Masters in International Economics with a Focus on China

An Analysis of the Role of Science & Technology and Economy Growth in Safeguarding China's Food Security

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Abstract: This study contributes to the literature discussing food security in China. This study holds food security to rest on two complementary dimensions: food availability and food accessibility. This study looks at both dimensions. It examines the food availability dimension by evaluating the effects of government's expenditures on agricultural science & technology on China's grain output. Running time series regression for the 1978-2006 period, it finds that governments' expenditures on agriculture science & technology have played a positive important role in promoting grain domestic production, and thereby food security. Looking forward, it recommends that science & technology play a pillar role in promoting domestic production. This study examines the accessibility dimension of food security by evaluating the effects of growth on poverty. It focuses on poverty because the poor are most vulnerable to fall into food insecurity. Running time series for the 1978-2006 period this study finds that growth has been the engine of poverty reduction in China. However, looking forward this study concludes that, as income disparities continue to increase and salaries remain low in China, promoting growth is not sufficient to safeguard China food security in. Thereby, this study recommends complement the traditional free market policies promoting growth with policies implementing safety nets.

Keywords: Food Security, China, Science & Technology, Grain Production, Growth, Poverty

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"All's Well That Ends Well"
William Shakespeare

"Food for thought is no substitute for the real thing"
Walt Kelly

"The superior power of population cannot be checked
without producing misery or vice"
Thomas Malthus

"Both the jayhawk and the man eat chickens;
but the more jayhawks, the fewer chickens,
while the more men, the more chickens"
Henry George, dismissing Malthus

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I. INTRODUCTION

The future has a way of making even the brightest minds look foolish. In 1798, in an Essay on the Principles of Population Thomas Malthus wrote: "The power of population is indefinitely greater than the power in the earth to produce subsistence for man." The world's population was then only nine million people and yet thanks to the ingenuity of mankind, six billion people later Malthus' view seems obsolete.

But in a way Malthus concern about population increases being married to misery today is more relevant than ever. By most accounts nearly one billion people worldwide go to sleep without sufficient food every night, and another couple of billion people have only a thin buffer to stand food price hikes or unemployment shocks. Furthermore, the world's largest countries today remain rural and as these countries industrialize, urbanize and consume more; the question as to where the food to feed them will come from still remains unanswered. Indeed, neglecting the importance of food production and food distribution can lead to food shortages, price hikes, and famines – the consequences of which would certainly be unwanted.

China, with nearly 1.4 billion people and a rapidly growing economy; and food, which is essential to human's survival, stands at the epicenter of this study. Specifically, this study contributes to the literature discussing food security in China by looking at both the food availability and food accessibility dimensions upon which food security rests. It looks at the food availability dimension by evaluating the role that government's expenditure on agricultural science & technology has played in promoting China's grain production. It focuses on domestic grain production because China is big and the extent to which it can rely on global food market is uncertain. Further, China faces serious hurdles as urbanization and industrialization threaten China's land availability. It focuses on government's expenditure on science and technology because China's commitment to the WTO permits unlimited government's expenditures on science & technology while severely restricting other tools which the government has used in the past like direct subsidies, and prohibitive tariffs. Running time series regressions for the 1978-2006 period, this study finds that government's expenditures on science & technology, while not the main engine of China's grain production, did contribute significantly. Looking forward, it recommends that government's expenditures on science & technology play a pivotal role in China's policies to safeguard food security.

Secondly, this study looks at the food accessibility dimension by examining the role that growth plays on poverty reduction. It focuses on China's poverty because the poor are most likely to be vulnerable to food security. It focuses on growth because growth is widely recognized as the best engine for poverty reduction. Running time series regressions for the 1978-2006 period, this study finds that growth has indeed been the main engine of China's poverty reduction. However, this study concludes that growth is not sufficient to safeguard China's food security. The literary review discussed in this thesis highlights that income inequality has continued to increase in China in the last decade despite China's high growth. Further, it notes that despite China's continuing growth, poverty reduction has stagnated in the last decade. Furthermore, in China salaries are low, and the large majority only has very thin buffer to stand financial shocks and price hikes. Therefore, looking forward, this study recommends that China complements policies promoting growth with policies establishing safety nets, which, as some of the literature suggests, could be effective in reducing poverty as well as have a positive reinforcing effect in promoting growth.

All said, others studies available discussing China's food security follow the simpler task of focusing only on either a food accessibility or food availability factor but in the process leave the reader hanging as to how the results fit in the food security puzzle. This study, instead, dares to provide the reader with a more holistic framework for understanding food security by focusing on both the availability dimension (the role of science & technology on domestic production) and the accessibility dimension (the role of growth on poverty).

This essay proceeds in section II by providing a summary of the concept of food security. Section III begins by first discussing the availability dimension of food security and the role that agricultural science and technology can play on promoting domestic production. Afterwards, it discusses the accessibility dimension of food security and the role that growth can play in reducing poverty. Section IV presents the methodology theory this study follows. Section V presents the empirical analysis for both the grain production regression (availability) and the poverty regression (accessibility). Finally, section VI presents the thesis discussion, while Section VII presents the conclusion.

II. EVOLUTION OF FOOD SECURITY

Food has always been essential to human's survival but the concept of food security is complex and multidimensional, varies with the beholder, and has undergone major shifts in the last six decades. This section first discusses the development of the right to food. Secondly, it discusses the development of food security definitions oriented towards food supply. Thirdly, it discusses the development of more holistic food security definitions highlighting the importance of both food availability and food accessibility.

2.1. THE RIGHT TO FOOD

From an international perspective, 1948 marks a milestone in the development of the food security as a universal concept. In 1948 the United Nations General Assembly adopted the Universal Declaration on Human Rights recognizing the right to food as a core element of an adequate standard of living.[1] Similarly, from an international perspective, 1966 is also recognized as important year because then the General Assembly developed further the concept of the right to food in Article 11 of the International Covenant on Economic, Social and Cultural Rights.[2] Finally, the next milestone came later in the 1974 World Food Summit, when building on the work from 1948 and 1966, governments examined the global problem of food production and consumption, and proclaimed that "every man, woman and child has the inalienable right to be free from hunger and malnutrition in order to develop their physical and mental faculties" in the "Universal Declaration on the Eradication of Hunger and Malnutrition."[3]

2.2. SUPPLY FOCUSED DEFINITIONS

As the idea of humans having the right to food developed so did the need to come up with a definition. The World Food Summit in 1974 marks a milestone in the development of a definition of food security at an international level. This summit resulted in the first globally accepted definition of food security. It defined food security as: "availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices." (UN 1975). A look at

[1] United Nations. Universal declaration of human rights. Adopted by the General Assembly of the United Nations on December 10, 1948.
[2] The United Nations. The International Covenant Universal declaration of human rights. Adopted by the General Assembly.
[3] Office of the High Commissioner for Human Rights. Universal declaration on the eradication of hunger and malnutrition. Adopted November 16, 1974, by the World Food Conference convened under General Assembly resolution 3180 (XXVIII) of December 17, 1973, and endorsed by General Assembly resolution 3348 (XXIX) of December 1, 1974.

this definition indicates that the focus is on food availability. The implication being that the key to securing food for all is escaping the Malthus trap of there not being enough food. Indeed, in the 1960s and 1970s, the general view was that food insecurity was solely caused by lack of aggregate food availability. In this sense, food security at the global level was understood mainly as a supply issue at the national level.

It should not be surprising that the first globally accepted definition focus on supply. This was likely motivated by the significant shortage in food supply and high food prices the world experienced in the early 1970s. The main concern was that the world was running out of food, and there would not be enough food to feed all. This worry was in line with the work by Robert Malthus presented in An Essay on the Principle of Population in 1798, arguing that food supply expansion is linear whereas human growth is exponential, and that since population growth is bound to exceed agricultural growth, there must be a stage at which the food supply is inadequate for feeding the population.

Furthermore, the focus on equating food security with having enough aggregate food at the national level probably also had to with the special stigma attach to food by policy makers around the globe, whom particularly in closed and militarized economies tend to equate food security to food self-sufficiency. In fact, looking at the national level, through history many countries have equated to some extent or another food security with self-sufficiency. China, for instance, has been among the countries that have narrowly defined food security as the state of being self-sufficient. The idea being, rather than the Malthus trap, that due to food strategy's importance, and its potential use by other countries as political weapon, it is not safe for a country to rely on other countries for food. Indeed, as recently as 1996 China still had an official target of 95 percent net self-sufficiency in grain specified (Information Office of State Council 1996). This target, although having been relaxed, still remains somewhat of an official policy with the focus having lessened to remaining 95% self-sufficient only on wheat.

2.3. SUPPLY AND DEMAND FOCUSED DEFINITIONS

Over the past three decades, even though some countries' rhetoric and agenda have remained stagnated on the narrow view that food security equals food self-sufficiency, the general perception on food security has shifted away from the food supply led view. The driving force behind this change in perception has likely been the fact that widespread hunger at the individual level have existed globally despite favorable supply conditions and low food prices level after the 1970s. (Sijm 1997). In general the shift in thinking regarding food security has been characterized by greater focus on household and the individual instead of national aggregate food supply. (Maxwell 1996).

Indeed, this shift in perception is evident in the definitions adopted by world organizations in the decades after the 1970s. For instance, in 1983, marking an important milestone in food security which imprint is still widely recognized today, the United Nation's Food and Agriculture Organization (FAO) expanded the definition of food security to include not just sufficient food availability but "both physical and economic access" to food to meet dietary needs. (FAO 1983). Building on the accessibility concept, in 1986, the World Bank (1986, p. 1) defined food security as "access by all people at all times to enough food for an active and healthy life." Similarly, the 1996 World Food Summit added another layer to the definitions by including the concept of "safe and nutritious" food commensurate with dietary needs and "food preferences" required for an active and healthy life. (FAO 1996).

In fact, numerous organizations currently use slightly different versions. For instance, the USAID definition holds food security to exist "When all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life." (USAID 1992). Along similar lines, the current U.S. Department of Agriculture's definition holds that: "Food security for a household means access by all members at all times to enough food for an active, healthy life. Food security includes at a minimum (1) the ready availability of nutritionally adequate and safe foods, and (2) an assured ability to acquire acceptable foods in socially acceptable ways (that is, without resorting to emergency food supplies, scavenging, stealing, or other coping strategies)." Furthermore, the current FAO's definition states that "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." (FAO 2008).

Indeed, all together since 1948 hundreds of definitions for food security have emerged.[4] However, it is futile and unnecessary to list them all. It is only necessary to remark that by large they tend to highlight the importance of both food availability and food accessibility.

III. FOOD SECURITY FRAMEWORK AVAILABILITY AND ACCESSIBILITY

In line with contemporary definition this essay holds food security to rest on food availability and food accessibility. This section first discusses the food availability dimension and secondly it discusses the food accessibility dimension.

3.1. AVAILABILITY

This section first explains why this thesis focuses on food availability and specifically on domestic production. Afterwards, this thesis discusses in detail the potential role that agricultural science and technology can play in promoting grain production.

3.1.1. Importance of Domestic Production

As mentioned in the previous section food security rests on both food availability and food accessibility. Food availability refers to the supply side of food. As mentioned earlier, the ample global food supply in the last decades has shifted the focus away from food availability as a determinant of food security to food accessibility. Nonetheless, while the global widespread hunger despite ample food supply show that food accessibility matters, food availability still remains a precursor to food security.[5] Indeed, if on average there is not enough food for all, certainly there will be bound to be individuals that will not have access to sufficient food. Since, food availability is a precursor to food accessibility; this thesis focuses on food availability.

Food availability in turn depends on domestic production, imports, and food reserves. (FAO 2006). Of these three elements, this thesis holds domestic production to be most meriting of research. This is because in the long run food reserves must come from either domestic production or imports. Regarding imports, China is already taking the necessary

[4] Over a decade ago there were more than 200 different definitions of food security alone according to Maxwell, S. 1996. Food-security: a post-modern perspective. Food Policy. 21(2), 155-170.
[5] For instance, Atwood (1991) note that failure to avert food crises has occurred when substantial attention is paid to food accessibility but supply indicators are ignored. Likewise, Devereux (2002) note that the Malawi 2002 famine resulted largely due to exaggerated forecast of food production coupled with mismanagement of food reserves.

steps to increase food availability through imports by committing to the WTO. However, regarding domestic production, it still remains unanswered how, and even if China can increase its food production given its limited natural resources. For example, looking forward, Ye et al. (2000) project that China's capacity for producing food from agricultural crops will be affected by the loss of cropland area causing a 13–18% decrease in China's food production capacity by 2030 to its 2005 level of 482 million tons. Furthermore, China is such a large food consumer that it is uncertain the degree to which it can rely on other nations' for its food. Indeed, some argue that large dependency on other countries for food can make China vulnerable to food export embargoes. (see Doughty and Harold 1991; Paarlberg 1982; Wallensteen 1976; Lu 1997; Yang 2000). Moreover, China is such a large food producer, that sudden drops in its food supply could have impacts on the global food supply. For instance, in 2008 China accounts for nearly 20% of the global wheat production. Therefore, when looking at availability, this study focuses on domestic production.

3.1.2. Science and Technology's Role in Food Production

Given China's limited land and natural resources agricultural investment on science & technology may prove be a critical factor affecting domestic production. This is because investing in science & technology can have a lasting productivity effect. (Johnson 2000). Further, while some argue that China food production increases can come from efficiency gains, it is uncertain the social cost that could result from institutional reforms. For instance, Owen (1966) notes that smallholder farming can serve as safety nets for urban population when jobs are lost in crisis conditions. Further, it makes sense to focus on science and technology because given China's limited arable land and natural resources the production gains that can result from merely increasing physical inputs. Furthermore, WTO severely constraints the types of public investment China can undertake to increase productivity, but allows science & technology public investment. (Zhu 2004).

This section continues by first discussing the literary review addressing the role investment on agricultural science & technology has played in the world. Then it discusses the literary review discussing the role investment on agricultural science & technology has played in China.

3.1.2.1. Global Role of Science & Technology

There is much support at the global level for the view that R&D investment is a major source of growth in agricultural production. Alston et al. (2000) looking at 700 studies reports that returns to agricultural research are in the range of 35 percent (Sub-Saharan Africa) to 50 percent (Asia). Likewise, Alene (2009) evaluating the benefits of agricultural research in Sub Saharan African finds that the payoffs to agricultural research have an aggregate rate of return of 55%. He further calculates that agricultural research spending already reduces the number of poor by 2.3 million or 0.8% annually and a doubling of research investments in SSA would reduce poverty by a staggering 9% annually in Africa.

Along similar lines, Evenson and Gollin (2003) studying numerous developing countries over the period 1960 to 2000 and focusing on 11 food crops, note that international agricultural research centers, in collaboration with national research programs, were crucial to the green revolution. Using quantitative data they find that agricultural research centers and national research programs contributed to the development of modern or high-yielding crop varieties, which allowed increases in food production while minimizing the impact on the environment. Specifically, Evenson and Gollin focus on the development of modern or high-yielding crop varieties (MVs). They remark that the origin of modern or high-yielding crop varieties are associated with the two major international agricultural research centers (IARCs): the International Center for Wheat and Maize Improvement in Mexico (CIM-MYT) and the International Rice Research Institute in the Philippines (IRRI). Further, they note that the early successes in breeding rice and wheat MVs reflected the advanced state of research on those crops in the late 1950s. They compare those successes in breeding rice and wheat with the slower development of MVs in tropical beans resulting from no major research initiatives. Furthermore, they note that more than 35% of modern or high-yielding crop varieties released and adopted during the 1960-2000 period were based on crosses made in international agricultural research centers. In light of this, and other supporting facts, they conclude that all said strong national programs have provided effective research in many developing countries.

Evaluating science and technology from a different angle, Luh et al. (2008) look across countries and regress human capital endowment, domestic R&D, and international spillovers. They find that domestic R&D and its interaction with human capital constitute the major determinant of individual economy's progress in agricultural technology, whereas the human capital endowment is only crucial for the catching up effect. Furthermore, they note that for foreign knowledge to contribute to productivity growth either through innovation or through catching up, the host economy has to develop a sufficient learning capacity from education. Countries that do not attempt to develop the learning capability to assimilate and exploit the freely available knowledge may not benefit from international spillovers of agricultural R&D.

3.1.2.2. The Role of Science & Technology in China

Many studies have confirmed that agricultural science & technology has been source of growth in agricultural production in China. For example, Pratt et al. (2009) measuring and comparing agricultural production in China and India note that agricultural research has significantly contributed to improve agricultural productivity in both China and India. Specifically, they note that in the present returns to agricultural R&D investments are very high, with benefit/cost ratios ranging from 20.7 to 9.6 in China and from 29.6 to 14.8 in India.

Looking only at China, Fan and Pardey (1997) claimed that more than 20% of the production growth in Chinese agriculture from 1965 to 1993 came from increased agricultural research investment. Likewise, Fan (2000) estimate that the internal rates of returns for Chinese agricultural research range from 35% to 90%. Similarly, Chen et al. (2008), on the basis of a panel dataset of 29 provinces in China, find that over the 1990-2003 period the major source of agricultural productivity growth is technical progress. They remark that the main determinants of technical progress are agricultural tax cut, public investment in research and development and infrastructure and mechanization.

Likewise, Zhu (2004) finds that public investment in agricultural science and technology increases grain production in China. Specifically, using a Cobb-Douglas function, he finds that an annual increase of research expenditure of 5 and 10% percent will result in increase of grain output of 5–8% and 8–17 % in the next 20 years.

Along similar lines Liu and Wang (2005) looking at role of technological progress and land tenured finds that that technological progress played the most prominent role in explaining productivity growth in Chinese agriculture during the 1990s, with the former contributing 58 percent to growth in compared to 21 of tenured security.

Looking forward, Zuhui and Bolin (1997) reviewing China's 1978 to 1995 grain production note that China has a potential to increase production because it has the possibility to improve the application of science and technology. This is because in China less than 30 percent of annual agriculture growth is due to application of science and technology, compared with 60 percent in developed nations.

3.2. ACCESSIBILITY

This section first explains why this thesis focuses on food accessibility and specifically on poverty. Afterwards, this thesis discusses the theory and literary review addressing the role that growth plays in poverty reduction.

3.2.1. The Importance of Poverty

The accessibility dimension reflects the demand side of food security. Whereas availability is about proving Malthus wrong, the accessibility dimension of food security addresses food security's close relationship to social, economic and political disenfranchisement. Abundant literature support the importance of accessibility as a dimension food security (see Sen 1980, Iram and Butt 2004, Bohle 1993, Smith et al. 2000). For instance, Sen (1980) analyzing historical famines rejects food availability notion of food security as too simplistic. Along similar lines, Smith et al. (2000) measuring food insecurity in 58 countries finds little correlation between national food availabilities and food security. Likewise, Iram and Butt (2004) study the determinant of household food security in Pakistan and conclude that even with a per capita income of US$443 food, availability measures alone have a limited effect on determining the nutritional well being of individuals.

This thesis approaches the accessibility dimension of food security by examining the effect of growth on poverty. Poverty is a crucial indicator of accessibility because the poor are the most vulnerable to food insecurity. The poor are generally more vulnerable because people who earn less money have less money to spend on food.[6] Along the same lines, ceteris paribus, it is reasonable to expect that the poor in developing countries are more vulnerable than in developed countries. This is because in developed countries the poor are likely to spend less of their income on food than in developing countries.[7]

There is much support for the view that poverty is a solid indicator of the food security. Smith et al. (2000) looking at 58 developing countries examines the relative importance of

[6] For instance, Block *et al*. (2004) found that when rice prices increased in Indonesia in the late 1990s, mothers in poor families responded by reducing their caloric intake in order to feed their children better, leading to an increase in maternal wasting.
[7] Dessallien, R. L. 1999. Review of Poverty Concepts and Indicators. UNDP Poverty Programme. provides an overview of different concepts of poverty and approaches to its measurement. It notes that povery can be chronic or temporary.

deficient national food availability and the inability of people to access food due to poverty. Using child malnutrition as a proxy for food insecurity they find little correlation between national food availabilities and food insecurity. Instead, they find that the groups of countries that exhibit the highest severity of food insecurity are those with high poverty and food surpluses.

Along similar lines, there is much literature specifically addressing the risk of the poor or near poor to fall into food insecurity. For instance, Jalan and Ravallion (1999) looking at China find that the poorest wealth decile has the least insurance to financial shocks, with 40% of an income shock being passed onto current consumption. By contrast, they remark that consumption by the richest third of households is protected from almost 90% of an income shock and that the extent of insurance in a given wealth stratum varies little between poor and non-poor areas. Similarly, McCulloch Calandrino (2003) looking at poverty in Rural Sichuan note that poverty during 1991–1995 was both dynamic and persistent. It concludes that households in Rural Sichuan are highly vulnerable to falling into poverty even when their average consumption is some distance above the poverty line.

3.2.2. The Role of Growth on Poverty Reduction

It is reasonable to expect economic growth to have a strong relationship with poverty if for no other reason that economic growth determines the total size of the income pie. This subsection proceeds by first discussing the literature emphasizing the role of growth in reducing poverty. Afterwards it discusses the literature showing skepticism towards growth's ability to reduce poverty.

3.2.2.1. Growth as an Engine for Poverty Reduction

There is abundant support for the view that growth can lead to poverty reduction. (see Huang et al. 2008; Goh et al. 2009; Janvry et al. 2005; Appleton et al. 2010; Timmer 2002; Fan et al. 2004). For instance, Appleton et al. (2010) relying on the Chinese Household Income Project surveys note that income from government anti-poverty programs have little impact on poverty, which has fallen almost entirely due to overall economic growth rather than redistribution. In similar light, Yang and Huang (1997) show that price support policies are ineffective in reducing the gap between rural and urban households because the problem is a dynamic one and price policies cannot overcome such a problem unless the price distortions are continually increased. Likewise, Fan et al. (2004) remark that in China 51 percent of the reduction in rural poverty reduction as it declined from 33 to 11 percent can be attributed to the growth that resulted from market oriented institutional reforms.

3.2.2.2. Growth, and Rising Inequality

However, there is also substantial supporting literature for the view that growth alone is not sufficient to reduce poverty in large part because it appears to have diminishing impact on poverty, and it is associated with increasing inequality and transitory poverty. Regarding the diminishing power of growth to reduce poverty, Huang, Zhang, and Rozelle (2008) provide some insight into this topic by examining the driving forces of poverty reduction in China using time series and cross-sectional provincial data. They find that while economic growth played a dominant role in reducing poverty through the mid-1990s, its impact has diminished since that time. Instead, the note that rather than general growth, growth in specific sectors of the economy containing the majority of poorest such as agriculture are more effective in reducing poverty. In light of this finding they conclude that in the future China will need to reduce poverty by measures that help the poor to increase their human capital and incomes.

Regarding growth's association to the rise of income disparities substantial literature provides insights. For instance, Huang et al. (2007) analyzing the impact of trade liberalization on China's agriculture by commodity and by region find that while the trade liberalization will promote growth and by large have a positive effect on farmers, not all household and not all commodities will be treated equally. Specifically, they find that poorer households, in particular those in the provinces in the western parts of China, will be hurt most. They explain that this occurs because farmers in Western China are currently producing commodities that are receiving positive rates of protection, rates of protection that will fall with additional trade liberalization. Hence, they recommend that policies be implemented to minimize the effect on these households either by providing them with direct assistance or by eliminating constraints that are keeping households from shifting their production towards those commodities that will benefit from trade liberalization.

Similarly, looking at it at the national level, Ravallion and Chen (2007) find that as industrial growth accelerated the difference between urban and rural mean incomes increased by 150 per cent from 1980 to 2002. Along similar lines, Chen et al. (2003) observe that even though there are less poor people in 2002 than in 1988, the incomes of the poorest fell during 1988–1995 even when growth was high. This decline contributed to a rise in inequality.

Looking at income disparities at a more regional Goh et al. (2009) reach a similar conclusion. Examining the growth performance and income inequality in eight Chinese provinces during the period of 1989–2004 using the China Health and Nutrition Survey data Goh et al. find that poverty incidence has fallen because income grew for all segments of the population. However, they note that income growth has been uneven, most rapidly in coastal areas, and among the educated. They conclude that income growth can largely be attributed to increases in returns to education making those with low education least likely to gain from growth.

Moving on to the significance of rising inequality as it relates to growth and poverty, literature seems to support the view that increasing inequality should not be taken lightly. According to the World Bank (2005) high levels of inequality may hinder growth and poverty reduction.[8] Jalan and Ravallion provide other insights as one of the ways that inequality cripples growth. Focusing on rural China and using panel data for 6,000 households, Jalan and Ravallion 2001 test for nonlinearity in the dynamics of household incomes and expenditure. They find that nonlinearity exist between household incomes and expenditure. They interpret the nonlinearity they find to mean that the recovery from an income shock is appreciably slower for the poor than for others. Accordingly, they conclude that effective policies protecting the poor from transient poverty could have lasting effects since the poor's slow income and expenditure gained recovery weights on growth.

Along similar lines Zhu Zhongyi (2004) note that the food-for-work policy and programmes in Danfeng County of Shanxi Province and Mabian County of Sichuan Province played an important role in employment generation and temporary and chronic poverty alleviation in rural China.

[8] Indeed, the consequences of inequality on growth while often neglected can be severe. For instance, Faber (2009) on the basis of several economic literature explain that great depressions can result from growing income inequality because production outgrows consumption capacity. This happens because those who can consume do not need to and those who want to consume cannot because of lack of disposable income. In the end, aggregate consumers' purchasing power simply turns out to be insufficient to absorb the growing supply of consumer goods.

IV. METHODOLOGY

This thesis conducts its quantitative analysis using time series. There are two kinds of time series: stationary and non-stationary. Stationary time series means that the time series expectation and variance are not affected by time. On the contrary, non-stationary time series mean either that their expectation, or variance, or both; vary with time. It is important to note that spurious regressions can result when the variables are non-stationary times series due to the fact that non-stationary times series are trended. In order to make sure that the regressions are sensible, it is crucial to first test for cointegration. The core of cointegration test is the unit root test. Thus, this section first discusses three ways of doing the unit root test. Secondly, it discusses the conintegration test.

4.1. UNIT ROOT TEST REVIEW

The three tests described below are:

- Dickey-Fuller (DF) test
- Augmented Dickey-Fuller (ADF) Test
- Phillips-Perron (PP) Test

4.1.1. Dickey-Fuller (DF) test

The simplest form of the DF test amounts to estimating:

$$y_t = \rho y_{t-1} + \varepsilon_t$$

Where: ε_t is white noise, and the value of $|\rho|$ determines the property of the series:

- If the coefficient of $|\rho|$<1, the time series of y_t is stationary
- If the coefficient of $|\rho|$>1, the time series of y_t is explosive which make no sense
- If the coefficient of $|\rho|$=1, the time series of y_t is non-stationary

Thus, the null hypothesis should be H_0: $|\rho|$=1 against the alternative H_1: $|\rho|$<1.

However, in the practice, the test equation is always in the form of $\Delta y_t = \gamma y_{t-1} + \varepsilon_t$ and the null hypothesis is changed to be H_0: $|\gamma|$=0 against the alternative H_1: $|\gamma|$<0.

When y_0 is not equal to zero, then it is better to allow a constant to enter the regression model when testing for a unit root. Thus:

$$\Delta y_t = c + \gamma y_{t-1} + \varepsilon_t$$

It is also possible that there is a time trend t to in the regression model used to test for a unit root changing the equation to:

$$\Delta y_t = c + \alpha t + \gamma y_{t-1} + \varepsilon_t$$

4.1.2. Augmented Dickey-Fuller (ADF) Test

In the DF test, if y_t follows an AR(p) process rather than an AR(1), then the error term will be auto correlated. This is so in order to compensate for the misspecification of the dynamic structure of y_t, which will invalidate the assumption that u, is 'white noise' in the DF. Therefore, it does not suffice to use the DF test.

Instead, the ADF test is used. Thus, assuming y_t follows an pth order of AR process, then the equation is:

$$\Delta y_t = \gamma y_{t-1} + \sum_{i=1}^{p-1} \varphi_i \Delta y_{t-i} + \varepsilon_t$$

The hypothesis test of ADF is the same as that of the DF test and the value of p will be given by EVIEWS automatically. There are also two other kinds of equation which include the intercept and trend.

4.1.3. Phillips-Perron (PP) Test

PP test is also a method test for unit root. It builds on the Dickey–Fuller test of the null hypothesis $|\gamma| = 0$, in $\Delta y_t = \gamma y_{t-1} + \varepsilon_t$.

Like the ADF test, the Phillips–Perron test addresses the issue that y_t might have a higher order of autocorrelation than is admitted in the unit root test equation. This would make y_{t-1} endogenous and thus invalidate the Dickey–Fuller t-test. While the ADF test addresses this issue by introducing lags of Δy_t as regressors in the test equation, the Phillips–Perron test makes a non-parametric correction to the t-test statistic. The test is robust with respect to unspecified autocorrelation and heteroscedasticity in the disturbance process of the test equation.

4.2. COINTEGRATION TEST REVIEW

This study uses Engel-Granger (EG) test to check for cointegration. EG test is the most popular way to test cointegration.

First, this method requires testing that all variables be first order of integrated.

Secondly, the EG test tests the unit root of the residual in the long run equation in the following form:

$$y_t = c + \alpha x_t + \varepsilon_t$$

The null hypothesis is that y_t and x_t are not cointegrated. The way to test this null hypothesis is to check whether the residual (ε_t) is first order of integrated. That is to test whether $\varepsilon_t \sim I(1)$ against the alternative that $\varepsilon_t \sim I(0)$. To test whether the residual is first order integrated, Engle and Granger advocated using the ADF tests in the following form:

$$\Delta \hat{\varepsilon}_t = c + \phi t + \varphi \hat{\varepsilon}_{t-1} + \sum_{i=1}^{P-1} \gamma_i \Delta \hat{\varepsilon}_{t-i} + \mu_t$$

If the residual has a unit root then there is no cointegration. The null hypothesis of the unit is based on a t-test with a non-normal distribution.

Nonetheless, it is important to note that we can not use the standard DF tables of critical values. There are two main motives for this. First, since OLS methods aims to minimize the square of the residue with the smallest variance, the $\hat{\varepsilon}_t$ appears as stationary as possible. Therefore, the standard DF distribution tends to over-reject the null. Secondly, the number of regressors (n) included in long run equation affects the distribution of the test statistic under the null hypothesis. Thus, different critical values are needed as n changes.

Therefore, a different approach must be followed to calculate the critical value. MacKinnon provides guidance as to how to proceed. MacKinnon linked the critical values for specific test to a set of parameters of an equation of the response surface.[9] Accordingly, to obtain the appropriate critical value for any test involving residuals from an OLS equation we can use MacKinnon's table of *Response surface estimates of critical values*, and the following relation:

$$\hat{c}(p,T) = \hat{\beta}_{\infty} + \beta_1 T^{-1} + \beta_2 T^{-2}$$

Where $\hat{c}$ is the critical value, T is the observation number, $\hat{\beta}_{\infty}$, β_1, β_2 are given in the table.

V. EMPIRICAL ANALYSIS

First, this section discusses the grain production model (availability) used to examine science & technology effect on grain production. It begins by introducing the availability grain production model. It continues by describing the data variables. Next, it tests for cointegration. Finally, it presents the results. Secondly, this section discusses the poverty model (accessibility) used to examine the effect of growth on poverty. It begins by introducing the Poverty Model. It continues by describing the data variables. Next, it tests for cointegration with structure break. Finally, it presents the results.

This section uses EVIEWS 6.0.

5.1. AVAILABILITY
SCIENCE & TECHNOLOGY AND GRAIN PRODUCTION

The Grain Production Model this study uses relies on the classical Cobb-Douglas function form of production functions. In economics, the **Cobb–Douglas** functional form of production functions is widely used to represent the relationship of output to inputs. For production, the function is:

$$Y = AK^{\alpha}L^{\beta}$$

where:

- Y = total production (the monetary value of all goods produced in a year)
- L = labor input

[9] Richard Harris, Robert Sollis,2003, Applied Time Series Modelling Forecasting. John Wiley & Sons Ltd Press

- K = capital input, always mean net fixed asset
- A = total factor productivity
- α and β are the output elasticity of labor and capital, respectively. These values are constants determined by available technology

However, it is obvious that only labor and capital variables could not explain the production perfectly. Considering other impact factors, the expansion of C-D model could be:

$$f(x) = A\prod_{I=1}^{n} X_i^{ai}$$

Where:

- *f(x)*= total production
- X_i = affecting factor on production
- A = total factor productivity
- α_i is the output elasticity of affecting factors on production, respectively.

This study takes advantage of the expansion of Cobb-Douglas model. The expansion Cobb-Douglas model form is:

$$\ln Y_t = A + \alpha_1 \ln E_t + \alpha_2 \ln F_t + \alpha_3 \ln M_t + \alpha_4 \ln S_t + \alpha_5 \ln L_t + \alpha_6 \ln N_t + \mu_t$$

Where:

- Y= amount of grain domestic production (1000tons)
- A= constant
- E=government expenditures on agriculture: science & technology promotion & trials (billion)
- F= amount of total fertilizer consumption (1000tons)
- M= amount of total power of ag machinery (10000kw)
- S=amount of total sown area (1000 hectares)
- L= amount of rural employment in farming, forestry, fisheries (10000)
- N= areas affected by natural disaster (1000hectares)

5.1.1. Data Description

The dependent variable in the Availability Model is China's Grain Domestic Production. The independent variable is government's expenditure on science & technology. The control variables are total sown area, fertilizer consumption, machinery power, labour and area affected by natural disaster.

5.1.1.1. Dependent Variable: Grain Domestic Production

Grains, either directly or indirectly represent the major source of food. Indeed, China has commonly equated food security to grain security. Accordingly, this study focuses on grains. China experienced considerable increased in grain production between 1978 and 2008. While in 1978 it produced 304,765,000 tons, in 2008 it produced 528,710,000 tons. This adds up to a total increased of 73.5 per cent which averages 1.97 % yearly rate.

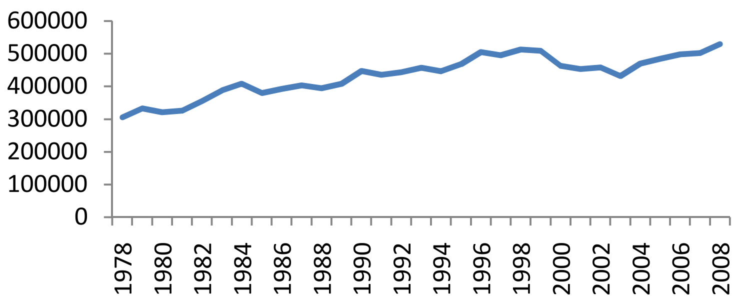


figure 5. 1 Amount Of Grain Production (1000 Tons)
source: website of state data bank of China (http://219.235.129.58/indicatorYearQuery.do)

5.1.1.2. Independent Variable: Government Expenditures on Science & Technology

Government Expenditures on Agricultural Science & Technology increased from 0.11 billion in 1978 to 2.14 billion in 2008.

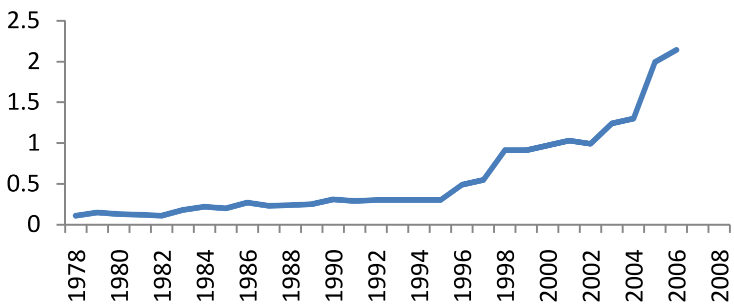


figure 5. 2 Government Expenditures On Agriculture Science &Technology Promotion& Trials(Billion)
source: the website of USDA (United States Department of Agriculture)

http://www.ers.usda.gov/Data/China/NationalForm.aspx

5.1.1.3. Control Variables

The control variables are total sown area, fertilizer consumption, machinery power, labour and area affected by natural disaster.

<u>Total Sown Area</u>

Poet Butler Yeats exclaimed, "All that we did, all that we said or sang must come from contact with the soil…" Indeed, despite humans technological advancements land remains an essential input to grain production. In China controlling for land is valuable because industrialization and urbanization are fiercely competing with agriculture for valuable land. There is much literature supporting the view that urbanization and industrialization jeopardize China's domestic production by affecting soil availability and quality. (See Fan 1997, Lichtenberg and Ding 2008, Yang and Li 2000, Yan et al. 2009, Tian and Zhang-Yue 2005, Monchuk et al. 2010, Jikun and Rozelle 1995, Ye et. al. 2000). However, there is also literature supporting for the view that market efficiencies gains can make up for the losing arable land.[10] (see Chen 2007, Lichtenberg and Ding 2008, Tien and Zhou 2005, Wang and Chen 2000, Yang and Tian 2000, Wen 1993; Kalirajan et al. 1996; Tian 2000; Colby et al. 2000; Fan 1997; Fan et al. 2004).

This studies uses total sown area used to capture the input factor land. In China the amount of total sown area has increased only slightly since 1978. In 1978 it was 150,105 thousand hectares while in 2008 it was 156,266 thousand hectares. This only a total of 4 per cent increase for the whole period.

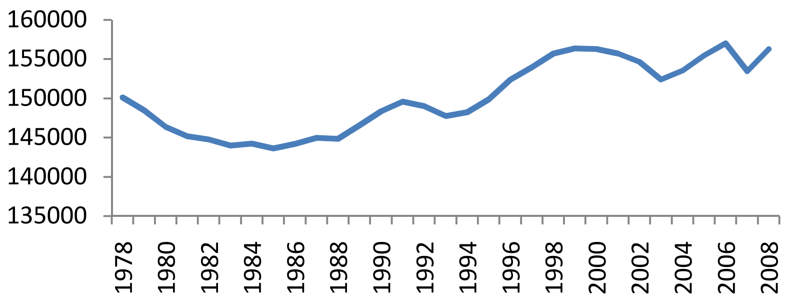


figure 5. 3 Amount Of Total Sown Area (1000 Hectares)

source: website of state data bank of China (http://219.235.129.58/indicatorYearQuery.do)

[10] For example, Wang and Chen (2000) estimate that China could increase grain output by nearly 50 million tones if land fragmentation were completely eliminated due to reduce transportation costs and specialization.

Fertilizer

There is widespread consensus that fertilizer is an important input in food production. Fan (1997) notes that the share of chemical fertilizer has increased from almost none in 1952 to more than 12% of the total production cost in 1995. However, Tian (2000) notes that the environmental cost arising from further application of chemical fertilizer also needs to be taken into account. For instance, Zhang Fusuo (2010), from the China Agricultural University in Beijing finds that heavy use of nitrogen fertilizers in China since the 1980s has resulted in severe acidification of its soil. Furthermore, Tian (2000) notes that the marginal productivity of fertilizers has become low and is declining rapidly for rice and corn.

China's total fertilizer consumption measured in tons has experienced very rapid increase. It increased more than five folds from 8,840 thousand tons in 1978 to 52,390 thousands tons in 2008. The increased was pretty constant though the whole period.

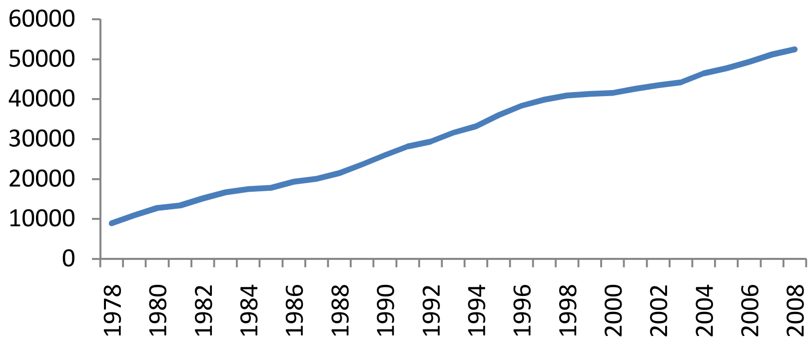


figure 5. 4 Amount Of Total Fertilizer Consumption(1000 Tons)
Source: the website of USDA (United States Department of Agriculture)
http://www.ers.usda.gov/Data/China/NationalForm.aspx

Labor

Labor is an important input in agriculture. As John Locked noted: "All wealth is product of labor." However, labor's importance as an input factor in agriculture can vary drastically between abundant labor abundant countries to land abundant countries; and between industrialized nations and non industrialized nations. China is a labor abundant country (Huang 2000a, Huang and Chen 1999) that is rapidly is undergoing industrialization and urbanization. However, the role that labor plays in China is likely to be affected by China's rigid labor restricting mobility between the urban and rural areas. For instance, Xiurong et al. (2003) note that China's registered permanent residence system restricting the population and labor flow have contributed to a large rural population and labor force living on agriculture, and negatively affected farmer's income. Furthermore, Monchuk et al. (2010) find evidence that counties with a large percentage of the rural labor force engaged in agriculture tend to be less efficient.

This study uses the amount of rural employment in farming, forestry, fisheries as a proxy for labor. It is important to note that this data, although commonly used by many studies focusing on grain production, is not the ideal one to use for this regression. This study focuses on China's domestic grain production and the ideal data would include only the employment in grain production, not on all food production. However, such data does not exist, and thereby, like it often happens in economics this study uses the second best option: rural employment in farming, forestry, fisheries. On the positive side, grain production represents the major bulk of agricultural production in China so this data is a good proxy.

An overview of this variable shows that China has experienced a small increased in the 1978-2008 period from 284,556,000 in 1978 to 348,740,000 in 2008 in rural employment in farming, forestry, fisheries. However, since population has increased, as a percentage of the population, rural employment has experienced decreased from 29.56% in 1978 to 26.53% in 2008.

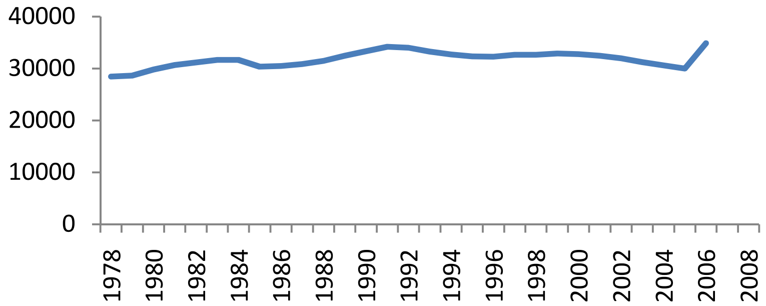


figure 5. 5Amount Of Rural Employment In Farming,Forestry, Fishries(1000)

source: the website of USDA (United States Department of Agriculture)

http://www.ers.usda.gov/Data/China/NationalForm.aspx

Machinery

Agricultural Mechanization is important because it can free labor and lead to increasing productivity. Indeed, historically it has been a critical factor to enhance production scale. Machinery's demand is affected by natural, economic, technological and social factors. For instance, labor abundant countries are less likely to rely on machinery than land abundant countries.

Analyzing the role of machinery power, Fan (1997) notes that despite increasing in total amount between 1978 and 1995 total power of machinery had a declining share of total cost in this period. He argues that this is mainly a result of more efficient allocation of inputs by farmers when production was decentralized to household. This is consistent with Fan and Ruttan's (1992) finding that centrally planned economies often overused capital because of the ideology belief. Nonetheless, Fan (1997) notes that it is reasonable to expect machinery usage to increase as China industrializes and becomes richer.

This study uses machinery power to represent machinery. China has experienced large increases of machinery power since 1978. In 1978, the amount of total power was 11,749.9 ten thousand kw while in 2008 it was 82,190.4 ten thousand kw. This is nearly a seven fold increase. The increase has been mainly constant.

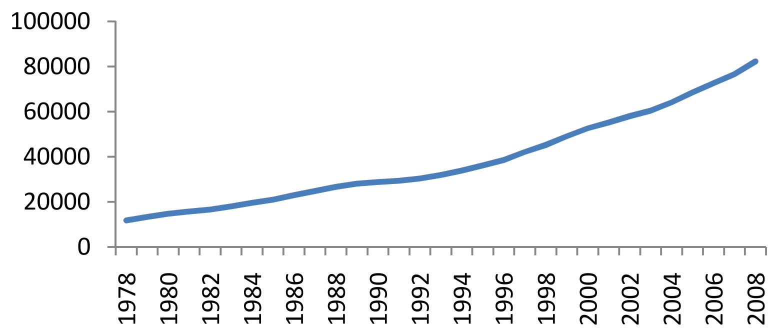


figure 5. 6 Amount Of Total Power Of Ag Machniery(10000 Kw)

source: website of state data bank of China (http://219.235.129.58/indicatorYearQuery.do)

Natural Disaster

It is important to include the control variable natural disaster because agriculture depends on nature. Indeed, natural disaster can have severe short term impacts on grain production. (Zhao Junye et al. 2006). This study uses areas affected by natural disaster to measure this variable.

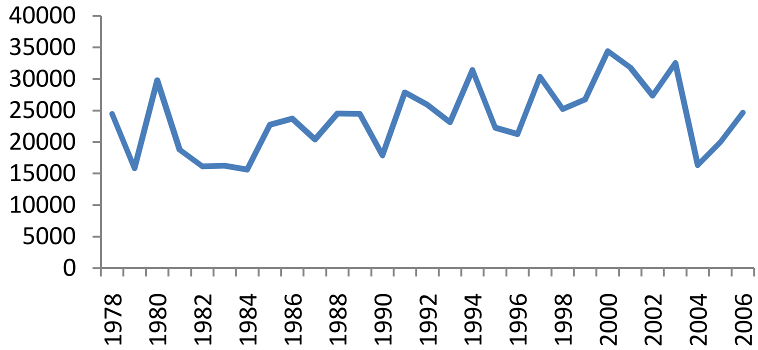


figure 5. 7 Areas Affected By Natural Disaster
source: website of state data bank of China (http://219.235.129.58/indicatorYearQuery.do)

5.1.2. Cointegration Test

All the variables described above are time series which may have spurious regressions. In order to make sure the regression is sensible; here we test cointegration.

5.1.2.1. Testing the Integration Order of All Variables

The conintegration testing results are listed below in table 5.1. The table shows that all the variables are I(1), thus the study should go to the second step to test the unit root of the residual. The variables F, E, S, L and N were found to be I(1) using the ADF Test. However, the variables of Y and M turned out to be of second order integrated using the ADF test. Yet, according to experience from other countries' data, these time series should be first order integration. In case of China, ADF may have generated the incorrect results because of the small sample. Thus, we use PP test instead of ADF for unit root testing of Y and M. And the test result suggests that these two variables are of first order integrated as well.

table 5. 1 Conclusion Of Variables In Production Model: Order Of Integrated

Variables	Level series: With intercept	Level series: intercept &trend	Level series: none	First difference series: With intercept	First difference series: intercept & trend	First difference series: none	comment
log of grain production(lnY) #		-0.8673			-5.6126***		I (1)
log of fertilizer consumption(lnF)		-3.1692			-4.2571***		I (1)
log of ag machinery (lnM) #		-3.1692			-4.9313***		I (1)
log of science & technology(lnE)		-2.1206			-3.2822**		I (1)
log of sown area(lnS)		-3.0667			-4.0030***		I (1)
log of employment(lnL)		-3.2500				-2.0505**	I (1)
log of areas affected by natural disaster(lnN)	-2.1777			-4.1455***			I (1)

responds to using PP test, and others using ADF test
***,**,* responds to rejecting the null hypothesis about non-stationary variables at the 1,5 and 10% level respectively

5.1.2.2. Unit Root Test for Residual

First we estimate the long run equation as follows:

$$\ln Y_t = A + \alpha_1 \ln F_t + \alpha_2 \ln M_t + \alpha_3 \ln E_t + \alpha_4 \ln S_t + \alpha_5 \ln L_t + \alpha_6 \ln N_t + \mu_t$$

We obtain the residuals and do unit root test. The null hypothesis is H_0: $|\gamma| = 0$: $\hat{u}_t$. it has a unit root and there is no cointegration. Against the alternative H_1: $|\gamma|<0$: $\hat{u}_t$, it has no unit root and there is cointegration.

$$\Delta\mu_t = c + \gamma\mu_{t-1} + \sum_{i=1}^{p-1} \varphi_i \Delta\mu_{t-i} + \varepsilon_t$$

The observed ADF t-statistic value is -5.9337.

Then we calculate the critical values, where the number of observation (T) and independent variables are 29 and 6 respectively; the critical values $\hat{c}$ **(p)** are the:

table 5. 2 Critical Values

Size (%)	$\hat{\beta}^{*}_{\infty}$	β_1*	β_2*	$\hat{c}$ (p)
5	-4.4185	-13.641	-21.16	-4.91404
10	-4.1327	-10.638	-5.48	-4.50604

* The values for $\hat{\beta}_{\infty}$, β_1, β_2 were taken from TableA.6 in Harris and Sollis (2005).
Where the above values for $\hat{c}(p,T)$ is calculated with: $\hat{c}(p,T) = \hat{\beta}_{\infty} + \beta_1 T^{-1} + \beta_2 T^{-2}$

By comparing the observed ADF t-statistics with the manually calculated critical values we can conclude that the ADF t-statistic value is smaller than the $\hat{c}$ (p) under both 5% and 10%. Therefore the null hypothesis should be rejected. In other words, the estimated residuals do not have a unit root. Thus, there is cointegration among these variables which make support the significance of this regression.

5.1.3. Results

The domestic production, table 5.3 shows the effects of the input factors. The coefficient stands for the elasticity of independent variable towards dependent variable. For instance, the coefficient of lnF indicates that a 1% change of lnF would lead to 0.63% change of lnY. The results in general are consistent with expectations. Labor (lnL), fertilizers (lnF) and spending on agricultural & technology (lnE) have significant impact on domestic production, with elasticity of 0.33%, 0.64% and 0.11% respectively. In the past thirty years, sown area (lnS) and natural disaster (lnN) have small and negative effect on production.

table 5. 3 Regression Results Of Production Model[11]

Variable	Coefficient
C	9.816334
Fertilizer Consumption(lnF)	0.638482
Power of ag Machinery(lnM)	-0.5274
Government Expenditures on Agriculture: Science & Technology Promotion & Trials (lnE)	0.11108
Sown Area(lnS)	-0.03583
Rural Employment(lnL)	0.32825
Areas Affected by Natural Disaster(lnN)	-0.07729

[11] Please note that the relevant values in the results ares the coefficient of the independent variables. The significance of the independent variable makes no sense because the independent variables time series are non-stationary. According to the ADF test, all the variables have unit root. This means the variance of non-stationary varies with time. Because standard error equals the unbiased estimation of variance, thus value of the variance must be very big. What´s more, the t-statistic value which is calculated using stand error also loses effect.

5.2. ACCESSIBILITY GROWTH AND POVERTY

This model relies on the linear equation to examine the effect of growth on poverty. Because different variables have different units, we log all the variables to delete the unit impact. Our model looks like this:

$$\ln Y_t = c + \alpha_1 \ln P_t + \alpha_2 \ln G_t + \alpha_3 \ln I_t + \alpha_4 \ln E_t + \mu_t$$

Where:

- Y = percentage of poverty in rural area
- P = index of grain price
- G = Gross Domestic Product (%)
- I = amount of investment on agriculture(one hundred million)
- E = Percentage of people in rural area who educated upper than high school

5.2.1. Data Description

The dependent variable is China's Poverty level in percentage. The independent variable is growth. The control variables are food prices, education, and government's investment in agriculture. .

5.2.1.1. Dependent Variable: Poverty Percentage

This study uses the poverty percentage data issued by the China National Statistic Bureau (NSB) because it is the most complete data for the 1978-2006 period. As the NSB poverty percentage line can be controversial this thesis proceeds by comparing it with that of the World Bank After, this thesis moves on to describe the NSB poverty percentage data.

Measuring Poverty

Measuring poverty is in itself a complex and controversial task. The NSB and World Bank data differ significantly in their poverty measurement. For instance, the World Development Report (2005) state that poverty percentage was 16.6% in 2001 while the NSB stated it was just 3.1%. This huge difference in percentage between the World Bank and the NSB arises because each calculates the poverty line different and the poverty measurement.

As to coming up with a poverty line, the World Bank uses the rather simplistic one U.S dollar per day. It converts it using purchasing power parity calculated by World Bank in 1993, and updates it using Chinese CPI. On this basis, it obtains the poverty line. The NSB rural poverty standard, instead, is calculated by relying on the national rural household survey in 1985, 1990, 1994 and 1997. The poverty lines in the other years are updated using the CPI in each year. Indeed, table 5.4., shows that the poverty level in China in 2005 was 683 yuans per year according to the NSBa, whereas it was 935 yuans according to the World Bank.

table 5. 4 Poverty Line Of China And World Bank

	2000	2001	2002	2003	2004	2005
Chinese Poverty Line(yuan)	625	630	627	637	668	683
International Poverty Line(yuan)	876	882	873	884	918	935

Source: Wang Pingping, 2006

However, while the World Bank Poverty data is more prestigious internationally is not without controversy. For instance, according to the Wang Pingping et al. (2006) the World Bank overestimates the poverty level in China. They explain that this happens because of the way the World Bank measures expenditures. Specifically, Wang Pingping et al. explains that the World Bank counts people as poor in the year they did not invest in housing, but if housing expenditure was distributed in across years, they would not be treated as poor. Similarly, Wang Pingping et al. remark that such problems also arise with education and health expenditures.

However, all said it is not the aim of this thesis to debate which poverty measurement is better. What is relevant to this thesis is that all the poverty level calculated by different measures show that the poverty percentage of China experienced a remarkable decrease since 1978. Further, since this study uses the log value of the poverty level, the log value just shows the trend of the poverty changes. Thus, it is not critical which measuring standard is used as long as the same measuring standard is used for the whole period.

<u>China's Poverty Percentage</u>

Rather than look at poverty at the national level this model focuses on poverty on the rural area. This makes sense for several reasons. Much of the poverty in China is rural. Further, in contrast to the urban population, the government provides no basic living allowances to the rural population.

A quick look at China's rural poverty, the data reveals that China has experienced significant poverty reduction. A visual analysis reveals that the percentage of poverty decreased dramatically since 1978, with the number decreasing from 30.7% in 1978 to 2.5% in 2005.

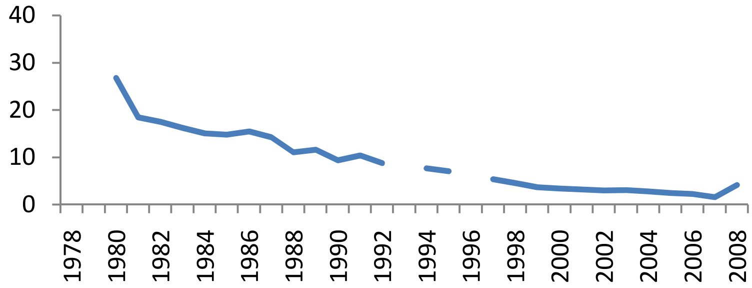


figure 5. 8 Percentage Of Poverty %
source: China Yearbook of Rural Household Survey, 2009

Although the poverty percentage data is nearly complete there are three missing values: 1979, 1993 and 1996, respectively. In order to make sure the continuity of the sample data, this section first predicts the missing values. The first step is to rely on a visual analysis of the the available data (figure 5.8) to obtain the trend form. In light of the visual analysis, we assume the trend of poverty percentage follows the form of logarithm：

$$y_t = c + \alpha \ln t + \mu_t$$

The outcome calculated by Eviews 6 is shown in table 5.5. The high value of R-squared indicates the high correct probability of prediction and the prediction of missing data in 1979, 1993 and 1996 as shown in table 5.6.

table 5. 5 Regression Results Of Poverty Percentage

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	33.1655	0.7650	43.3508	0.0000
Lnt	-9.1402	0.2985	-30.6151	0.0000
R-squared	0.9730	F-statistic	937.2840	
Adjusted R-squared	0.9719	Prob(F-statistic)	0.0000	

table 5. 6 Prediction Data Of Poverty Percentage

year	percentage of poverty%	year	percentage of poverty%
1978	30.70	1994	7.70
1979	***26.83***	1995	7.10
1980	26.80	1996	***6.25***
1981	18.50	1997	5.40
1982	17.50	1998	4.60
1983	16.20	1999	3.70
1984	15.10	2000	3.40
1985	14.80	2001	3.20
1986	15.50	2002	3.00
1987	14.30	2003	3.10
1988	11.10	2004	2.80
1989	11.60	2005	2.50
1990	9.40	2006	2.30
1991	10.40	2007	1.60
1992	8.80	2008	4.20
1993	***7.82***		

5.2.1.2. Independent Variable: Growth

The independent variable is growth. The data in this model comes from China's Statistics Yearbook. A quick look at the graph shows that in the 1978-2008 period China has experienced rapid growth. It has averaged 9.8% per year.

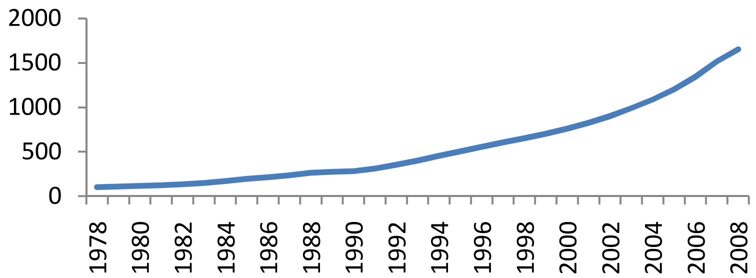


figure 5. 9 Gross Domestic Product %
Source: China Statistical Yearbook 2009

5.2.1.3. Control Variables

The Control Variables are food prices, education, and government's investment in agriculture

<u>Food Prices</u>

It is reasonable to expect food prices to have a relationship with poverty if for no other reasons that people must eat. Further, it is sensible to expect that the effects of food price rises will differ on individuals with different professions and income levels. While higher food prices will likely directly hurt those in the urban areas, they may benefit food producers.

Similarly, while the well off maybe able to sustain food consumption by cutting other expenditures, the poorest may need to reduce food consumption itself, and the households just above the poverty line may fall below the poverty line.[12]

There is much support for the view that high food prices are bad for the poor because most of the poor are net food buyers, even in rural areas (Ravallion 1989; Christiaensen and Demery 2006; Seshan and Umali-Deininger 2007; Byerlee, Myers and Jayne 2006). For instance, FAO (2008) estimates that the increase of food prices between 2003–2005 and 2008 increased the number of people that went hungry worldwide by 75 million. Nonetheless, there is also support for the view that high food prices could lead to poverty reduction. For instance, FAO (2009) argues that many of the developing nations where poverty prevails continue to be characterized by producing commodities population and thus can benefit from higher income prices.

The national cross price index of grain is used to measure food prices. A brief look at the price index of grain in China reveals that it increased more than 6 times since 1978. During the period of 1992 and 1997, this number experienced rapid growth, increasing from 277.64 to 525.54. But after 1997, it back to normal situation.

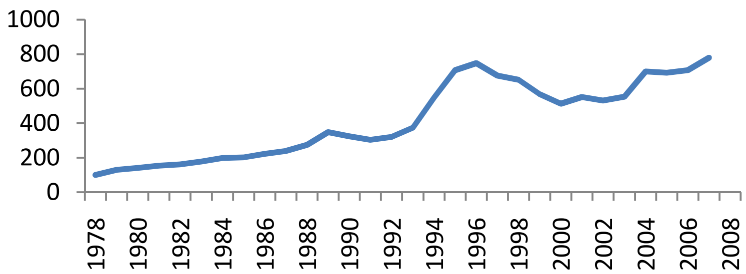


figure 5. 10 National Cross Price Index Of Grain
source: China Yearbook of Agricultural Price Survey, 2008

Education

It is important to control for education because education is widely recognized as an important tool to reduce poverty. For instance, Zhang et al. (2005) estimating the returns to schooling in urban China find a dramatic increase in the returns to education, from only 4.0 percent per year of schooling in 1988 to 10.2 percent in 2001. They observe that most of the

[12] For instance, Block *et al*. (2004) found that when rice prices increased in Indonesia in the late 1990s, mothers in poor families responded by reducing their caloric intake in order to feed their children better, leading to an increase in maternal wasting.

rise in the returns to education occurred after 1992 and reflected an increase in the wage premium for higher education. Further, Goh et al. (2009) hold that income growth can largely be attributed to the increase in returns to education and to the shift of employment into secondary and tertiary sectors. Furthermore, Luh et al. (2008) note that for foreign knowledge to contribute to productivity growth either through innovation or through catching up, the host economy has to develop a sufficient learning capacity from education. They remark that countries that do not attempt to develop the learning capability to assimilate and exploit the freely available knowledge may not benefit from international spillovers of agricultural R&D.

This study measures education by the percentage of population in rural area that completed high school. The data in this model comes from China Yearbook of Rural household survey. However, it is missing some values: the data between 1978 and1982. To predict the missing values we first graph the available data to obtain a general trend.

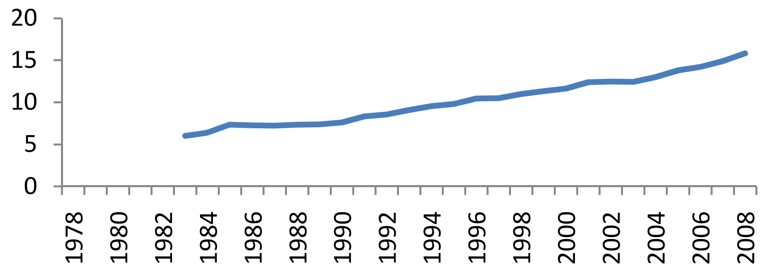


figure 5. 11 Percentage Of Population In Rural Having Completed High School %
source: China Yearbook of Rural Household Survey, 2009

The data value in 1985 is 7.4% which is close to the number of 7.6% in 1990. However, a visual analysis reveals that after 1990 there was a rapid increase. Thus we assume the trend of this variable obey the form of an exponential function:

$$E_t = ce^{\alpha t \varepsilon}, \ln E_t = c + \alpha t + \mu_t$$

The results obtained below are listed in table 5.7. The high R-squared supports the results.

table 5. 7 Regression Results Of Education

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.6136	0.0170	94.6516	0.0000
t	0.0363	0.0008	42.5653	0.0000
R-squared		0.9869	F-statistic	1811.807
Adjusted R-squared		0.9863	Prob(F-statistic)	0.0000

table 5. 8 Prediction Data of Education

year	education%	year	education%
1978	***5.21***	1994	9.54
1979	***5.40***	1995	9.81
1980	***5.60***	1996	10.42
1981	***5.81***	1997	10.48
1982	***6.02***	1998	10.98
1983	5.99	1999	11.33
1984	6.38	2000	11.62
1985	7.31	2001	12.36
1986	7.26	2002	12.46
1987	7.22	2003	12.4
1988	7.33	2004	13
1989	7.35	2005	13.8
1990	7.57	2006	14.2
1991	8.32	2007	14.9
1992	8.54	2008	15.8
1993	9.07		

Government Spending in Agriculture

It is reasonable to expect that government spending in agriculture could have a significant effect on poverty because China remains an agricultural country. There is much support for the view that investment in rural areas affects poverty. (see World Bank 2007, Bravo-Ortega and Lederman 2005, Bezemer et al. 2008, Strasberg et al. 1999, Timmer 2002). For instance, World Bank (2007) highlights that 75–80 percent of the dramatic drop in national poverty in China during 1980–2001 was the result of poverty reduction in the rural areas and that that GDP growth generated in agriculture was at least twice as effective in reducing poverty as growth generated by other sectors. Similarly, Bravo-Ortega and Lederman (2005) find that in developing countries agricultural labor productivity leading to increases on GDP is on average 2.9 times more effective in raising the incomes of the poorest quintile than an equivalent increase in GDP coming from nonagricultural labor productivity.

A quick look at government expenditures on agriculture reveals during the period of 1978 to 1988, it experienced a slow growth, and the average increase rate is just around 4.5%. However, since 1989, there is a dramatic rise, with the number increasing from 26.59 billion yuan in 1989 to 317.1 billion yuan in 2006. And the average growth rate for the second period was 16.8%.

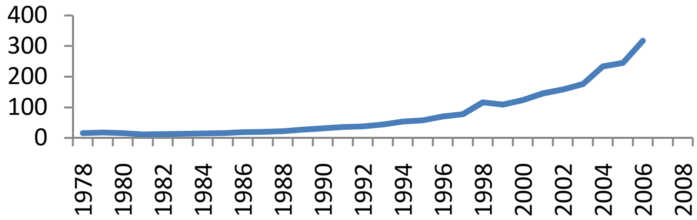


figure 5. 12 Government expenditures on agriculture (billion yuan)
source: the website of USDA (United States Department of Agriculture)
http://www.ers.usda.gov/Data/China/NationalForm.aspx

5.2.2. Testing for Cointegration with A Structural Break

First, this study uses the ADF test to determine all variables' order of integrated. After, this study tests the unit root of the residual given by the long run equation.

5.2.2.1. Test the Integration Order of All Variables

The conintegration testing results are listed below in table 5.9. The table shows that all the variables are I(1). Thus the study can proceed to to test the unit root of the residual.

table 5. 9 Conclusion Of Variables In Poverty Model: Order Of Integrated

	Level series			First difference series			
Variables	With intercept	intercept &trend	none	With intercept	intercept & trend	none	comment
log of grain poverty(lnY)		-3.6154		-6.1999***			I (1)
log of grain price(lnP)		-2.2242		-3.6850**			I (1)
log of ag growth (lnG)		-4.2297		-3.6906**			I (1)
log of investment in agricultural(lnI)		-2.7707		-4.6684***			I (1)
log of education(lnE)		-3.1710		-5.4216***			I (1)

***,**,* responds to rejecting the null hypothesis about non-stationary variables at the 1,5 and 10% level respectively

5.2.2.2. Unit Root Test for Residual

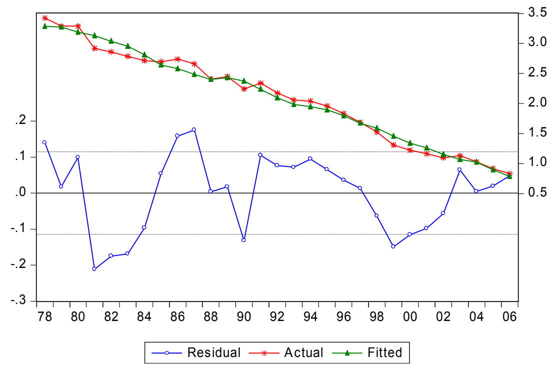
The first step is estimate the long run equation as follows:

$$\ln Y_t = c + \alpha_1 \ln P_t + \alpha_2 \ln G_t + \alpha_3 \ln I_t + \alpha_4 \ln E_t + \mu_t$$

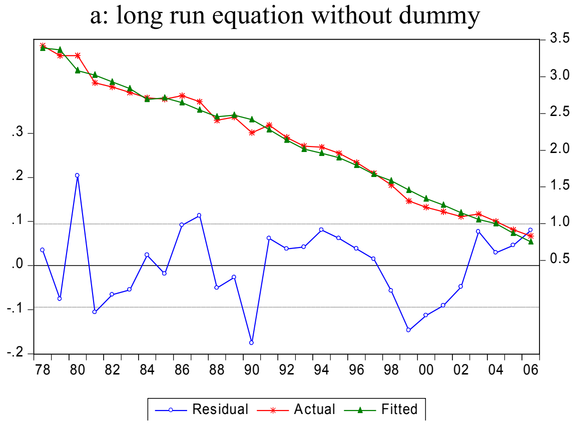
The next step is to run the regression and obtain the residual graph. It is clear that there is structure break during the period of 1980 to 1984. This structural break likely relates to the major institutional reforms implemented early in the reform period. Thus, it is better to add a dummy variable into the equation. With dummy variable the long run equation is:

$$\ln Y_t = c + \alpha_1 \ln P_t + \alpha_2 \ln G_t + \alpha_3 \ln I_t + \alpha_4 \ln E_t + \alpha_5 d_1 + \mu_t$$

$$\text{Where, } d_1 = \begin{cases} 1 & 1980-1984 \\ 0 & other \quad years \end{cases}$$



a: long run equation without dummy



b:long run equation with dummy d_1

figure 5. 13 Residual Graphs

However, according to the above graph figure 5.13b, there is still a structure break during the period between 1997 and 2000. This structural break could relate the temporary agricultural price hikes experienced in 1996. Therefore, it is appropriate to add another dummy into the equation. This becomes:

$$\ln Y_t = c + \alpha_1 \ln P_t + \alpha_2 \ln G_t + \alpha_3 \ln I_t + \alpha_4 \ln E_t + \alpha_5 d_1 + \alpha_6 d_2 + \mu_t$$

Where, $d_1 = \begin{cases} 1 & 1980-1984 \\ 0 & other \quad years \end{cases}$ $d_2 = \begin{cases} 1 & 1997-2000 \\ 0 & other \quad years \end{cases}$

Here the observed ADF t-statistic value is -5.5759.

The critical values are shown in table 5.10.

table 5. 10 Critical Values

Size (%)	$\hat{\beta}^*_\infty$	β_1*	β_2*	$\hat{c}$ (p)
5	-4.4185	-13.641	-21.16	-4.91404
10	-4.1327	-10.638	-5.48	-4.50604

* The values for $\hat{\beta}_\infty$, B_1, B_2 were taken from TableA.6 in Harris and Sollis (2005).
Where the above values for $\hat{c}(p,T)$ is calculated with: $\hat{c}(p,T) = \hat{\beta}_\infty + \beta_1 T^{-1} + \beta_2 T^{-2}$

By comparing the observed ADF t-statistics with the manually calculated critical values we conclude that the ADF t-statistic value is smaller than the $\hat{c}$ (p) under both 5% and 10% significance level. Therefore, the null hypothesis should be rejected. In other words, the estimated residuals do not have a unit root. Thus, there is cointegration among these variables which make sure the significance of this regression.

5.2.3. Results

Table 5.11 below shows the results. The coefficient here stands for the elasticity. Firstly, growth (lnG) plays the most important role in poverty reduction. The elasticity of growth (lnG) is 1.297 which means when lnG increase 1% and poverty is reduced by 1.297%. Further, there is a positive relationship between education (lnE) and poverty reduction (lnY). The coefficient of investment in agriculture (lnI) is negative but small. With regards to the effect of grain price (lnP), it turned out to be positive, indicating that higher grain prices did not reduce poverty in China.

table 5. 11 Regression Results Of Poverty Model[13]

Variable	Coefficient
C	7.757138
Education Level(lnE)	-0.07197
GDP(lnG)	-1.29746
Investment in Agriculture(lnI)	0.087495
Grain Price(lnP)	0.315915

VI. DISCUSSION

This study aimed to gain some insights as to how China could safeguard its food security by following an innovative dual approach. First, this study focused on the availability dimension of food security by examining with time series regressions the role that government's expenditure on agricultural science & technology plays on China's grain production. To the extent that this regression uses grain production, instead of food production, the implications of the results are narrow and apply only to grain production. Nonetheless, the implications of the results are wider than it would seem at first. Grain production still represent the bulk of agricultural production and consumption worldwide, and grain production encompass to a large extent meat production since feeding grains play a large and critical role in meat production.

Secondly, this study focused on the accessibility dimension of food security by examining with time series regressions the role that growth plays in poverty reduction. To the

[13] Please note that the relevant values in the results are the coefficient of the independent variables. The significance of the independent variable makes no sense because the independent variables time series are non-stationary. According to the ADF test, all the variables have unit root. This means the variance of non-stationary varies with time. Because standard error equals the unbiased estimation of variance, thus value of the variance must be very big. What´s more, the t-statistic value which is calculated using stand error also loses effect.

extent that measuring poverty in China remains a controversial issue and this study uses data from the China National Statistic Bureau it can be viewed with skepticism. However, as mentioned in the data section, regardless of how poverty is calculated there seems to be consensus that China experienced remarkable decreases in poverty since 1978. As this study uses the log value of the poverty level, it is not critical which measuring standard is used as long as the same measuring standard is used for the whole period.

This section first proceeds by analyzing the grain domestic production regression showing the role of government's expenditure on science & technology. Afterwards, it analyzes the poverty regression showing the effects of growth on poverty reduction.

6.1. THE ROLE OF SCIENCE & TECHNOLOGY

The regression shows that government's investment in science and technology indeed had a positive impact on grain production between 1978 and 2008. This positive result is consistent with the existing literature which by the most part argues that science & technology has played play a significant role both globally and in China in food production. This should not be surprising. As, Evenson and Gollin 2003 point out science & technology was critical to the green revolution and focused by large in the major grains. Looking forward, the implication of this result is that science & technology in the future should an important role in safeguarding China's domestic production. As China's commitment to the WTO prevents it from using policies it used in the past to support its agriculture like direct subsidies and prohibitive tariffs, China's agriculture could suffer as farmers find it more costly to produce. However, since the WTO allows unlimited government investment in agricultural science & technology, and since science & technology has a positive effect on production, the government can continue to incentivize production by increasing its expenditures.

With regards to the fertilizer control variable, the result add support to the view that looking forward government's expenditure in science & technology can be pillar to China's food domestic policy agenda. The regression shows that fertilizers consumption is the driving engine behind China's domestic production. To the extent that fertilizers has potential harm the environment (Zhang Fusuo 2010), in the future investment in science & technology can be valuable to agriculture by providing guidance as to how to continue exploiting the potential benefits of fertilizers without harming China's environment.

As to the land coefficient, it is both negative and small. The implication for this control variable as it relates to science & technology is that increases in land will not be a part of China's agricultural growth because land availability in China is limited. This is in line with the literature on land availability discussing that both the quantity and quality of land in China are being jeopardize by urbanization and industrialization. The major implication from this result is therefore that China's domestic production increase will have to come from elsewhere. Specifically, they will likely have to come from increases in yield which are related to both fertilizers usage and investment in science & technology. Thereby, giving additional support to the recommendation that China should invest in science & technology.

As to the control variables machinery the results are unexpected. The coefficient for machinery is negative. This indicates that machinery power has a negative impact on domestic production. This could be because labor is abundant in China. Nonetheless, looking forward, as China continues to industrialize and urbanize, it is reasonable to expect that machinery will play an increasingly important role in China's Agriculture and to the extent that agricultural mechanization and science & technology are intertwined, government's expenditure on science & technology could play a positive role in developing machinery that consistent with China's agricultural needs rather than the need of land abundant countries.

6.2. THE ROLE OF GROWTH ON POVERTY REDUCTION

This study examined the effects that growth had on poverty reduction. The results show that growth has been the engine in China's poverty reduction. This result is consistent with economic theory and the predominant economic literature. The implications of the regression results are that China should continue to promote growth policies. Nonetheless, the economic literature while supporting the view that growth is a crucial ingredient for poverty reduction, also support the view that growth alone is not sufficient. Inequality has increased and disparity between the urban and the rural area have widened in the last decades. (Ravallion and Chen 2007). This inequality could hinder growth (World Bank 2005). Furthermore, the literature argues that transitory poverty is not necessarily reduced by growth and can actually hinder growth. (Jalan and Ravallion, 2001). Specifically, as it relates to food security, transitory poverty is also critical because food security is concerned with both temporary and chronic food insecurity. In conclusion, in light of shortcomings mentioned in the literary review, this study hypothesis that growth will likely be more effective in reducing poverty if complemented with policies directly addressing poverty. Which poverty reduction and safety nets to implement is beyond the scope of this thesis. Probably both safety nets as well food-for-work programs like the one discussed by Zhu Zhongyi 2004 could play role.

With regards to the control variable food prices, the coefficient is positive, suggesting that even in rural areas food prices increases increase poverty. Accordingly one can deduce that in China higher food prices hinder poverty reduction and food security. As it relates to growth, one reasonable implication of high food prices hindering poverty reduction is that food tariffs resulting in higher food prices are bad for poverty both because they hinder economic growth and because they directly negatively affect Chinese households. Another implication, as it relates to developing poor countries like China, is that food prices can make families reduce calories intake (Block et al. 2004). To the extent that calories intake reduction lead to undernourishment, and undernourishment lowers productivity, food price hikes have the potential indirectly affect growth.

With regards to the education and government investment in agriculture control variables, both coefficients are small. However, the education coefficient is negative indicating that a higher education is related to a lower poverty, while the coefficient of investment in agriculture is positive indicating it hinders poverty reduction. As education relates to growth, a possible conclusion to draw is that to the extent to which education reduces income disparities (Goh et al. 2009), it can promote growth. As to government investment in agriculture, the negative effect could be because the type of investment the government has been in conflict with policies promoting growth. Still, the coefficient is so small that is not safe to draw any conclusions. Still, looking forward, this thesis views government investments in agriculture in ways that do not conflict with the market mechanisms that promote growth such as investment in science & technology and education as logical.

6.3. FOOD AVAILABILITY AND ACCESSIBILITY

By large this study has discussed food availability (the role of science & technology on grain production) and food accessibility (the role of growth on poverty) separately. However, regarding food security these two dimensions are complementary and intertwined. As mentioned in section 3.1.1., food availability is precursor to food accessibility. This should be obvious. If on average there is not enough for all, there will some individuals that will not have access to enough food. However, it is also true, although in a less obvious way, that food accessibility plays an important role in determining food availability. The more accesses people have to food, the higher the demand for food will be, and therefore the greater need to increase food availability.

Considering specifically this study's focus, it is valuable to point out that the role of science & technology on grain production is intertwined with the role that growth plays on poverty in difficult to quantify ways. As to availability, governments' expenditure on science & technology by increasing grain yields, reducing food prices, and protecting China's environment is likely to have positive spillover effects on China's economic growth.

Likewise, China's economic growth, by reducing poverty is likely to have a positive spill over effect on the effectiveness of government's expenditure on science and technology in increasing grain production. For instance, it is likely that as income increases the population invests more in education, and as Luh et al. (2008) note, even to acquire agricultural productive technology sufficient learning capacity is necessary. Furthermore, growth and poverty reduction promotes political stability, which allows the government the resources and will to invest in agricultural science and technology.

All said, it is much easier when discussing food security to focus on one dimension of food security, either food accessibility of availability. While there is great value to it since permits the researcher to specialize in one issue, it is important keep in mind that when it comes to food security the food accessibility and food availability dimensions are married and interact with each other, sometimes in ways which that although difficult to quantified, are significant.

VII. CONCLUSION

This study aimed to contribute to the literature discussing food security in China. It noted that food security rests on two dimensions: food availability and food accessibility. While other economic literature discussing food security by large focuses either on elements affecting food availability or on elements affecting food accessibility, this thesis recognizes the importance and complementary roles of both dimensions by examining both the role that science & technology plays on grain production (food availability) and that growth plays on poverty (food accessibility).

Regarding food availability, this study notes that China faces serious hurdles ahead to maintain its grain production. Urbanization and industrialization are limiting China's land availability, and China's commitment to the WTO limits the type of policies China can use to promote domestic production. In this light, this study ran a regression to examine the effect that government's investment in science & technology had on China's domestic grain production. The results show that government's expenditure on science & technology played a positive role in China's domestic output. Looking forward, investment in science & technology can be valuable to China's agriculture. It can lead to higher yield seeds, better irrigation technology, and provide guidance as to how to continue exploiting the potential benefits of fertilizers without harming China's environment.

Regarding the food accessibility dimension, this study notes that millions of Chinese remain poor and salaries are so low in China that even those who are not poor risk falling into poverty. In this light, this study focuses on examining the effect of growth on poverty reduction. To this end, this study ran time series regressions. As expected, the results show that growth was the main engine behind China's poverty reduction. Nonetheless, incorporating the literary review with the regression results, this study concludes that in the future the power of growth to reduce poverty however great is not absolute. Indeed, in China inequality has increased and the urban and rural income disparity continues to widen. All said, the buffer for Chinese to stand financial shocks or food hikes is thin. In this sense, government's investments in education and safety net measures in rural areas that assist the poorest, as well as investment in science & technology leading to increases in grain production, should be the cornerstone of China's food security policies.

Yoga Berri said that "it is difficult to make predictions, especially about the future." Berri was right on point. The future certainly seems to have made some of Malthus predictions foolish. And yet in a way so far Malthus has been proved wrong only temporarily. After all, the world has never experienced urbanization and industrialization by so many people at such a rapid pace. Furthermore, in way Malthus has only been proved wrong partially. In the world, even as food supply is ample, by many accounts there are nearly one billion people experiencing food insecurity.

Bearing this in mind, to sit back, and either take for granted that the earth can produce enough food for all or ignore the food distribution is negligent. If Malthus was proved wrong before it was because so much effort was spent by scientists, farmers, and his fellow economists into proving him wrong. Vast work and research remains to be done regarding food security. For instance, the question as what role can institutional reforms play in promoting food domestic production remains unanswered. Furthermore, determining what type of safety nets is likely best reduce transitory poverty and prevent chronic poverty is crucial to improving food security.

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