Farmers, Food production and Financial markets

A review of the literature on agricultural sector in developing countries

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Abstract

In 2015, the world community adopted 17 Sustainable Development Goals (SDGs) at a United Nation Summit. One of the goals, is to end hunger and to achieve food security for the poor by 2030. This paper will review existing literature on the agricultural sector in developing countries, to illustrate why this goal may be not so easy to achieve. Agricultural markets, rural finance, financial constraints, and nutrition and productivity are some of the topics which will be reviewed, discussed, and criticized. The discussion will be supplemented with assorted data from Food and Agricultural Organization of the United Nations, to present an overview of the current and past status of the agricultural sector. In addition, one agricultural household model will be derived to demonstrate the similarities and differences in comparison with neoclassical household models.

Acknowledgement

I would like to thank my supervisor Assistant Professor Yikai Wang for his valuable comments and feedback throughout the writing process.

To Professor Stein Terje Holden at the Norwegian University of Life Sciences, thank you for helping me with sources in an early stage of the process.

Finally, I want to thank my girlfriend Cathrine Sørensen for her endless support and encouragement.

Dedication

I would like to dedicate this thesis, first of all, to my parents. As first generation Syrian refugees, you don’t know how much I’m grateful for the struggle and stress you have been through to provide me and my siblings a better life.

Secondly, I want to dedicate the paper to my brother and my sister, my friends, and the academic staff at the University of Oslo. You have inspired me in many ways, and made my journey towards the degree exceptional.

Preface

This thesis was written as a completion of the Master of Philosophy in Economics at the University of Oslo.

In an ideal world, we would like farming households to produce (to gain food and income) and to consume (to gain nutrition, productivity, and well-being) their way out of poverty. And to make the transition to a modern lifestyle, where the heads of the family work normal hours and the children go to school, to be educated and have a decent amount of playtime. But in reality, the households engage in an environment with imperfect markets, receive low support from their governments, and are exposed to harsh climatic forces which can ruin their livelihood, if they're not fully insured.

This paper will review the literature on agricultural sector in developing countries, to illuminate and address the behavior and challenges for farming households.

I'm solely responsible for any errors or inaccuracies in the thesis.

Table of Contents

List of tables:

List of figures:

Introduction

> *You might say that economic history is the history of people learning to manage risk. – James Surowiecki (American journalist at The New Yorker)*

What is the link between agriculture sector and financial sector? There's not an easy answer to it. Agricultural sector is still an important sector. Reason I say still, is that it's associated with economies in primary states. The role of agriculture as a main center for human and economic development has gradually ceased. Most economies have gone through the basic transitions to industrial and then to service sector.

Agriculture is fascinating because it's so important to our human existence and it involves interaction with nature. The interplay of human, animals and plants require caution and respect. To grow our own food is vital for humanity and our presence. That's also why some countries have high import tariffs on agricultural goods in order to protect their own farming sector from world market competition. For a country, trying not to lose skills and ability to produce their own food is highly demanded and important, especially when food and nutrient crises are ongoing. Nevertheless, there are few countries today which are fully self-sufficient.

Motivation

The reason I want to study the agricultural sector, is that there's consensus among economists that agricultural production is correlated with economic growth, human development and a getaway from poverty. Many farmers are dependent of food production both for own consumption but also for trade and export. Food consumption is obviously important to survive and live, but in a production sense, economists are also interesting in conducting the relation between food consumption and productivity, and economic growth. Many farmers in developing countries doesn't have access to proper formal labor markets, financial markets or other formal institutions such as schooling and education. Since farming and harvesting is such a huge part of daily life, we as a world community want to ensure that poor farmers produce food as efficient and organic as possible. FAO and the World Bank states that agriculture is the largest source of income and jobs for poor rural households, providing income for more than 30 per cent of today's global population (FAO, 2015).

General overview

How big is the agricultural sector? The sector is very wide in definition and may involve production of food items (rice, cereal, vegetables etc.) and non-food items (flowers, tobacco, biofuel, medicine, cotton etc.) in soil, but also keeping animals in captivity (livestock) for consumption, pasturing or breeding. Let's take a quick overview of the current and two past decades in the world:

	1990	**2000**	**2014**
Population in total (in millions)	5320.8	6127.7	7243.8
Population, rural (in millions)	3033	3263.4	3362.5
Employment in agriculture (%)	35.3	38	30.7
Employment in agriculture, female (%)	9.2	20.3	25.2
Prevalence of undernourishment (%)	18.6	15	10.8
Food production value (in 2004-2006 US $ millions)	1 294 508	1 618 814	2 246 912
Food production value per capita (in 2004-2006 US $)	243.3	264.2	310.2

Table 1: World indicator comparisons, statistical data gathered from FAO's yearly statistical pocket book (FAO, 2015). Source: Population data, undernourishment data and food production data are from FAO statistical division, while employment data are from World Bank.

Table 1 shows us a brief overview on the agricultural status in the world. What is interesting is that the world has had a rapid growth in population, while the rural population has more or less been stable the last two decades. This could imply that the urban part of the population must have driven the population growth. Some of the growth could be explained by population migration from rural areas to urban areas. Another indicator of this hypothesis is the slowly decline of employment in agriculture. What is most interesting perhaps is that female proportion of the agriculture employment has almost tripled from 1990 to 2014. There could be many explanation to that, e.g. higher individual dependency for women, lower discrimination of women labor, increased human capital, more men shifting to non-farming jobs such that farming families are more dependent on help from female labor or simply, better data access and data quality. Lastly, prevalence of undernourishment has declined in the same period. This is not necessarily breaking news, since the world population has increased in the same time frame, in absolute value the undernourishment could be unchanged. Now,

over to food consumption measured in kilo calorie (kcal) intake for an arbitrary selection of developing countries.

	Country-level	*Household size: One person*	*Household size: 2 to 4 people*	*Household size: 5 or more*
Bangladesh	2119.18	2501.77	2216.83	2070.18
(2005)	(563.65)	(821.47)	(623.39)	(523.27)
Cambodia	2013.54	2807.61	2270.83	1908.22
(2004)	(821.16)	(1636.40)	(887.53)	(761.47)
Guatemala	2289.96	4416.36	2773.11	2063.87
(2006)	(1109.34)	(2863.53)	(1228.78)	(896.00)
Kenya	1798.67	4331.5	2381.86	1561.83
(2005-2006)	(1198.94)	(2442.46)	(1333.25)	(943.95)
Niger	1937.64	Not available	2187.45	1890.92
(2007-2008)	(659.38)		(809.65)	(614.34)
Sri Lanka	2181.81	3371.78	2423.7	2015.43
(1999-2000)	(832.30)	(1492.91)	(840.82)	(771.44)
Uganda	2158.88	3847.5	2405.03	2056.78
(2002-2003)	(1113.51)	(2587.87)	(1348.06)	(938.75)

Table 2: Data from household surveys in FAOSTAT's online database. The surveys conducted in the year shown in parenthesis below each country name in the first column. The values are in mean kcal/capita/day, with standard deviation in parenthesis below. Source: FAOSTAT (2017a)

Table 2 provide us data on average calorie consumption for seven developing countries. It's not easy to provide cross-country surveys for the same time periods, although this is just an illustration. According to World Health Organization, an adult, in order to sustain a healthy diet, should consume approximately 2000 kcal per day (WHO, 2015). The data in Table 2 is aligned with the recommendation from WHO, especially on country-level. What is also not very surprising is that the average calorie consumption per capita is decreasing as the number of members in the household increases. Obviously more members, more head to share food with within the family. What's frightening however, is the large standard deviation in calorie

consumption for some of the countries. Look at Kenya for instance, in households with 5 or more members the average (mean) calorie consumption was approx. 1500 kcal, which is a bit below the recommended level. But, the standard deviation is around 900 kcal, meaning that there's some values in the distribution which go as low as 600 kcal consumed per capita per day, which is pretty poor[1].

In September 2015, the United Nations had Sustainable Development Summit where 17 global goals were adopted to improve nutrition, end hunger, reduce inequality and tackle climate changes by 2030. According to UN and World Food Programme:

> *"795 million people – one in nine – still go to bed on an empty stomach each night. Even more – one in three – suffer from some form of malnutrition."*

Quote: World Food Programme Zero Hunger Goal (World Food Programme, 2015)

A quick look at India

Let's take a quick look at India (Figure 1), which is an emerging economy with a huge rural population, and the world second largest populated country. There's no doubt that crop and food production has increased from 1996 to 2013. The population has increased rapidly. From 1990 to 2014 the population increased from roughly 869 million to 1267 million (145 % increase). The rural population in the same time period increased as well, from 647 million to 857 million, translated to 132 % increase in same period (FAO, 2015). What is interesting here is that although production has increased from 1990 to 2014 (161 % increase for crop production and 165 % increase for food production), the food supply of rice and cereals in per capita has more or less been stable, while food supply of vegetables has fluctuated with production. An idea is that as the economy grows and production increases, the sector is shifting to more vegetables and varied production items, while rice and cereal is consumed in fixed proportion independent of the economic state.

[1] It's important to remember that the data does not take into account regional differences, differences within a household, differences in the size of observations and differences in seasons.

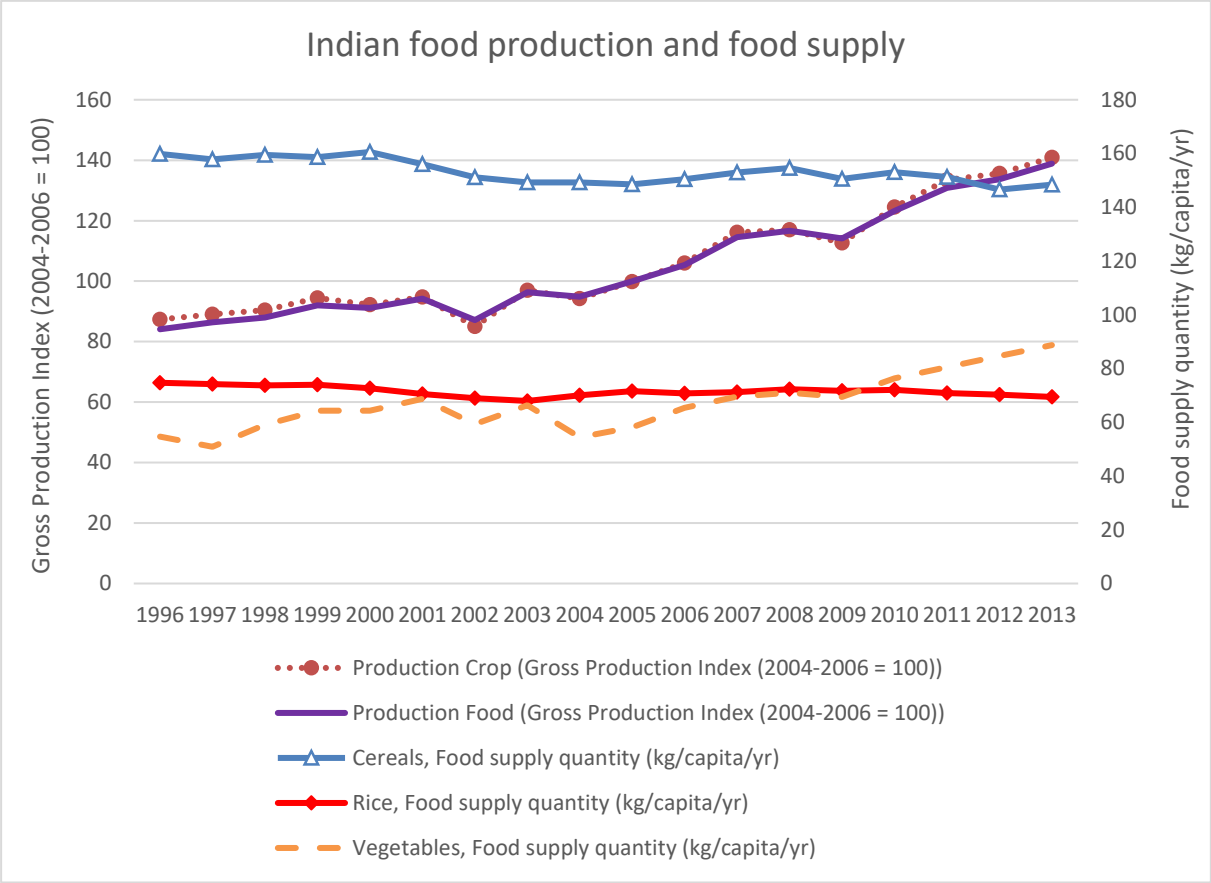

Figure 1: Historical data on food and crop production in comparison to food supply of Cereals, Rice and Vegetables for India. Production index has the base year around 2004-2006). The supplied quantities are in kg/per capita/per year. Data inserted in MS Excel by the author, to obtain a graph. Source: FAOSTAT (2017b)

Investigating changes in production and supply of food for India gave us a modest taste of the subject this thesis will handle. As mentioned earlier, approximately one-third of the world population have agricultural sector as livelihood. When so many people are depended primarily on one single sector, how is the daily life affected by different shocks to their production and income? How are they insured when there are unexpected changes in precipitation (too much or too little rainfall), diseases attacking the crop, extreme heat, lack of access to clean water or pollution affecting health condition? Do the poor farmers have access to social security in order to smooth consumption when they're facing bad or low crop in one season? What can the financial sector do to improve life of millions of farmers living from hand to mouth in an environment which involves uncertainty about their livelihood and the search of a prosperous life? This thesis will examine the existing literature on agricultural sector, and its characteristics, to moderately answer these questions.

Agricultural sector

There are a lot of challenges in the agricultural sector in economic sense. Historically there have been conflicts over land and resources as far as history goes back in time. As the primary sector, we've been dependent on land and food production to evolve and grow into a modern civilization. Our history of land hasn't always been a success story. We've had land inequality (disproportion factor endowment) as results of land reforms and conflicts, we've had colonial division of land, expropriation, forced labor in plantations, deforestation of rainforest which is vital for diversity of species and protection of the biological flora, and different land and agricultural policies which has not benefitted the affected regions (Sokoloff and Engerman, 2000, Easterly, 2007).

Why should we ensure that the agricultural sector is properly functioning and efficient? Well, the main goal is to provide food security for the population, but also equip rural population with a life purpose, a profession and a source of income. Although we must keep in mind that the usage of land, along with water draining and bio decomposition, is a scarcity and we should use it as efficient, organic and in a respectable way to the biological diversity we are a part of.

Land cultivation is also associated with different externalities; pollution, tampering nature, and it demands high volume of clean water, which can lead to drought of rivers and other water reserves. Even though drought is somehow not completely a cause of land production, it's somehow connected[2]. Scientists claim that the rapid changes in our climate is a result of the explosive gas emission to the atmosphere leading to global warming, drought, increased sea level and increased temperature and frequent natural disasters. In agriculture, mostly carbon dioxide and methane gas are emitted because of various activities, especially from livestock rearing. The livestock sector accounts for almost 40 % of the agricultural gross domestic production, and with a growing population and incomes, along with shifts in food preferences, the climatic impact can be colossal. It's predicted that the global production of meat will double from 2000 (229 million tons) to 2050 (465 million tons). And since livestock sector demand substantial land area for grazing (including land for cereal production to feed

[2] There's different types of drought, you have (1): Meteorological drought, which come from lack of precipitation (some will argue that this is caused by global warming, but this is a different discussion), (2): Agricultural drought (which come from lack of soil moisture, not access to water) and hydrological drought, which are drought in rivers, lakes and groundwater. WIREs Water (2015)

livestock), deforestation in large scale has been common (particularly in Latin America) and is one of the largest source of anthropogenic carbon dioxide emissions. (FAO, 2006)

Land usage

How huge is the agricultural sector in land usage? Let's first look at how much of the land is suited for agriculture:

	Sum of land area suited and land area already used for agriculture, as % of total land	*Arable land and permanent crop area as % of total land*
World	37,67	12,18
Africa	38,17	9,13
Americas	31,71	10,41
Asia	53,17	18,30
Europe	21,16	13,22
Oceania	49,46	5,85

Table 3: Table on agricultural land area. Data from 2014. The values are aggregated numbers, but computed to percentage as share of total land. Notes from FAOSTAT: The data may include official, semi-official, estimated or calculated data. Source: FAOSTAT (2017c)

The table shows us that huge part of the total land in the world is already arable land and permanent crop. Take Asia for example, almost one fifth of the total land is already cultivated, while there's high potential for an increase. When you think of Asia as the biggest continent (in area) in the world, one fifth is not a small number. For India, arable land and permanent crop counts for almost 57 % of the total land area. While China has roughly 13 % crop area of the total land area (FAOSTAT, 2017c).

The first column (sum of land area suited and land area already used for agriculture, as % of total land) shows us that there's huge potential for increasing arable land. Land area itself is not a scarcity itself (yet), but land area is an immobile production factor, so in order to have suited land for agriculture, the respective infrastructure must be in place. Many people live remote unwillingly, and the consequence of that is high transportation cost of delivering necessary input to the land, but also exporting the output to the markets. Whereas there's

large potential for increasing land for production, we must keep in mind that more agricultural land would benefit the population, especially the poor, but it's important to also produce efficiently and in ways which also take the biological environment in consideration as discussed earlier. The goal must be efficient and sustainable production.

Population projection

What about the rural population? Let's now look at the 48 least developed countries in the world. The rural population is often associated with agricultural production and can give us a hint on how many people are employed in the sector. It's very hard to find particular good data on agricultural employment in developing countries, the reason is that many farmers work in agriculture as an informal job and the access to data is either very limited, or based on simple estimates.

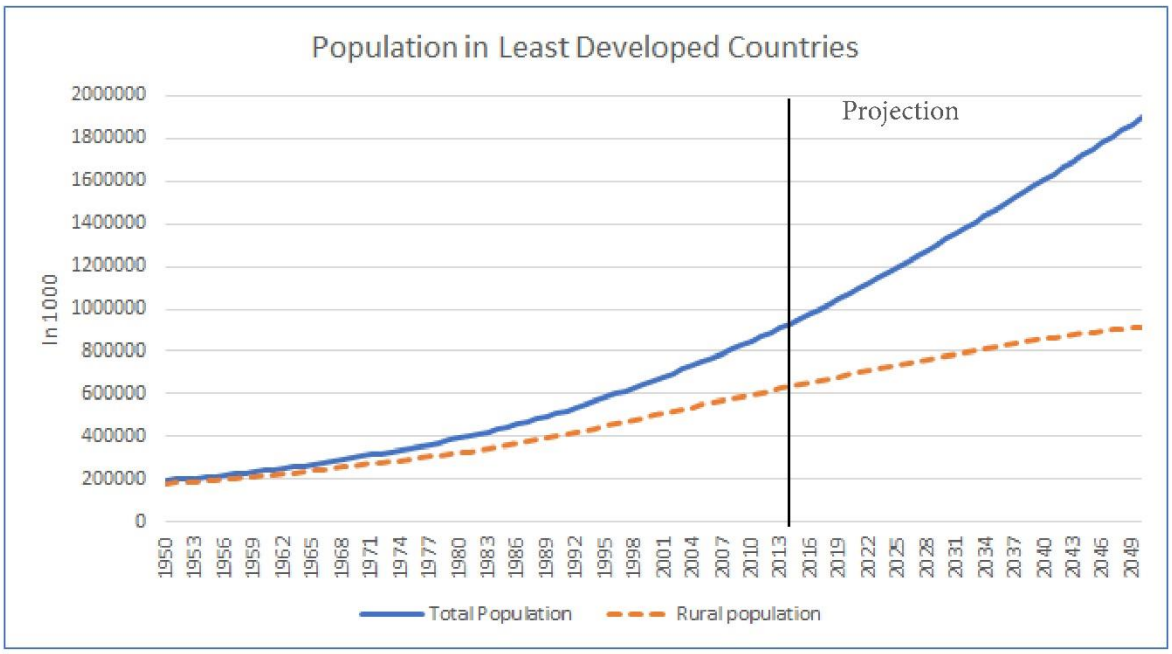

Figure 2: Historical and projected data on aggregated, rural and total population, from the 48 least developed countries. Data inserted in MS Excel by the author, to obtain a graph. See A2 in appendix for the complete list of all the countries. Source: FAOSTAT (2017d). Notes from the source: The data are aggregated, may include official, semi-official, estimated or calculated data. Population data refers to the World Population Prospects: The 2015 Revision from the UN Population Division. Rural population data refers to the World Urbanization Prospects: The 2014 Revision from the UN Population Division. Time series estimates and projections from 1961 to 2050.

From the graph in Figure 2 we can see that there's increasing gap between the total population and the rural population from 1950 to 2014. There could be two reasons for that, either

birthrates are increasing in the urban areas compared to rural areas, or there's population migrations from rural sector to urban sector leading to urbanization, or a combination of those two. FAO's statistical division has also forecasted the both population measures for the next 35 years, which shows us an increasing urban share of the population in the least developed countries[3].

- *We can ask ourselves, how will the farming share of population, when it's continuously reducing, sustain food security for the least developed countries?*

An increased urbanized world will decline the ratio of food producers to food consumers. Urbanization is inevitable as the economies grows and people demand more and more goods and services located closer to cities, enhancing cluster development (Satterthwaite et al. 2010). The consequence is an urgent need for technological innovation to fed the world population, either by *robotification*, or advanced genetically engineering. Some argues that the world is not short of food, the problem is inadequate distribution and logistical systems, and a need of better techniques to boost food durability. Having said that, no one can disregard that the world is wasting too much food[4].

Food production

According to Gilland (2002), to maintain the present global cereal production, will only be justifiable if it's a small increase in grain consumption per capita in less-developed countries, by means of an increase in net import of grain from the more-developed countries. One explanation is the change in consumer preferences. We can think of cereal as an inferior good. The more income and wealth you have, the less you would demand the good. Gilland (2002) claims that a substantial proportion of cereal production is fed to livestock (animals). Such that animal food products are preferred by those who can afford it. Animal food products is more a kind of luxury good, where the demand increases with wealth but there also a shift in

[3] We can read the urban share of the population as the difference, in numbers, between the rural population and the total population.

[4] Roughly one-third of food produced for human consumption is wasted. It amounts to 1.3 billion tons per year. Not all food is lost at consumer level, in low-income countries the proportion of lost food is in the supply chain, while in middle- and high-income countries most of the food is discarded at consumer level (either by consumers after bought from a store, or disposed by the store when passed expiration date). Much of the food waste also happens because consumer preference and attitude changes (FAO 2011a). Discounted food prices can create incentives for throwing perfectly consumable food. Furthermore, aesthetical preferences and expectations of how e.g. vegetables should look like and smell, may force producers and retailers to produce and sell only physical appealing items, sustaining a waste culture.

the consumer bundle of food items. Couple reasons are explained for the consumer shift to animal products, (1): Animal products are more nutrient with higher levels of protein and fat, (2): Animal products are more profitable to sell than cereal and vegetables, and (3): Animal products are associated with a higher standard of living. Gilland's last remark (Gilland, 2002), food production in present time has outpaced population thanks to improved plant varieties, and increase in nitrogen, potassium and phosphorus fertilizers. Other reasons are increased irrigation areas, and better and effective disease and insect control.

This is a major critic to *Malthus Law*[5]. The Economist Malthus proposed that the population would grow at a geometrical rate while the food supply would grow at a constant rate. Such that population would increase faster the food supply (or production), because of diminishing returns in food production. The Malthusian theory has been debunked by many economists in modern history because it does not take into consideration the technological improvement and innovation in food production. However, the theory is somehow important because it created a benchmark, and it reminds us that we cannot take food for granted, since we're part of a fragile biological system.

[5] Developed by the English economist Thomas Robert Malthus (Malthus, 1798).

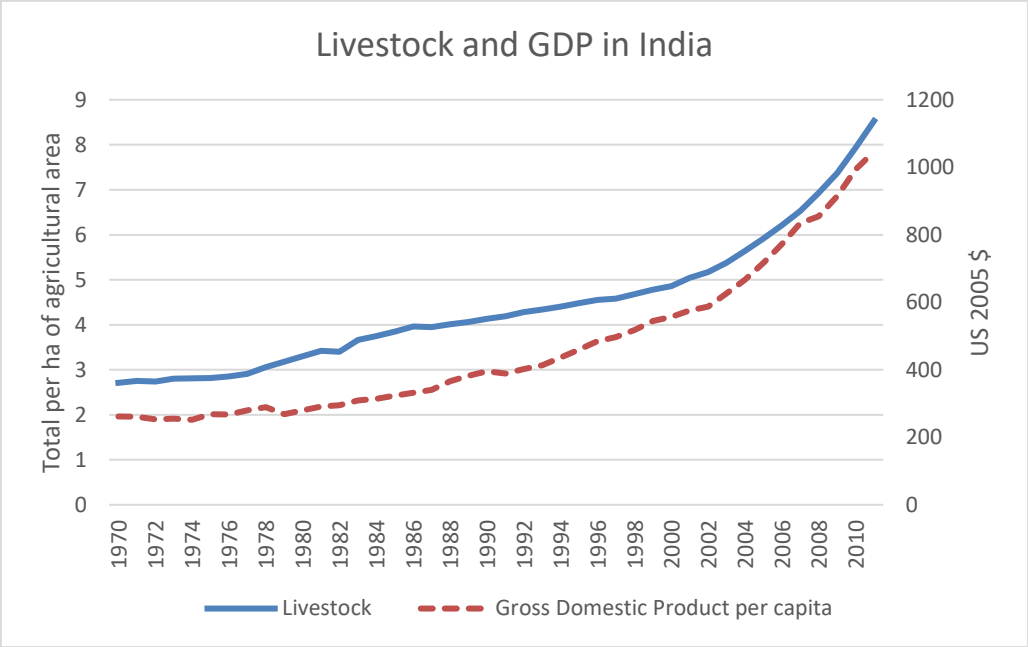

Figure 3: Historical data on the relationship between aggregated livestock ownership and GDP per capita in India. The total livestock value is the aggregate of main species (cattle, pigs, sheep and goats, poultry). Data inserted in MS Excel by the author, to obtain a graph. See A3 in the Appendix for the data used. Source: FAOSTAT (2017e).

Now, let's look at the relation between livestock and GDP per capita in India (Figure 3) to see if we can somehow say anything about which type of good animal products are. From the figure we can interpret, that livestock per hectare agricultural land have more than tripled (from 2.71 to 8.53) in the last forty years, while GPD per capita in 2005 prices (adjusted for inflation) has almost quadrupled (from 262,13 US dollars to 1046,29 US dollars), yielding an elasticity to 0.78, which do not support a claim of livestock being a luxury good (a luxury good has an income elasticity of demand greater than 1) in this simple data check. But testing for Kenya (elasticity of 2.49), Nigeria (elasticity of 1.53) and Guatemala (elasticity of 2.05) show the contrary[6]. Although data provided here only shows the number livestock which are alive (reported) and not the demand of meat, the livestock density on land has increased for all four countries from 1970 to 2011.

[6] The elasticities were acquired with this equation: $\frac{change\ in\ livestock}{change\ in\ GDP\ per\ capita}$. The changes where calculated by subtracting the start value (year 1970) from the end value (year 2011), then divide it on the average of the respective sequence. Since the data is non-linear, the elasticities are rough estimations. See A3 in the Appendix for the data set.

A report from FAO (FAO, 2011b) states that, despite a reducing population growth in the world, food consumption will in future increase to an average of 3000 kcal per capita (projected). In order to uphold that, the agricultural production must increase by 70 % (developing countries must increase their production by 100 %) within 2050 to cope with a 40 % population increase.

Agricultural markets

As any other sectors, the agriculture sector has different and various markets. There are markets for land (purchase and renting), internal and world markets for inputs such as; seeds, fertilizers, livestock, chemicals, capital (human and machinery), knowledge and logistics, and financial markets for insurance, credit, loans and deposits. Usually there are imperfections and efficiency loss in these markets. There can be lack of information, not optimally functioning policies, weak property rights, exploitation of labor and animal, and low rate of security towards fluctuations in output, prices or weather conditions. The rural sector in developing countries are often associated with informal markets, markets where there's non-monetary transactions (exchange of favors, goods, and services), and to some extent abuse of market power. Agricultural markets are a huge source of income for rural population, but also urban population, since most of the food comes from agricultural sector. One major feature of the sector is how it's contingent on seasonal variations, which involves coordination in the production and the supply chain. Another feature is the vulnerability of shared failure to the supply chain. These two features will be discussed more deeply.

Seasonality

Agricultural markets are highly sensitive to seasonality. Seasonality and synchronic timing are major causal drive of prices and production in agriculture (Binswanger and Rosenzweig, 1986, Binswanger and van den Brink, 2005). Climatic variation in connection with immobility of land creates a coordination problem in the sector. A farmer has to time when to buy or rent input, such that she can plan when to seed and when to harvest in order to maximize yield. If the plot is dispersed far away from input and output markets, planning for production can be an exhausting and tedious project. Not to mention, costly if infrastructure is badly developed. Because of seasonality in production, the risk of price and output volatility, will mostly be covariant (affecting jointly). Binswanger and van der Brink (2005, p. 277) explain the issue of seasonality and synchronic timing in agricultural production as follow: at the beginning of the season, farmers wants to buy seeds, so there's a need for liquidity. Since the season starts for all the farmers in the region simultaneously, the price of credit (interest rate) can or will increase because of the aggregated demand. Later when it's time to harvest (and since harvesting period is more or less at the same time for the farmers) there could be a huge overflow of products to the markets. The result is less profitability for

farmers since competition and supply is too high (assuming that farmers are price-takers) leading to reduction in overall food prices[7].

Covariate Risk

The agricultural sector is sensitive to covariate risk because of factor immobility, but also because of the role climate has to affect prices and output (Binswanger and Rosenzweig, 1986, Binswanger and van den Brink, 2005, Alderman and Haque, 2007, Barrett, 2011). Covariate risk is when a whole neighborhood faces the same shock, in opposition to idiosyncratic shocks which only one neighbor (or household) faces a shock. It's important to study covariate risk to understand agricultural households. The main problem with managing this kind of risk is the high cost of financial intermediation (Binswanger and van den Brink, 2005, Alderman and Haque, 2007). It's very hard for a financial company to provide insurance when all the costumers (or households) in the region defaults on their credit obligations or have to cash out insurance at the simultaneously. This is the same type of risk a deposit bank is trying to avoid, the risk of a majority of the clients asking for their deposits at the same time, forcing the bank to fire sell their assets[8], and eventually becoming insolvent.

So, what is the essence of covariate risk? Well, first of all, it's the seasonality of the agriculture sector, and second, the unexpected variations in weather condition which creates high entry cost for a financial intermediary to establish in the region. Because of seasonality the demand of credit or insurance will be pretty much the same for all the farmers in the region. Binswanger and van den Brink (2005, p. 277) present an example as follow: (1): At the beginning of the farming season, farmers want to borrow, or withdraw savings, to buy inputs. For a financial intermediary to not go bankrupt, it has to have large reserves or perhaps have multiple branches (in either other agricultural climatic zones or in other sectors) to diversify their portfolio. (2): At harvest time, the agricultural traders will want to borrow to purchase new crop, farmers cannot have yet deposited the profit from their sales. A new liquidity crunch arises.

Unexpected variations in weather, or insect infestation and pest (if it's contagious) to the insured crop, will create risk management problems for an intermediary. If the households

[7] Noorani et al. (2015) also support the same narrative when they studied prices and seasonal variations of the most common vegetables in Pakistan.
[8] Fire sale means liquidation of assets at highly discounted value.

have bought a yield insurance, more than one household, if not all, will be affected at the same time such that everyone has to collect compensation simultaneously leading to a failure in the insurance scheme (equal scenario to mass deposit withdrawal).

"Seasonality and co-variant risks together explain why the micro-lending successes are largely concentrated in irrigated areas, with lower agricultural production risks than dry-land agriculture, or in peri-urban areas, where there is a significant non-farm sector, which does not exhibit co-variance with the farm sector"

- Quote from "Credit for small farmers in Africa revisited: Pathologies and Remedies" (Binswanger and van der Brink, 2005, p. 275)

Informal markets and crop sharing

Agricultural sector is also full of informal and interlinkage markets. Existing literature on land renting (Stiglitz and Weiss, 1981, Binswanger and Rosenzweig, 1986, Ray, 1998,) share the same story, where a landlord and a tenant can engage in form of a contract with multiple transactions. In poor farmer household, it's more usual to rent land. Reason is that land plot has either been allocated historically through reforms or inherited from previous generations such that majority of land is in the hand of few (Sokoloff and Engerman, 2000). The challenge with land renting is to design an optimal and efficient contract. Some places there's sharecropping, where the tenant has to submit a share of her crop to the land lord as rental payment, or you have fixed rent payment schedule. There are inefficiencies associated with both type of contracts. In sharecropping, the landlord cannot (mostly) observe the effort or the type of the tenant, if the landlord is located for example in a nearby city. The landlord wants the tenant to produce as much output as possible, but effort is costly for tenant, especially when she cannot keep the entire produced output (low incentives for inducing effort). Risk sharing between the contracting agents where asymmetric information is an aspect, often causes efficiency losses.

Stiglitz and Weiss (1981) argue that sharecropping (revenue sharing) is inefficient with pretty much the same rationale, that the tenant doesn't have enough incentives to give full effort. Their explanation is that the tenant will only take into account her own share of the output (on the margin) when utilizing effort, rather than the total output, therefore too little effort will be given. The landlord wants to maximize his revenue such that he wants the tenant to give full

effort and produce as much as possible. The landlord doesn't have good screening and monitoring technology to select (adverse selection) the desired tenant, and observe (moral hazard) the effort when the tenant is hired, or it's costly (a supervisor can be hired). This is a classic principal-agent problem. The second type of contracting, as mentioned, is where there's fixed rental payment from the tenant to the landlord. The landlord prefers this type of contract, since the tenant bears all the risk. The landlord has a stable source of income, but the tenant is not insured against downside risk. The tenant will not perceive fixed payment as fair if she is risk averse (only if she is risk neutral), on the grounds that the fixed rate will occupy a large share (small share) of her income in bad times (good times), enlarging the income gap between the good state and the bad state. The literature on asymmetric information solves the issue of adverse selection and moral hazard, where the principle offers the agent a contract where the agent is reimbursed a higher wage than market wage to induce effort, but also punishes the agent by paying a lower wage than market wage when effort is low. In this case, when the agent is a lazy type, she will receive a lower wage, but if she is productive, she will be rewarded[9] (Laffont and Martimort, 2002).

Landlord and tenant can also engage in a contract with several transactions, also called interlinking (Ray, 1998). For example, the tenant can loan funds from the landlord at the beginning of the season, holding her yearly share of the crop as collateral. There is often very high interest rate on loans from informal markets[10], making the tenant (and the family of the tenant) in deep debt to the landlord. Interlinkage could be preferable for both parties, the collateral is highly suitable since embezzlement would lead to eviction and ruined reputation for the tenant (Besley et al. 1993). The problem is that an agency cost would arise here as well, the tenant has low incentives to give full effort if she knows in advance that she will default, because the crop will not be kept by her.

[9] The theory is based on couple assumptions, (1): The agent's cost function is known to the principle, (2): The contract is fully enforceable and (3): There's strong causality between the agent's effort and output level.
[10] One explanation is that higher interest rate attracts borrowers who have been rejected by formal banks (Stiglitz and Weiss 1981).

Finally, let's create an outline of the agricultural sector:

Inputs	Outputs	Agents	Type of markets	Market imperfections	Exogenous shocks	Contractual agreements	Contractual imperfections
Seeds	Cereals	Households	Agricultural property	Monopolies	Price variations	Input/Output sales	Asymmetric information
Fertilizer	Vegetables	Landlords	Merchant markets	Monopsonies	Weather variations	Insurance	Risk
Chemicals	Animal products	Tenants	Financial	Externalities	Political instability	Credit	Legal enforcement
Land	Flowers	Moneylenders	World markets	Rationing	Disease attack on crop or/and humans	Land/Agriculural property sales/renting	Power abuse
Farmer	Other food items	Merchants	Labor	Lack of access	Climate changes	Fixed rates	Weak property rights
Expertise	Other non-food items	Banks	Input	Lack of information	Technological changes	Sharecropping	Bailout/Contract breach
Machines		Government		Taxes and subsidies	Property sabotage	Interlinkage	Defaults
Livestock		NGOs					Embezzlement
Water		Social institutions and entrepreneurs					
Storage unit							
Trees							

Table 4: An outline of the agricultural sector from different sources in the author's reference list. Created by the author in MS Excel.

Financial markets

Consider a case where a farmer has an objective function to maximize her own and the household's utility. The farmer wants to smooth consumption over the life-cycle and can produce food for the household's consumption and sell some excess in local markets. The household require a minimum certain amount of food daily, and more than that can either be restored or traded for cash or other goods. We know that storage and conservation of food demands space and is only for limited periods. If the household doesn't have savings, how can they then smooth consumption over the life-cycle? The answer must be engagement in financial markets. Markets for insurance and credit is a way to solve this problem. The farmer wants insurance in bad states and are willing to pay a risk premium in good states. This dependence of course on the risk profile of the farmer (Morduch, 1995). A risk averse farmer has incitement to smooth consumption, because he doesn't like fluctuations in consumption (or income). So, he will give up some consumption today (to buy coverage), if he knows risk will occur in future. An intermediary will offer coverage, but in return a premium will be required. The premium is analogous to the cost of phasing out uncertainty.

Rural financial sector may be underdeveloped but desired. The farmers are commit to a production chain involving uncertainty in several links. From the producer point of view, the main objective is to maximize the yield given the limited inputs available. But for many, the farmer lifestyle may be involuntary, and so different options to achieve better life may be considered. The farmer family may migrate to urban sector (or abroad), invest in education for their children (Conning and Udry, 2007), so the children can take care of the elder when they've grown up. The family can also engage in side projects, like crafting, opening a small business, or seek charity to raise liquidity and avoid being stuck to only one uncertain income source.

Credit rationing and Collateral

Stiglitz and Weiss (1981) derive a theoretical analysis on why the law of supply and demand often doesn't hold. Their analyses show that credit must be rationed rather than given to the borrower with the highest marginal willingness of payment. The reason shortly explained, is that higher interest rate on loans issued is preferable for the bank, but it will attract bad borrowers. The bank wants to use the interest rate as a signaling device to attract desired

clients (clients with good reputation to repay their loans, clients who are willing to induce effort for the success of their project, rather than misuse the fund for their personal gain), because of asymmetry on the information the bank possess. The theory states, there will exist one interest rate which maximizes the expected return to the bank, and that interest rate is not as high as infinity, such that there must exist an interior solution. A higher interest rate, will attract borrowers and entrepreneurs with riskier projects, involving higher rate of default. Graphically, the borrower face a convex profit function of the return on the project (the borrower will be tempted to take greater risk if there's asked for higher return on the project), while the return to the bank is a concave function of the return on the project. That's why too high interest rate is not desired to the bank since it will change the mix of borrowers, pooling too many risky borrowers in the bank's portfolio leading the expected return to decrease.

There are other issues in addition to asymmetric information which restrict potential borrowers getting credit, and that is providing sufficient collateral. A general requirement in financial sector. The bank wants to share some of the risk with the borrower, increasing the liability for the borrower, and they do so by legally claiming mortgaged assets in case of default. Obviously poor rural households have either limited assets or they have assets not suitable as collateral. The absence of suitable collateral will increase the risk for an intermediary to enter the sector. The increased risk will be reflected in higher interest rates or intensely screening the clients.

So, what can the farmer bring to the table when he asks for credit? Well, we mentioned a case where e.g. the tenant can submit the crop (or a share of it) as collateral. The problem is that when it's a bad season, the tenant's risk of default increases. The reason is this, when a shock occurs to the crop, it generally hits many farmers at the same time, such that the crop supply will be reduced. Lead to higher prices on items the tenant demand. So, if there's one single lender and many tenants, the lender's expected return will decrease with the magnitude of default. Should the lender increase the proportion of collateral when there's excess demand of credit? Stiglitz and Weiss (1981) argue that increasing collateral requirements will attract mostly smaller projects and increase the riskiness of the projects, which will lower the lenders expected return[11].

[11] Binswanger and Rosenzweig (1986) equate collateral requirement and interest as substitutes. Which also explain why unsecure loans and informal loans have higher interest rate relatively to secure instruments.

The literature on collateral does not present a straight forward answer in sense of general equilibrium analysis. Binswanger and Rosenzweig (1986) distinguish between different types of collateral with attributes like *appropriability, absence of collateral specific risk* and *accruals of return to borrower*. The types of collateral which are mentioned are financial assets and gold, land, real estate, vehicles, animals (and slaves), human capital, and producer and consumer durables.

Imagine a farmer wants to loan some funds at a moneylender. If the moneylender has limited information on the borrower's ability to repay, requiring some collateral will mitigate or eliminate the loss for the lender in case of default. So, what type of asset is best suitable as collateral? Binswanger and Rosenzweig (1986) ranks financial assets and gold as the highest overall ease of use as collateral. The second highest is land, which is possible to appropriate by evicting the borrower or use law enforcement to collect. This require strong property rights and well established institutions for legal enforcement. The lowest ranked collateral are animals (and slaves) and human capital. The reason is that the owner of animals (and slaves) have better information on e.g. health condition of the animal which can make it hard to set a correct asset price. The same for human capital where the correct asset value can be biased due to adverse selection and moral hazard.

One the demand side, many rural households doesn't open a bank account, because of lack of information, low trust, unreliable service, and high fees on withdrawal and maintenance (Dupas et al. 2002, Cole et al. 2013). When it comes to lack of information, marketing can be improved and targeted more to rural sector, increasing financial inclusion[12]. But trust issues and unreliable services seems to be one of the main reasons behind low financial entry. Many banks and financial intermediaries in developing countries have gone through scandals. The formal financial sector is often accompanied with the government sector, so if there's political instability, one belief a contamination to the financial sector will come to pass. Dupas et al. (2002) show evidence for as low as 15-20 % having bank account in rural Kenya. Primary reasons are, on the borrowing side, (1): The risk of losing the collateral, which is dominating.

[12] Lot of poor people are illiterate, so it's not easy for them to understand e.g. the terms of an insurance product, or how to open a bank account. This problem is also present when researchers want to conduct an experiment or a survey. Binswanger (1980) had a creative solution when they tested for attitudes toward risk, playing a simple game with the villagers, involving only coin toss. Cole et al. (2013) faced also the issue of illiteracy among Indian villagers. They tried to conduct a video experiment to educate and endorse one insurance product, but their coefficients were not significant though.

While on the saving side, (2): The risk of embezzlement is dominating because of low trust to the sector. When it comes to personal saving, Dupas and Robinson (2013) show evidence of increased personal saving for health shocks in the same country[13], by introducing informal saving technologies (e.g. handing out moneyboxes to villagers).

Sectoral issues in financial markets

In the section on agricultural markets, we discussed seasonality and covariate risk as some of the issues facing the rural sector. For a financial intermediary, seasonality and covariate risk play a crucial role in creating a functional and profiting establishment. Seasonality increases the cost of intermediation, while covariate risk increases the rate of default. This is on top of the issues regarding information and collateral, especially for a small local intermediary. A bank can reduce the cost associated with seasonality and covariate risk by diversify the portfolio with non-farming sectors. For example, by being located in urban areas, the bank can diverse the client portfolio between rural and urban customers. Now you have borrowers and depositors from both sectors, reducing the risk cost of seasonality and covariate risk. This is of course at local level. If covariate risk occurs on national level, a new approach has to be applied. Now that the bank has located in urban areas to attract non-farming customers, the cost of gathering information from farming sector increases. This is the cost trade-off an intermediary face (Binswanger and van den Brink, 2005).

[13] The results differed when it comes which head of the family was responsible for the savings. Women had higher saving motives than men. That's way microfinance often target women (Vonderlack and Schreiner, 2002).

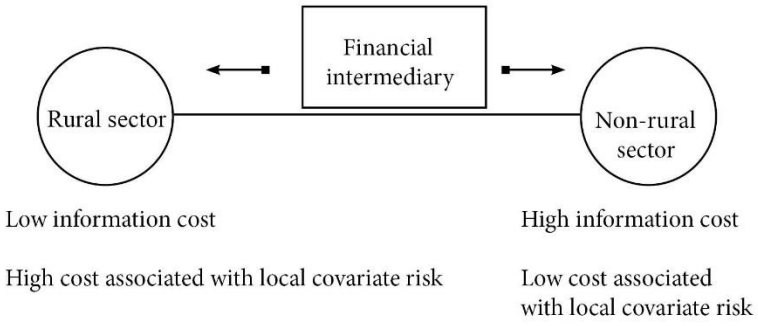

Figure 4: Illustration of location planning for a small intermediary and what trade-off has to be made. If the intermediary is located in the rural sector, it will face low cost due to gathering information on the borrowers and insured, but the cost associated with jointly default will increase because of low portfolio diversification. As for being located in non-rural sector (e.g. urban sector), the cost of gathering information on rural sector will increase because of the distance, but there's greater opportunity to diversify the client portfolio. Created by the author in Adobe Illustrator.

Binswanger and van den Brink (2005) argue that an intermediary can reduce cost associated with information gathering and monitoring by providing insurance or credit for cases where risk occurs without the influence of the engaging parties, e.g. rainfall-based insurance. As opposed to crop insurance, where sufficient information needed to collect insurance benefits must be unbiased. Meteorological data is easy to gather and unbiased[14].

Heterogeneity

Another barrier to provide adequate insurance model, which hasn't been discussed much, is to define standards for "normal output". If an intermediary has to pay up in bad states, *a good*

[14] Although an insurance scheme based on meteorological data is more suitable. It will often only work in cases with massive drought or floods, and not with small weather variations, because of low or undefined causality between incremental change in weather condition and output volume in agriculture (Binswanger and van den Brink, 2005).

state has to be defined and communicated when a contract is signed ex-ante. A good state is what a farmer can expect of yield in a normal year on average. Agricultural experts or a surveyor can of course provide expertise on e.g. expected yield per hectare, but in agricultural sector, as any other sector, there's heterogeneity in the production. Different items have different production functions, and usually they're not easy to derive. Therefore, the insurance company has to offer a menu of insurances (perhaps to every item) to mitigate costs associated with farmer producing profitable, but high risk items. A complex insurance product may be undesired for a farmer (Cole et al. 2013). Last point, which is the acceptance of a *wiggle room (*an allowable margin of variation) in the production volume. The production functions for agricultural products are complex and even though there haven't been huge weather variations in the season, along with fully optimized factor and techniques, the farmer can never foresee the exact volume of output[15].

Heterogeneity in agricultural production is also a risk diminishing strategy in economic and ecological[16] sense (Ballivian and Sickles, 1994, Di Falco and Chavas, 2008), the reason is that, producing crops of various items reducing the risk of crop failure if a shock hits one particular plot (e.g. a specific plant disease, or human mistakes). In contrary, heterogeneity is also costly in terms of not taking advantages of increasing return to scale when specializing the production to few items. Producing more than one output item involves more inputs, skills, chemicals and other soil products, including engagement in several markets. The farmer is facing a tradeoff between diversifying the type of items produced or increasing the return to scale (Klasen et al. 2016).

Insurance models

If a bad shock hits the production, it will affect the prices and income negatively, but also nutrition and productivity, which will in turn affect the health status and labor supply, throwing the households downward in a poverty spiral. The long-term effects can be disastrous. For an insurance company to provide sufficient compensation for a producer facing bad output, they must know that effort to a satisfied level is given to mitigate production loss in case of an unexpected shock. Nalebuff and Stiglitz (1983) offers a very

[15] Some of the produced output may also be not suitable for consumption. Food waste in the supply chain is an issue in low-income countries FAO (2011a).
[16] Producing homogenously (one or few products) reduces the biodiversity, which can have fatal consequences for some animal species, as a result of the food chain they're part of.

fascinating solution (when it comes to low effort given to maintain the insured production), introducing competition to induce effort. Their research mainly focus on the relation between an employer and an employee, but their model can be applied to different frameworks, as the paper itself suggest. If an intermediary is afraid of the scheme to collapse, promoting diverse measure to keep the farmer endeavoring for their output, can be profitable for both parties. The insurer can offer discount on the premium if e.g. the insured has opened a saving account in the same company (signaling precautionary action), or the insured has invested in high quality factors of production, better storage technology, education in the profession of agriculture and so on. The insurer can also host periodically seminars or assemblies to inform on risk-mitigating actions and e.g. host annually farming awards (or events) to motivate and show appreciation for their hard work.

The literature on agriculture cannot stress enough the importance of ex-ante and ex-post strategies to cope with output and income risk. Some more strategies are income source diversification[17] (Reardon, 1997, Barrett et al. 2001), engaging in microfinance, or liquidate assets when cash is needed. Other activities the farmer can do to collect food and income, are fishery and aquaculture (Stanley 2007), and gathering non-timber forest products (Pattanayak and Sills, 2001).

According to Alderman and Haque (2006), when it comes to forming a sustainable safety net, it must have a counter-cyclical budget, target transitory needs and have flexible implementation strategy. Yet two issues are brought up by the authors, (1): It's very hard to know how many households are affected by an external shock (e.g. natural disaster), even if the statistical probability of the shock is known ex-ante. (2): A public safety net can be hard to sustain in bad periods, because of the negative impact on the state budget and the trade balance[18], promoting a need for public-private cooperation (or domestic-international cooperation) on providing a sufficient insurance scheme for the beneficiaries (Alderman and Haque 2006).

[17] Reardon's findings (Reardon, 1997) shows poor distribution of non-farm earnings in rural Africa, due to high entry barriers and market segmentation. Which he argues could lead to skewed distribution of land and other assets eventually, hence more inequality.

[18] A natural disaster on an agricultural economy may force the government to import more food, because of the destruction on the crop field. Implying that exports will be reduced because of the disaster on the same sector, creating a trade deficit, in worst case throw the economy into recession.

Binswanger and van den Brink (2005, p. 283-284) present a very interesting solution to manage covariant risk and informational issues, and that is to create an institution with reserve of funds, operating as a hierarchy of geographical levels. At the bottom, you have (1) *Community Reserve Fund* for individual, idiosyncratic shocks. The Community Reserve will work like a micro-finance club, e.g. a ROSCA[19]. The advantage of a ROSCA is the low costs of monitoring and screening. Usually the members know each other so they possess, to a certain degree, financial and private information on each other. Another advantage is that since the members are friends or acquaintances, it's easier to "keep each other in check", make it easier to educate one another in good habits for borrowing and saving. Default on the ROSCA can lead to ostracism, exclusion from further ROSCAs, or in worst case scenario eviction from the village. The disadvantage of ROSCA is the vulnerability of covariate risk on local level. If an external shock hits the production at local scale, it could increase the number of defaulters, breaking the scheme totally (Besley et al. 1993, Dupas and Robinson, 2013).

(2) *District Reserve Fund* – District Reserve Fund will insure the Community Reserve Funds from breaking apart. If one Community Reserve Fund fails because of a local shock, the District Reserve Fund could bail out the failing Community Reserve Fund. A scheme like this can be established if the Community Reserve Funds agrees on paying a premium to the District Reserve Fund. Now since the District Reserve Fund is higher on the hierarchy, information on local level is costly. This will be implemented in the premium rate. But District Reserve Fund would still be vulnerable on regional level.

(3) *National Reserve Fund* – National Reserve Fund will cover fail (reinsure) for one or several District Reserve Funds if a shock hits regionally. A safety net on this level is highly demanded since bad weather shocks that can hurt agriculture, are often on regional level, rather than local. For a large country with distinct climatic and agricultural regions, a National Reserve Fund will manage risk close to perfection.

(4) *International Reinsurance* – What if an external shock hits on national level? Like a tsunami or a flood. The National Reserve Fund will break unless it holds high level of reserves. Recovery from a natural disaster can be a long-term project, which may drain the

[19] ROSCA – Rotating savings and credit association: A saving and loan club where the members meet frequently to e.g. make deposits, also called Peer-to-Peer borrowing and lending.

reserves. To solve that, the National Reserve Fund should be internationally reinsured by a global insurance network.

This system is genius, because you have different layers of reinsurance so that risk is managed through diversification on different geographical levels. One thing we should have in mind though is that the more layers of reinsurance, the higher premium for the individual. The premium the individual is paying must finance all four insurance layers, could make the scheme too expensive to engage in[20].

[20] Binswanger and van den Brink (2005) argue that there's low demand for agricultural credit or insurance because of low profitability in agriculture, while Binswanger and Rosenzweig (1986) and Alderman and Haque (2007) claims that there's undersupply of insurance and credit in agriculture, or the schemes have not functioned as desired, because of problems related to asymmetric information (high agency cost).

Nutrition-productivity relation

In this part, the literature on nutrition and productivity will be reviewed. The idea is that although agricultural shocks affect income and prices, they will also affect nutrition and productivity, since farmers consume what they produce. There are several literatures on the nutrition-productivity relation (Strauss, 1986, Singht et al. 1986, Bliss and Stern, 1978, Croppenstedt and Muller, 2000, Taylor and Adelman, 2003, Ulimwengu et al. 2011). Productivity is not something one can quantify or measure easily. Economic theory treats productivity as *human capital*. And we believe that there are certain measure an individual can do to improve their human capital. Education and physical ability are some of the elements we believe drive productivity. Investment in health has also income enhancing effects through elevated productivity (Banerjee et al. 2004).

Efficiency wage hypothesis

Nutrition is important for maintaining productive. The notion is that, better and more quality nutrition in your diet will lead to higher productivity, eventually lead to higher wage. This is related to the *efficiency wage hypothesis*[21]. Efficiency wage is one of the reasons, why an employer offer higher wage than equilibrium wage to attract and incentive high productive employees. In this section, the existence of a biological relationship between nutrition and productivity will be discussed.

Economists have for a while tried to understand and formalize the relationship between consumption and productivity. Myrdal (1968) reveals low productivity in labor (by dietary deficiency causing reduced work ability) as one of the main reasons behind undernourishment and malnutrition in South Asia. But before that, Leibenstein (1957) studied the relation between wages and labor supply (effort) which led to *Critical Minimum Theory*. The theory says, underdeveloped countries may be trapped in a vicious circle of poverty, where low income per capita may be a stable equilibrium. In order to improve the situation, a critical minimum of investment must be made to push the agents upward to new and better off equilibria. The same story can be applied to the nutrition-productivity relation. At the beginning of life, if investment in good health and enough quality nutrition has been made,

[21] Originally developed by Harvey Leibenstein (1957) and Dipak Mazumdar (1959), formalized later by Carl Shapiro and Joseph Stiglitz in 1984 (Shapiro and Stiglitz, 1984).

work ability later in life must be high, assuming no chronic injuries or long-term illness have occurred. Leibenstein's theory also explains the existence of natural unemployment. In a competitive market, the equilibrium wage will not be market clearing, since the wage for the lowest productive individuals will be so low, that consumption of essential goods cannot be made.

The S-shaped relation

Mirrlees (1975) and Stiglitz (1976), has had important contribution in formalizing labor markets with optimum allocation, shadow wages and endogenous productivity. Which later has been reviewed and tested by Bliss and Stern (1978). One crucial element in Mirrlees-Stiglitz model is the S-shaped relation between consumption and efficiency hours per worker. Efficiency hour is much more suitable when deducting productivity, rather than looking at total hours supplied. The idea is that a task can be done differently in manner of hours and effort. So, by looking at efficiency hours, productivity and labor effort can correctly be measured.

While the authors contributed to Efficiency Wage Hypothesis have looked at the link between wage and productivity, other researchers have used that theory but with more intermediate steps (Singh et al. 1986). Health status and nutritional status have played a more important role in understanding productivity, namely *Nutrition-Productivity Hypothesis*. Strauss (1986) has used household-level data from Sierra Leone to test whether higher calorie intake stimulates and increase family farm labor productivity. The study showed a high significant effect.

Testing this relation is not an easy task[22]. Keys et al. (1950) did an experiment on starvation in Minnesota where the daily calorie intakes of 32 men were reduced from 3500 kcal to 1500 kcal over a 24-week period. As a result of the experiment, activity levels for the individuals dropped when they were exposed to reduction in calorie intake from moderate to extremely low levels[23]. Sukhatme and Margen's findings (Sukhatme and Margen, 1982) support the

[22] To test the relation between nutrition and productivity in rural sector, there's need for input and output in production data, as an addition to data on food consumption. The problem however is not the lack of data in agricultural sector, but the poor quality of data generally in less developed countries.
[23] We cannot tell if this holds for long-term reduction in calorie intake (Strauss, 1986).

results of the experiment. The authors claim that the human body adjust energy expenditure with energy intake, in sort of an energy equilibrium.

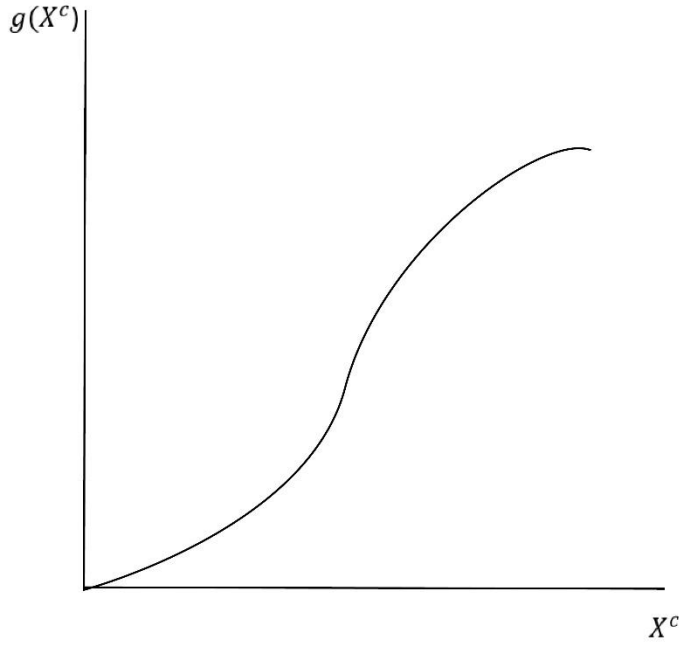

Figure 5: The S-shaped relationship between nutrition and productivity. Replicated from Strauss (1986, p. 303), but used notation from Sur and Senauer (1999). The graph is created by the author in Adobe Illustrator. The variable on the vertical axis is food consumption, while the variable on the horizontal axis is labor productivity. The idea here is that there's an accelerating (the convex part) relation in the beginning, then there's must exist an inflection point before the relation decelerate (the concave part). The inflection point can be seen as the average needed calories to perform a certain task.

There are some assumptions behind the S-shaped relation. First of all, we assume that the relation is continuous, which doesn't have to be true. It's not believed that an infinitesimal reduction in calorie intake will affect productivity (very hard to test). Low food consumption could have an effect on the mind and on the mood, without affecting working capacity. But a systemic calorie deficiency in relation with productivity is more of an interest for economic and health science. Secondly, calorie consumption is aggregated without taking into account that different sources of calorie (protein, fat and carbohydrates) affect the body differently.

The two-dimensional S-shaped figure (Figure 5) treats all sources of calorie as the same, while a multidimensional approach would be more realistic, but more complex to derive[24].

Empirically, there are several issues in testing the nutrition-productivity relation. One issue is the simultaneity problem, since better income also affect consumption of nutrients, advance empirical techniques (e.g. 2SLS, 3SLS, Diff-in-Diff or Regression discontinuity design) must be applied. Weight-for-height, generally called *Body Mass Index (BMI),* is often taken as a proxy for current nutritional and health status[25]. BMI as a measure of good health and wellbeing are highly mainstream in popular science and magazines. But it's not the best indicator of health status alone. A study on health and nutrition should obviously include more precise parameters in addition to BMI. Health and nutritional status depends on current and past food consumption, along with past illness and medical history. External factors will also play a role, like climatic stress, hygiene routine, sanitation, infrastructure quality (e.g. accessibility of clean water, road dust and distance to the nearest hospital), housing qualities (which type of building materials have been used, noises, humidity, and how much space the family has to share) and working damages from agricultural production (chemical exposures, heavy lift and sun exposure for long hours). Finally, predetermined factors like genes and family illness history will also have effect on health, nutrition and anthropometry.

[24] Ulimwengu et al. (2011) used a structural equation model (non-recursive) to test the relation. Their study included data gathered on different food items and their nutrient content like the main calorie sources, but also micronutrient (Vitamins, Iron and Zink).
[25] Six studies using weight-for-height as health indicator were cited by Martorell and Arroyave (1988).

Agricultural Households

In the previous sections, several aspects of the agricultural sector were presented and discussed. Different features have been highlighted. Especially, the associated markets, and productivity as a development accelerator. In this section, we will review the literature on agricultural household models with a demonstration of an existing model. The motivation for doing so, is to illuminate couple basic issues arising when modeling agricultural households. Many researchers have modeled agricultural households to understand why farmers in developing and developed countries behave in certain ways. Modeling agricultural households have also been of interest for governments, development organizations, financial sector and policymakers. Agricultural households are not much different than pure consumer households in economic theory, except the duality of being a producer and consumer simultaneously, which ensue new challenges (Taylor and Adelman, 2003).

When an agrarian household produces, and consumes food items, it's not perfectly clear if a change in food price or a change yield output will affect them in a good or bad way. According to Taylor and Adelman (2003), the dual role of the household will add an extra term to the household's Slutsky equation, called "farm profit". When the price of a food item increase, they would be worse of if the household were a pure consumer agent. But in an agrarian case, the household could earn more from a price increase, since it implies higher profit from sales. The dual role creates an internal shadow price for food consumption. In other words, the household demand food from itself when being the consumer and the producer. An increase in food prices creates higher opportunity cost of consumption[26].

Another duality the farming household engage in, is the optimum allocation of own labor usage and hired labor rented. In pure consumer households, if the household wants to consume more, they must give up some leisure in order to supply labor and then consume more. If an agricultural household wants to work more, the household can do so by either supply more labor or hire from the labor market. Practically making the household able to both consume more and have more leisure at the same time.

[26] Taylor and Adelman's review (Taylor and Adelman, 2003) of Singh et al. (1986) have found evidence of a positive own-price elasticity of food demand in four out of seven empirical assessments.

Nonseparability

Agricultural household models along with traditional household models often suffer from nonseparability (Singh et al. 1986). The issue of nonseparability is that we treat decisions within the households as independent. In the sense that decisions regarding production and consumption are separable (decisions are often endogenous). Since decisions are often not separable, and we model household as if they were so, empirical assessments will produce statistically inconsistent estimates (Singh et al. 1986). Separability is often achieved by assuming perfect substitution between factor of production, or consumer preferences. The problem is that they're often not perfect substitutes, and by treating them that way, the predicted estimates will be biased.

In Sur and Senauer's model (Sur and Senauer, 1999) and Strauss' model (Strauss, 1986), family and hired labor is treated as perfect substitutes[27]. Farmers will mostly prioritize family members in production decisions, corresponding to a difference between internal farming labor wage and external farming labor wage. Aggregating farm labor within the household can also be inaccurate, because it does matter of whom the male head, or female head of the family is working primarily on farming. There could be many reason for that, (1): Some farming tasks can be physically demanding, such that it's more practical for the male to abide these tasks. (2): There could be traditional or cultural reasons for different labor division within the household, leading to natural discrimination.

Lastly, one issue in modeling farming-households, is that risk often occurs after all input decisions are made, which remind us that timing is also something we haven't paid attention to. Agricultural households are often aware of different risk involving in production, and with cumulative local knowledge, the better is production planning (purchase of inputs) and risk coping ex-post.

A model demonstration

In this subsection, we will look at the efficiency conditions and uncertainty[28] in an agricultural household. The purpose is to illuminate what decisions the household faces in a

[27]The assumption of aggregating on-farm labor has been announced in Strauss (1986).
[28] Uncertainty and risk can be traced back to the work of John W. Pratt, *Risk Aversion in the Small and in the Large* (Pratt 1964), and Kenneth Arrow's *The Theory of Risk Aversion* (Arrow 1965).

simple general equilibrium with competitive markets. This paper has couple times mentioned the farmers fear of different types of shocks to their crop and income. Let's sketch a simple demonstration where uncertainty appears. The notation and the sequence of Sur and Senauer's model (Sur and Senauer, 1999) will be used. Some features from Ulimwengu et al. (2011) will also be used.

The household jointly maximizes utility:

$$U(X^c, Y, l)$$

With respect to food consumption (X^c), non-food consumption (Y) and leisure (l). Subject to the household's agricultural production function:

$$X = f(L^e, L_h, \boldsymbol{V}, \boldsymbol{A})$$

Where output (X) is equal to a Cobb-Douglas production function containing household labor in efficiency units (L^e), hired labor (L_h), vector of non-agricultural inputs ($\boldsymbol{V}$) and vector of fixed factors in agriculture ($\boldsymbol{A}$). Household labor in efficiency units are again a function of labor quantity supplied by the household (L_f) and quality of labor ($g(X^c)$), yielding:

$$L^e = L_f g(X^c)$$

The quality of labor is a function of food consumption, because it's assumed that higher food consumption, more productive labor, hence better quality of supplied labor[29]. The household is also time constrained:

$$T = L_f + L_O + l$$

Where total healthy time (T) can be allocated to farming labor (L_f), non-agricultural labor (L_O) and leisure (l). And finally, the monetary constraint (the profit function is embedded in the budget function):

$$\boldsymbol{P_y} Y + wL_h + \boldsymbol{P_v V} = P_x(X - X^c) + w^f(T - L_f - l) + E$$

Where expenditure on the left-hand side ($\boldsymbol{P_y}$ is vector of prices of non-food items, $\boldsymbol{P_v}$ is vector of prices of variable inputs and w is wage for hired labor) must equal income on the

[29] You can also think of the quality function as a health function (Ulimwengu et al. 2011).

right-hand side (E is exogenous income (e.g. remittance, social transfer etc.), while w^f is the virtual farming wage, can also be expressed as $w^f = w^e g(X^c)$, where w^e is wage per efficiency hour).

Two first-order conditions, (1) and (3) in Sur and Senauer (1999, p. 5) are of interest for now. Let's begin with condition (3):

$$(3): \lambda \left[P_x \frac{\partial X}{\partial L^e} \frac{\partial L^e}{\partial L_f} - w^f \right] = 0$$

$$P_x \frac{\partial X}{\partial L^e} g(X^c) = w^f$$

$$P_x \frac{\partial X}{\partial L^e} = \frac{w^f}{g(X^c)}, equivalently: \frac{\partial X}{\partial L^e} = \frac{w^e}{P_x},$$

Condition (3) tells us that marginal value product of efficiency labor is equal to wage-price ratio in equilibrium. The Langrange multiplier is cancelled out, since we're assuming binding conditions, implying that the wage is fully consumed (no saving).

$So\ if\ X^c \uparrow\ (increased\ calorie\ consumption) \rightarrow g(X^c)\ \uparrow$
$(increased\ quality\ of\ labor) \rightarrow \frac{\partial X}{\partial L^e} \downarrow$
$(decrease\ in\ marginal\ value\ product\ of\ labor) \rightarrow w^f \uparrow (increased\ wages).$

Now over to condition (1):

$$(1)\ \frac{\partial U}{\partial X^c} + \lambda \left[P_x L_f \frac{\partial X}{\partial L^e} \frac{\partial g}{\partial X^c} + w^e \frac{\partial g}{\partial X^c} \left(T - L_f - l \right) - P_x \right] = 0$$

Let's insert condition (3) in (1):

$$(1)\ \frac{\partial U}{\partial X^c} + \lambda \left[L_f w^e \frac{\partial g}{\partial X^c} + w^e \frac{\partial g}{\partial X^c} \left(T - L_f - l \right) - P_x \right] = 0$$

$$\frac{\partial U}{\partial X^c} + \lambda \left[w^e \frac{\partial g}{\partial X^c} (T - l) \right] - \lambda [P_x] = 0$$

$T - l = L_f + L_O$, which is the household's total labor supply. From the final equation, we can read that an increase in consumption has a positive effect on utility and a positive effect on the total labor supply. But we have also a negative price effect of food-consumption, due to the opportunity of selling the produced food instead of consuming it.

From the right-hand side of the monetary budget, we have $X - X^c$, which is the marketed surplus. If $X - X^c > 0$, the household can sell items to the market. If $X - X^c < 0$, the household doesn't produce enough to support their demand. Assuming a positive market surplus, we can rename $X - X^c = X^s$, and rearrange, $X = X^c + X^s$. The produced output can either be consumed by the household, be sold to an external market, or a combination.

$X = X^c + X^s$, and X^s is the supply of food.

Let's take a closer look at labor: Recall efficiency condition (3): $\frac{\partial X}{\partial L^e} = \frac{w^e}{P_x}$, condition (4) is: $\lambda \left[P_x \frac{\partial X}{\partial L_h} - w \right] = 0$, which is the efficiency condition for hired labor, marginal productivity of hired labor equal to the wage-price ratio. Combining (3) and (4):

$$(*) \frac{\frac{\partial X}{\partial L^e}}{\frac{\partial X}{\partial L_h}} = \frac{w^e}{w}$$

$(*)$ This efficiency condition is called, the marginal technical rate of substitution of on-farm labor, and it's equal to their input price ratio.

So, what happens when X is no longer certain? An unexpected reduction in produced output will affect either the consumption on food (reducing productivity, which will affect labor supply), or it will affect the amount the household wants to supply. Let's for now assume that a reduction in X will reduce both X^c and X^s (not necessarily an equal reduction). Why shouldn't a reduction in output only affect the supply, since food is highly necessary?

Well, first of all, the household is dependent on selling food to be able to consume non-food items, and to consume food items which the household doesn't produce itself[30]. Second if the household has rented labor to work on the plot, then liquidity is needed to reimburse[31]. Lastly, if a shock hits a village, it will for certain affect other farming households which will in turn increase the demand for food, such that food price will increase and so will the opportunity cost of food consumption[32]. Now, a household demanding three type of goods (food, non-food and leisure), and is the producer of a good which use several inputs (own-labor, hired

[30] It's natural to assume that the household prefer a variety of nutrition, and that the household cannot produce all the varieties because of the gains from specialization (return of scale and investment), agroclimatic reasons and broad preferences on consumption.
[31] The household can and will for sure (if possible) engage in non-agricultural jobs in order to raise liquidity.
[32] Although Taylor and Adelman's review (Taylor and Adelman, 2003) of Singh et al. (1986) show evidence of positive own-price elasticity in four studies on price increase.

labor and fixed factors) is hard to elaborate perfectly without a multi-market analysis, which is more sufficient, but harder to derive. Let's introduce uncertainty to Sur and Senauer's model (Sur and Senauer, 1999):

$$E[X] = E[X^c + X^s]$$

$$E[X] = E[X^c] + E[X^s]$$

$$E[X - X^s] = E[X^c], \text{ such that } E[X^c] = P \cdot X_H^c + (1 - P) \cdot X_L^c$$

$X_H^c =$ High food consumption and $X_L^c =$ Low food consumption.

And since X^c appears in the utility function, the utility function is no longer certain,

we have therefore expected utility: $E[U] = E[U(X^c, Y, l)]$

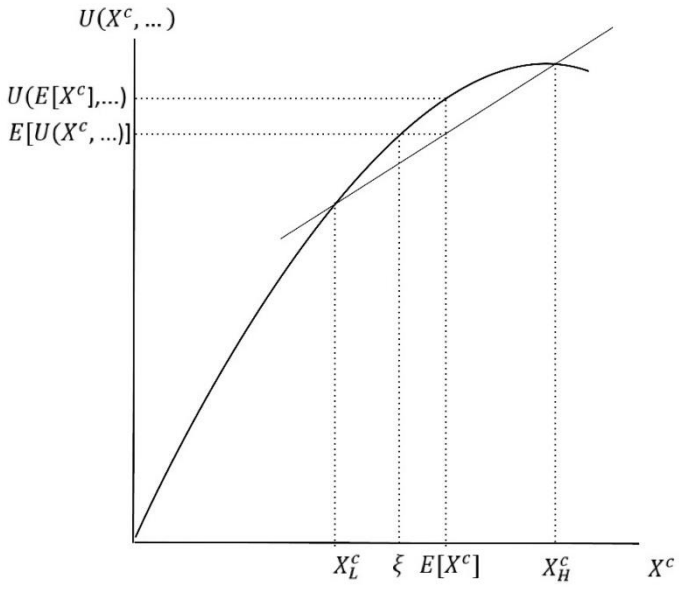

Figure 6: Illustration of Jensen's inequality.[33] Created by the author in Adobe Illustrator

[33] Named after the Danish mathematician Johan Jensen.

Figure 6 illustrates a basic concept in mathematics and economics where given a concave (convex) function, the function of the expected value will be higher (lower) than the expected value of the function. In this case with a concave utility function:

$$U(E[X^c], Y, l) \geq E[U(X^c, Y, l)]$$

For this relation to hold, we must assume that the household is risk averse, like numerous of literature on agricultural household suggest and have proven (Moscardi and de Janvry, 1977, Dillon and Scandizo, 1978, Binswanger, 1980, Antle, 1987, Antle, 1989).

From the graph, we can also induce a concept called *certainty equivalent.* Here it's translated to what is the equivalent amount of food the household can consume, in order to "eliminate" risk and be opt to certainty. Since the household is risk averse, they are willingly to be settled with a little bit lower utility (or pay a premium) in order to avoid risk. The certainty equivalent value from the graph is ξ. From this value, we can read the Arrow-Pratt's risk premium:

$$Risk\ premium = \ E[X^c] - \xi$$

Risk premium is how much the household must be compensated to bear risk, equivalently how much the household is willing to maximum pay for an insurance such that they are fully compensated when risk occurs. A positive risk premium can create a demand for insurance or credit[34].

Concluding remarks

This simple model demonstration shows us that a farmer household in a competitive market confront, to a certain degree, the same optimality conditions as a pure consumer (producer) when maximizing utility (profit). The complexity of modeling agricultural households is due to their dual role as a producer and a consumer of the same commodity. The household must make several decisions to be optimally positioned, and when risk occurs, demand for insurance or credit to smooth consumption, may be a necessity to not be thrown back to poverty.

[34] Finkelshtain and Chalfant (1991) claim that the Arrow-Pratt's risk premium measures the maximum amount that an agent would pay to avoid risk, when everything else is non-random, but it doesn't necessarily measure the willingness to pay.

Discussion

In this paper, we've discussed and reviewed the agricultural sector, including the usage of land, the prospect on rural population, the characteristics of the sector, and the complications of lacking formal markets. Couple examples have been presented, supplemented with various data from Food and Agricultural Organization of United Nations. The paper has also provided deeper understanding on the relation between nutrition and productivity, in the context of agricultural households. One intention was to exhibit the obstacles and methodological issues economists and policymakers faces when trying to assess and improve the living conditions for the rural sector in developing countries.

In 2015, the United Nations Sustainable Development Summit were held at the headquarter in New York. More than 150 countries attended. The result was an agreement on transforming the world to a better place by 2030, by adopting 17 goals. One particular goal was in the interest for the author before writing this paper, goal number two: Zero Hunger. One main target is to end hunger and ensure food access for all people. It seems a bit optimistic to accomplish the goal in less than thirteen years, but having set a goal, scientist, policymakers, entrepreneurs, activists, and the rest of the world community will try to reach out, to make the world a better place.

Studying agricultural sector and especially agricultural households, reminds us on how important it is to conduct interdisciplinary research, and better the cooperation between scientists and world leaders. Although the literature on the sector has been perhaps to narrow and to technical, the methods has definitely been improved. Ulimwengu et al. (2011) deserves an extra attention for their use of structural equation system to tackle and test the effect of nutrition on productivity, advocating the importance of food access for fighting poverty. The combination of economic expertize, medical science and agronomy can be jointly beneficial.

There're also couple more topics which has not been deeply discussed, though pretty interesting. One of them is, the role of government and policymakers in forming institutions and legal framework to move rural households out of poverty. Many developing countries lack proper institutions to preserve human and material rights, where the poor also suffer from bad or slow crisis response when help is needed. Many issues of this kind are a result of historic structural institutions and not because of market changes (Sokoloff and Engerman,

2000, Easterly, 2007). Economists and historians believe structural inequality (colonization, conflicts, slavery, land reforms etc.) has caused underdevelopment. Which is a hard path to break. Factor endowment gathered and allocated historically can explain why some countries are way ahead in development. Therefore, it's unsure if global aid or foreign direct investment can transitory changes for the less fortunate.

Lastly, couple words on one particular technological innovation, *Genetically Modified Crop* (GM crop). GM crop is created with advanced engineering techniques. The purpose is to modify the genetic material in biological organisms in order to improve the item with desirable traits. There are three main reasons for the use of GM crop. First, improvements in agronomic traits such as, better resistance to pest and diseases, lowering or eliminating the use of chemicals for soil and plants, and increasing production density and intensity. Second, improving the quality of the crop, like boosting nutrient contents, or adding new attributes (color, taste, size etc.). Third, design plants to produce elements tailored for pharmaceutical, industrial or commercial use (Qaim, 2009). Although, there're sign of great benefits of using GM crop, and perhaps increase the global production of food, many countries are still opposing a new technology where the long-term effects are unclear, and still need to be documented. Some argues genetically modified food can have negative impacts on biodiversity and human health, but also introducing a shift from traditional agriculture which is the livelihood of many poor.

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Appendices

A1. Data on Indian food production and supply

Year	Production Crop ((	Production Food ((	Cereals, Food supply quantity (kg/capita/yr)	Rice, Food supply quantity (kg/capita/yr)	Vegetables, Food supply quantity (kg/capita/yr)
1996	87,33	84,09	159,85	74,69	54,64
1997	89,07	86,41	157,87	74,2	50,88
1998	90,37	87,93	159,52	73,7	59,07
1999	94,42	91,95	158,65	73,94	64,35
2000	92,16	91,18	160,56	72,62	64,29
2001	94,75	94,2	156,02	70,46	68,74
2002	85,01	87,13	151,12	68,99	59,28
2003	97,02	96,29	149,18	67,92	66,31
2004	94,2	94,81	149,24	70,04	54,47
2005	99,85	99,9	148,57	71,57	58,15
2006	105,95	105,29	150,45	70,76	65,39
2007	116,09	114,51	152,93	71,2	69,59
2008	117,03	116,72	154,6	72,24	71,02
2009	112,68	114,1	150,55	71,69	69,38
2010	124,54	123,25	153,08	72,1	76,28
2011	133,49	130,87	151,21	70,82	80,53
2012	135,67	133,71	146,58	70,3	84,72
2013	140,89	138,87	148,45	69,49	88,71

A2. List of the 48 least developed countries

Afghanistan	Kiribati	Timor-Leste
Angola	Lao People's Democratic Republic	Togo
Bangladesh	Lesotho	Tuvalu
Benin	Liberia	Uganda
Bhutan	Madagascar	United Republic of Tanzania
Burkina Faso	Malawi	Vanuatu
Burundi	Mali	Yemen
Cambodia	Mauritania	Zambia
Central African Republic	Mozambique	
Chad	Myanmar	
Comoros	Nepal	
Democratic Republic of the Congo	Niger	
Djibouti	Rwanda	
Equatorial Guinea	Sao Tome and Principe	
Eritrea	Senegal	
Ethiopia	Sierra Leone	
Gambia	Solomon Islands	
Guinea	Somalia	
Guinea-Bissau	South Sudan	
Haiti	Sudan	

A3. Data on Livestock and GDP per capita

	India		Kenya		Nigeria		Guatemala	
Year	**GDP per capita**	**Livestock**	**GDP per capita**	**Livestock**	**GDP per capita**	**Livestock**	**GDP per capita**	**Livestock**
1970	262,13	2,71	522,04084	1,14	743,200828	0,98	1527,277773	4,52
1971	260,93	2,75	536,66225	1,19	829,480241	1,03	1567,908408	4,62
1972	253,42	2,74	543,78304	1,23	868,289141	1,08	1635,986147	4,69
1973	254,9	2,8	551,68405	1,26	899,062346	1,14	1698,332306	4,69
1974	252	2,81	557,90754	1,3	970,900094	1,19	1756,861279	4,82
1975	268,85	2,82	535,68547	1,31	951,392844	1,25	1742,627353	5,2
1976	267,4	2,85	536,95999	1,3	989,982498	1,32	1821,694733	3,96
1977	280,15	2,91	564,80502	1,4	1040,072372	1,38	1912,710454	4,69
1978	288,99	3,06	592,95845	1,53	979,604392	1,45	1956,383406	5,45
1979	268,22	3,18	592,45221	1,6	924,578027	1,52	1995,572773	5,54
1980	279,46	3,3	602,25646	1,54	918,415919	1,59	2016,562771	5,63
1981	290,9	3,42	601,51523	1,57	885,725284	1,67	1976,746646	3,85
1982	294,98	3,4	600,3027	1,66	848,064207	1,75	1856,371612	3,99
1983	309,65	3,66	585,76482	1,82	772,020154	1,82	1761,597278	4,24
1984	313,78	3,75	574,0533	1,64	742,491725	1,88	1724,375743	3,65
1985	323,57	3,85	576,72848	1,79	805,700417	1,99	1671,20362	3,86
1986	331,89	3,96	595,84992	1,81	799,765988	2,1	1632,70725	3,98
1987	340,22	3,95	608,85188	1,79	773,605349	2,19	1650,250964	4,12
1988	366,05	4,01	624,18589	2	810,624549	2,29	1674,100542	3,88
1989	381,97	4,06	631,3158	2,1	846,124915	2,4	1699,058674	4,01
1990	395,31	4,13	636,07663	2,18	918,204182	2,49	1710,025714	4,25
1991	388,98	4,19	624,05992	2,13	895,20452	2,41	1729,811619	4,43
1992	401,94	4,28	599,42922	2,15	895,852821	2,39	1769,368153	5,18
1993	413,64	4,34	583,0668	1,98	887,286125	2,45	1793,9364	5,46
1994	435,96	4,4	580,77838	2	872,195637	2,52	1820,787118	5,51
1995	460,37	4,48	589,41788	2,16	868,982225	2,6	1864,69682	6,66
1996	485,12	4,55	597,62761	2,19	882,587425	2,72	1873,45211	6,96
1997	497,43	4,58	584,15479	2,24	885,702596	2,86	1907,360224	7,25
1998	517,57	4,68	589,00515	2,21	888,152006	2,85	1950,753644	7,94
1999	544,52	4,78	586,78158	2,2	870,279137	2,92	1983,17695	7,73
2000	556,51	4,86	575,18812	2,11	893,807169	2,81	2005,544336	7,88
2001	575,49	5,04	585,84406	2,03	909,992818	3,05	2002,944935	8,12
2002	587,14	5,17	574,25843	2,22	1076,645292	3,09	2030,300873	8,72
2003	625,86	5,38	575,81063	2,34	1156,962418	3,2	2031,826181	7,53
2004	666,92	5,64	589,62067	2,33	1245,771823	3,28	2046,335043	8,01
2005	717,44	5,92	608,37669	2,44	1292,889685	3,32	2064,035298	8,54
2006	771,92	6,21	630,15842	2,43	1335,408788	3,39	2125,651253	9,99
2007	834,93	6,53	655,89472	2,37	1384,497993	3,52	2209,279454	8,44
2008	854,82	6,93	640,33433	2,8	1432,722879	3,71	2231,777287	8,81
2009	914,24	7,37	644,23386	2,67	1491,686399	4	2195,070407	8,82
2010	994,28	7,94	680,02251	2,62	1566,074241	4,06	2209,895023	9,05
2011	1046,29	8,53	702,56523	2,61	1599,024841	4,12	2253,382099	9,31
Notes on livestock data: Livestock total per ha of agricultural are, types: Cattle, Buffaloes, Pigs, Sheep, Goats, Poultry.								
Notes on GDP per capita data: Value US$, 2005 prices. Source: FAOSTAT (2017e)								