfer of her partner. Using our measure of return transfers, we investigate whether senders anticipate and react to the reciprocity intentions of their spouse, depending on the latter trustworthiness. Table 3.7 presents the same estimations as Table 3.6, including the average share returned by the spouse as an explanatory variable. The estimations are to be taken with caution because of obvious endogeneity concerns, which also prevent us from including household fixed effects[15].

[15] With household fixed effects, we compare the amount sent by the first player to that of his/her partner using the difference between what the same player and his/her partner sent back when they are second players as an explanatory variable. To the extent that a player's first move is strongly correlated to his second move, this creates serious issues of reverse causality. Moreover, the strong correlation between gender and the average amount sent (or returned) implies that within a couple, wives always send and return less than their husband. With a fixed effect, one obtains a negative correlation between the difference in the amount sent by the spouses and the difference in

Table 3.8: Household inefficiency: Share of total payoff foregone

VARIABLES	(1)	(2)	(3)	(4)
Female	0.181***	0.199***	0.180***	0.178***
	(0.034)	(0.033)	(0.034)	(0.040)
No trust	0.092***		0.092***	0.102***
	(0.026)		(0.025)	(0.032)
Decision share (self)		0.066	0.055	0.037
		(0.042)	(0.041)	(0.055)
Decision share (spouse)		0.050	0.065	0.026
		(0.043)	(0.040)	(0.057)
Observations	424	424	424	420
R-squared	0.220	0.206	0.229	0.619
Controls	YES	YES	YES	YES
HH FE	NO	NO	NO	YES

The sender's strategy seems to depend on the intended returns of the recipient, illustrating the incentives provided by return transfers. The coefficients on trust and female remain remarkably stable (column 2). As expected, the results reported in column (3) suggest that the spouse's return strategy only matters when the latter is trustworthy: the sum of the coefficient on the return strategy and its interaction with "no trust" is zero, even though the interaction is barely significant at the 12% level.

We summarize the above findings by providing an overall measure of household inefficiency. Efficiency matters for two of the decisions described above: the dictator game with multiplier and the trust game. Merging these two decisions, we define total household inefficiency as the share of the maximum possible payoff foregone from not sending the full amounts. Inefficiency when husbands play is equal to 37%. When wives play, it rises up to 56%. In other words, more than half of potential gains are left on the table when wives play. In Table 3.8, we investigate the determinants of household inefficiency, replicating the specifications used in Tables 3.5 and 3.7. Confirming the results presented in the previous section, female and lack of trust significantly increase inefficiency. Yet, trust plays a minor role: 16 percent of players do not trust their partner which implies, with an estimated coefficient of 0.10 that the lack of trust reduces on average efficiency by only 1.6 percentage points. By contrast, the female dummy by itself explains an efficiency loss of 18 percentage points.

the amount they return.

3.5.2 Collective Inefficiency and Individual Optimization

One possibility is that, in the trust game, players anticipate the return strategy of their partner and maximize their individual payoff at the expense of household efficiency. The above estimations suggest that this is not the case. The size of the coefficient attached to the return transfer is small at around 0.1 (Table 3.7): for each dollar returned, a player increases the amount sent by only 0.1 dollar. More generally, with a multiplier of three and husbands returning 58% of their gains, wives appear to prefer keeping one dollar than receiving an average of 1.74 dollars ($1*3*0.58). In contrast, as wives return 38% of their gains, husbands renounce to only 1.14 dollar when keeping one dollar. Each partner would obviously gain individually by transferring more in the first move. To explore further this possibility, we measure individual inefficiency as the share of the maximum individual payoff foregone in the trust game, assuming players correctly anticipate the return strategy of their partner. On average, men lose 18% and women 27% of these potential gains.[16] Women thus incur substantial losses. (These, however, remain lower than total losses under collective efficiency.) Men, on the other hand, are relatively close to their private optimum, suggesting that their behavior is much more consistent with an individual than with a household payoff maximization objective.

Table 3.9: Individual inefficiency: Share of maximum individual payoff forgone

VARIABLES	(1)	(2)	(3)	(4)
Female	0.083***	0.081***	0.069**	0.067**
	(0.029)	(0.029)	(0.029)	(0.031)
No trust	0.051*		0.061**	0.059
	(0.031)		(0.029)	(0.039)
Decision share (self)		-0.063	-0.070*	-0.085*
		(0.039)	(0.037)	(0.050)
Decision share (spouse)		0.106**	0.116***	0.058
		(0.042)	(0.041)	(0.056)
Observations	422	422	422	416
R-squared	0.076	0.086	0.097	0.551
Controls	YES	YES	YES	YES
HH FE	NO	NO	NO	YES

Table 3.9 reports the estimations of individual inefficiency. We again find that trust and female matter, even though the coefficient attached to female is now sensibly smaller than in the previous estimations. Interestingly, the structure of household decision making matters,

[16] 75% of the women could have increased their individual gains by sending more to their husband in the first stage.

as inefficiency is larger when the player's spouse takes more decisions on her/his own, and lower when the player has more decision power. In other words, giving up on expected return transfers is more prevalent when one has less decision power relative to the partner.

3.5.3 Demand for Agency

These results indicate among women a strict preference for one dollar directly received over one dollar sent by the spouse, particularly when the latter concentrates decision power. In line with the anthropological evidence presented above, we interpret these preferences as a demand for exclusive, unshared, decision power. This follows from the idea that, by giving money, the husband ensures some say on its use. This pressure need not be explicit and may well be fully internalized by the woman. When receiving a transfer from the husband, she takes the role of the household manager and spends this money according to the expected behavior attached to this role. The greater control over the amount privately kept is facilitated by secrecy, since the partner will never be informed about its existence and use (as explained above, players never learn about the amounts actually kept by their partner.) This interpretation is in line with the recent economic literature on the measure of female empowerment that insists on the difference between declared participation to decisions and effective control of household resources (Bernard et al., 2020; Donald et al., 2020). By contrast, the fact that men are close to their private optimum implies that they are almost indifferent between money kept or received. This suggests more freedom in the use of the money they were given by their wives.

Table 3.10: Spending patterns by type of voucher

	(1) Individual		(2) Couple		T-test Difference
Variable	N	Mean/SE	N	Mean/SE	(1)-(2)
Amount spent on female item	106	31.132 (4.148)	105	26.952 (3.736)	4.180
Amount spent on male item	106	43.585 (8.254)	105	79.810 (10.658)	-36.225***
Amount spent on household item	106	346.698 (12.808)	105	463.810 (12.976)	-117.111***
Coupon value	106	412.075 (11.320)	105	586.857 (9.682)	-174.782***

We find some support for this interpretation in the analysis of the spending patterns associated with the vouchers that were distributed after the games to compensate players for their participation[17]. The items available in the shop were chosen so as to be easily categorized between female (perfume, hairbrush...), male (male head cap, sunglasses...) and household items (food, children items...). Table 3.10 reports the average total amounts spent in each category by households who received individual (column 1) or couple vouchers (column 2). Couple vouchers are on average of a higher value (simply because they were determined by the outcome of a different game) than the sum of the individual vouchers (last row of Table 3.10). We thus expect expenditure on all types of items to be larger under a couple voucher. Surprisingly, while the amounts spent on male and household items are significantly larger, the amount spent on female items remains unchanged. This suggests that under joint decision, female preferences are not fully expressed or accounted for[18].

3.6 Conclusion

Our experiment highlights the prevalence of a general sharing norm whereby women manage two-thirds of household resources. This behavior reflects the typical organization of Philippine households described in the literature, where women enjoy a favorable status and are in charge of the household finances while men keep an allowance for their own private expenses. The norm seems to be fully internalized as reflected by the amounts sent by husbands and wives across all games. One would expect that such a norm, by clearly shaping expectations, would allow households to maximize their joint payoffs.

In this context, it is surprising to find levels of inefficiencies similar to those highlighted in the experimental literature in settings that are apparently more conflictual and less favorable to women. In our experimental games, women are willing to give up substantial gains when those are handed in by their husbands, revealing a strong, latent, demand for agency. This demand for agency expresses itself through a strong preference for money unknown to their spouse over (larger) transfers as the latter involve an implicit control over their use. This calls into question classical measures of female empowerment that rely on women nominal command over household resources.

The recent empirical literature highlights the prevalence of a demand for secrecy within households. Our interpretation introduces a subtle distinction between this demand for secrecy and a demand for agency. While a preference for secrecy typically signals a demand for agency,

[17] Unfortunately, as the coupon values are determined by the decisions made during the games, they also depend on the degree of cooperation between spouses which has a direct impact on their expenditure pattern. We cannot therefore provide a more detailed analysis of these data and we simply compare average expenditures across couple versus individual voucher categories.

[18] It is striking to note that the expenditure pattern under a couple voucher remains unchanged even when the wife comes alone to redeem the coupon.

the latter may manifest itself even under complete information. As we tentatively showed, the value of income at one's disposal differs depending on the identity of the person who generated it. This suggests a promising avenue for further research.

Appendix

Appendix A-3: Additional tables

Table A-3.1: Share sent in Dictator Game

	(1)	(2)	(3)	(4)
VARIABLES				
Female	-0.243***	-0.242***	-0.242***	-0.242***
	(0.033)	(0.033)	(0.034)	(0.034)
No trust	0.012	0.011	0.012	0.011
	(0.030)	(0.030)	(0.030)	(0.030)
Decision share (self)	0.003	0.002	0.004	0.003
	(0.046)	(0.046)	(0.047)	(0.047)
Decision share (spouse)	0.027	0.025	0.028	0.026
	(0.047)	(0.047)	(0.047)	(0.047)
Wife owns land		-0.011		-0.011
		(0.027)		(0.027)
Matrilocality			0.011	0.011
			(0.033)	(0.033)
Female * Matrilocality			-0.001	-0.001
			(0.040)	(0.040)
Observations	424	424	424	424
R-squared	0.250	0.250	0.250	0.250
Controls	YES	YES	YES	YES
HH FE	NO	NO	NO	NO

Table A-3.2: Share sent in Dictator Game with multiplier

VARIABLES	(1)	(2)	(3)	(4)
Female	-0.164***	-0.164***	-0.161***	-0.161***
	(0.038)	(0.038)	(0.038)	(0.039)
No trust	-0.111***	-0.112***	-0.111***	-0.112***
	(0.028)	(0.028)	(0.028)	(0.028)
Decision share (self)	-0.044	-0.047	-0.045	-0.048
	(0.044)	(0.043)	(0.045)	(0.044)
Decision share (spouse)	-0.055	-0.060	-0.055	-0.060
	(0.046)	(0.046)	(0.046)	(0.046)
Wife owns land		-0.021		-0.021
		(0.031)		(0.031)
Matrilocality			0.003	0.004
			(0.028)	(0.028)
Female * Matrilocality			-0.009	-0.010
			(0.037)	(0.038)
Observations	424	424	424	424
R-squared	0.181	0.182	0.181	0.182
Controls	YES	YES	YES	YES
HH FE	NO	NO	NO	NO

Table A-3.3: Share sent in Trust Game

VARIABLES	(1)	(2)	(3)	(4)
Female	-0.197***	-0.197***	-0.200***	-0.199***
	(0.037)	(0.037)	(0.037)	(0.037)
No trust	-0.074**	-0.075**	-0.074**	-0.075**
	(0.029)	(0.029)	(0.029)	(0.029)
Decision share (self)	-0.065	-0.067	-0.061	-0.063
	(0.052)	(0.051)	(0.052)	(0.051)
Decision share (spouse)	-0.075	-0.077*	-0.071	-0.073
	(0.047)	(0.045)	(0.047)	(0.045)
Wife owns land		-0.012		-0.012
		(0.031)		(0.031)
Matrilocality			0.032	0.032
			(0.030)	(0.030)
Female * Matrilocality			0.008	0.008
			(0.040)	(0.040)
Observations	424	424	424	424
R-squared	0.191	0.191	0.195	0.196
Controls	YES	YES	YES	YES
HH FE	NO	NO	NO	NO

Table A-3.4: Share returned in Trust Game

VARIABLES	(1)	(2)	(3)	(4)
Female	-0.193***	-0.192***	-0.160***	-0.159***
	(0.029)	(0.029)	(0.032)	(0.031)
No trust	-0.033	-0.035	-0.034	-0.036
	(0.029)	(0.029)	(0.028)	(0.028)
Decision share (self)	-0.020	-0.025	-0.023	-0.028
	(0.044)	(0.045)	(0.044)	(0.045)
Decision share (spouse)	-0.031	-0.038	-0.027	-0.035
	(0.042)	(0.042)	(0.042)	(0.042)
Wife owns land		-0.035		-0.036
		(0.030)		(0.030)
Matrilocality			0.063*	0.063*
			(0.037)	(0.037)
Female * Matrilocality			-0.105**	-0.105**
			(0.042)	(0.042)
Observations	424	424	424	424
R-squared	0.209	0.212	0.220	0.224
Controls	YES	YES	YES	YES
HH FE	NO	NO	NO	NO

Appendix B-3: Alternative Trust Game return

Table B-3.1: Share returned in Trust Game

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Female	-0.195***	-0.198***	-0.192***	-0.186***	-0.192***	-0.191***	-0.162***	-0.162***
	(0.028)	(0.028)	(0.028)	(0.032)	(0.028)	(0.028)	(0.032)	(0.032)
No trust	-0.027		-0.031	-0.035	-0.031	-0.032	-0.031	-0.033
	(0.031)		(0.030)	(0.042)	(0.030)	(0.030)	(0.030)	(0.030)
Decision share (self)		0.005	0.009	0.019	0.009	0.004	0.006	0.001
		(0.044)	(0.043)	(0.056)	(0.043)	(0.044)	(0.043)	(0.044)
Decision share (spouse)		-0.038	-0.044	-0.062	-0.044	-0.049	-0.043	-0.048
		(0.047)	(0.046)	(0.073)	(0.046)	(0.046)	(0.045)	(0.046)
Wife owns land						-0.029		-0.030
						(0.027)		(0.027)
Matrilocality							0.043	0.044
							(0.038)	(0.039)
Female * Matrilocality							-0.092*	-0.092*
							(0.047)	(0.048)
Observations	417	417	417	406	417	417	417	417
R-squared	0.202	0.201	0.204	0.631	0.204	0.206	0.212	0.215
Controls	YES	YES	YES	YES	YES	YES	YES	YES
HH FE	NO	NO	NO	YES	NO	NO	NO	NO

Table B-3.2: Share sent in Trust Game and spouse's return behavior

VARIABLES	(1)	(2)	(3)
Female	-0.212***	-0.198***	-0.202***
	(0.038)	(0.039)	(0.040)
Spouse's TG return	0.027	0.025	0.043
	(0.053)	(0.052)	(0.056)
No trust		-0.075**	-0.032
		(0.029)	(0.065)
Spouse's TG return * No trust			-0.081
			(0.102)
Observations	417	417	417
R-squared	0.167	0.179	0.179
Controls	YES	YES	YES
HH FE	NO	NO	NO

Appendix C-3: Script and scenarios

Table C-3.1: Game Scenarios

Scenario 1	Scenario 2
Dictator Game	Dictator Game with Multiplier
Dictator Game with Multiplier	Trust Game (sender)
Trust Game (sender)	Trust Game (receiver)
Trust Game (receiver)	Dictator Game
Scenario 3	Scenario 4
Trust Game (sender)	Trust Game (sender)
Trust Game (receiver)	Trust Game (receiver)
Dictator Game	Dictator Game with Multiplier
Dictator Game with Multiplier	Dictator Game

Figure C-3.1: Sample Game Script

INTRODUCTION

- You are going to perform a series of activities to help us better understand how households make decisions. In those activities, you will use fake bank notes but we ask you to act as if it was real money.
- To thank you and encourage you to play seriously, you will receive a gift voucher with a value between 0 and 400 pesos, proportional to your result in one chosen activity. We will only reveal which activity has been chosen at the very end.
- So you will only be paid for one activity, there is no link at all between the different activities and between the different decisions you are going to make. Since it is possible that some of you will get unlucky and will receive a voucher of 0 peso, you will also receive another voucher of 200 pesos to share between both of you no matter what happens during the activities. You will also receive it at the very end of the session.
- You will be able to exchange the gift voucher you will receive tomorrow/this afternoon for a series of goods that we brought with us that include food, clothes, school supplies etc.
- The value of your voucher will be known by you only and we will not tell anyone else about it, not even your spouse. You will be able to exchange it in private, without anyone else knowing what you choose, not even your spouse.
- Men and women will be separated for most activities. These activities are individual and we will not reveal any of your decision to anyone. There is no right or wrong answer. Each one may choose what s/he prefers.
- The session should take one hour and a half and will be followed by a small individual questionnaire. We will then go back to your house to ask more detailed questions to the head of the household about your agricultural practices.
- You are allowed to leave this session at any point but, in order to exchange your gift voucher, you need to participate to all activities, answer the small individual questionnaire and the detailed household questionnaire.
- If you have a question at any point, do not ask it out loud but please raise your hands and we will come to answer it in private.
- Please do not communicate with the other participants or try to look at what they are doing.

[IF THIS IS NOT THE LAST SESSION]

- Similarly, please do not talk about those activities with other people in this community as we will have several sessions with different households. Once you have exchanged your gift voucher, you will be able to talk about it to whomever you want.

[IF THIS IS NOT THE FIRST SESSION]

- If someone who has already gone through this session has told you about his/her experience, please try to abstract from it as this might make you misunderstand the instructions and you might make decisions that are not right for you.
- Is there anyone who wishes not to continue with the activities? If so, you can leave now. Otherwise, we will now separate men from women.

DICTATOR GAME, with MULTIPLIER, and TRUST GAME

- You have received two envelopes. In the BLUE envelope, there are 200 pesos in notes of 20 pesos. The RED envelope is empty.

- You can decide how to divide the 200 pesos between yourself and your spouse. The notes you leave in the BLUE envelope will be for you, the ones you put in the RED envelope will be for your spouse.
- You can give any amount you want to your spouse, between 0 and 200 pesos.
- For example, if I put 2 notes in my RED envelope, that's 40 pesos so my spouse will receive 40 pesos and I will keep 160 pesos.
- If I put 5 notes in my RED envelope, that's 100 pesos so my spouse will receive 100 and I will keep 100.
- If I put 9 notes in my RED envelope, how much will my spouse receive? (180). How much will I keep for me? (20).
- If this is the activity that we select to determine your earnings, you will receive a gift voucher with a value of the money you put in the BLUE envelope and your spouse will receive a gift voucher with a value of the money you put in the RED envelope.
- Please put in the RED envelope the amount of money you want to give to your spouse and in the BLUE envelope the amount you want to keep for yourself.

[DECISION]

- We will now collect the envelopes and distribute you two other ones. Again, the BLUE envelope will contain 200 pesos in fake 20-peso notes and the RED envelope will be empty.

[COLLECT ENVELOPES AND DISTRIBUTE NEW ONES]

- You are now going to repeat almost exactly the same task: decide how much to send to your spouse by putting money in the RED envelope.
- This time, however, your spouse will receive triple the amount that you send.
- The money that you leave in the BLUE envelope will be for you but will not be tripled.
- For example, if I put 5 notes in my RED envelope, that's 100 pesos so my spouse will receive 300 and I will keep 100 (the 5 notes that stay in my BLUE envelope).
- If I put 8 notes in my RED envelope, that's 160 pesos so my spouse will receive 480 and I will keep 40 (the 2 notes that stay in my BLUE envelope).
- If I put 3 notes in my RED envelope, how much will my spouse receive? (180). How much will I keep? (140). Again, you can give any amount you want to your spouse, between 0 and 200 pesos. It can be the same as in the previous activity or a different amount.
- Please put in the RED envelope the amount of money you want to give to your spouse and in the BLUE envelope the amount you want to keep for yourself.
- Once again, your spouse will receive triple the amount you put in the RED envelope.

[DECISION]

- We will now collect the envelopes and distribute you two other ones. Again, the BLUE envelope will contain 200 pesos in fake 20-peso notes and the RED envelope will be empty.

[COLLECT ENVELOPES AND DISTRIBUTE NEW ONES]

- You are now going to repeat the same task as before: decide how much money to send to your spouse by putting that money in the RED envelope. This time again, your spouse will receive triple the amount you decided to give him/her.
- This time, however, your spouse will then have an opportunity to send back some of the money s/he received. You will then receive the amount sent back by your spouse, which will not be tripled.

- So in the end, you will have the amount of money left in the BLUE envelope and the amount sent back by your spouse. And your spouse will have triple the amount you put in the RED envelope minus what s/he decided to send back to you.
- For example, if I put 5 notes in my RED envelope, that's 100 pesos so my spouse will receive 300. Out of those 300 pesos, she then decides how much to send back, between 0 and 300. Let's say she decides to send back 80. So in the end, I have the 100 pesos I kept in my BLUE envelope plus the 80 sent back by my spouse, so 180 pesos. She has the 300 pesos she received minus the 80 she sent back, so 220 pesos.
- Here is another example. If I put 8 notes in my RED envelope, that's 160 pesos so my spouse will receive 480. Out of those 480, let's say she sends back 200. In the end, I have the 40 pesos I kept in my BLUE envelope and the 200 my spouse sent me, so 240 pesos. She has the 480 she received minus the 200 she sent back, so 280 pesos.
- One last example. If I put 2 notes in my RED envelope, that's 40 pesos, so my spouse will receive 120. If she decides not to send me anything, how much will I have in the end? (160) and how much will she have? (120).
- Please put in the RED envelope the amount of money you want to give to your spouse and in the BLUE envelope the amount you want to keep for yourself.
- Once again, your spouse will receive triple the amount you put in the RED envelope and will then have the opportunity to send you back some money.

[DECISION]

- Imagine now that your spouse has played the same activity, has decided to give you some amount of money out of 200 pesos and that you receive triple that amount.
- You can then decide how much of the money you received to give back to him/her.
- To keep things simple, let's assume that your spouse could have sent you only 5 amounts: 0, 50, 100, 150 and 200 pesos. Which means that you can receive 0, 150, 300, 450 or 600 pesos.

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- Here is a list of all the amounts that you can receive. Next to each amount, you will write how much you would like to give back to your spouse.
- For example, the first row shows 150, which means that my spouse decided to send me 50 and that I received the triple, 150 pesos. I can then write any number between 0 and 150 which is the amount I would like to send back to her. If I write 40, this means that I will give her back 40 and keep 110 for myself.
- The second row shows 300, which means that my spouse sent me 100 and that I received the triple, 300 pesos. I can then write any number between 0 and 300, which is the amount I would like to send back to her. If I write 200, this means that I will give her back 200 and keep 100 for myself.
- The last row shows 600, which means that my spouses sent me how much? (200). If I write 100 next to it, how much will I give her back? (100). How much will I keep for myself? (500).
- You can send back any amount you want, between 0 and the amount you received.
- Please write next to each amount how much you would like to send back to your spouse.
- Once again, the amount you write cannot be bigger than the amount you received and your spouse will receive exactly that amount, it will not be tripled.

[DECISION AND COLLECT LIST]

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