Chapter 1

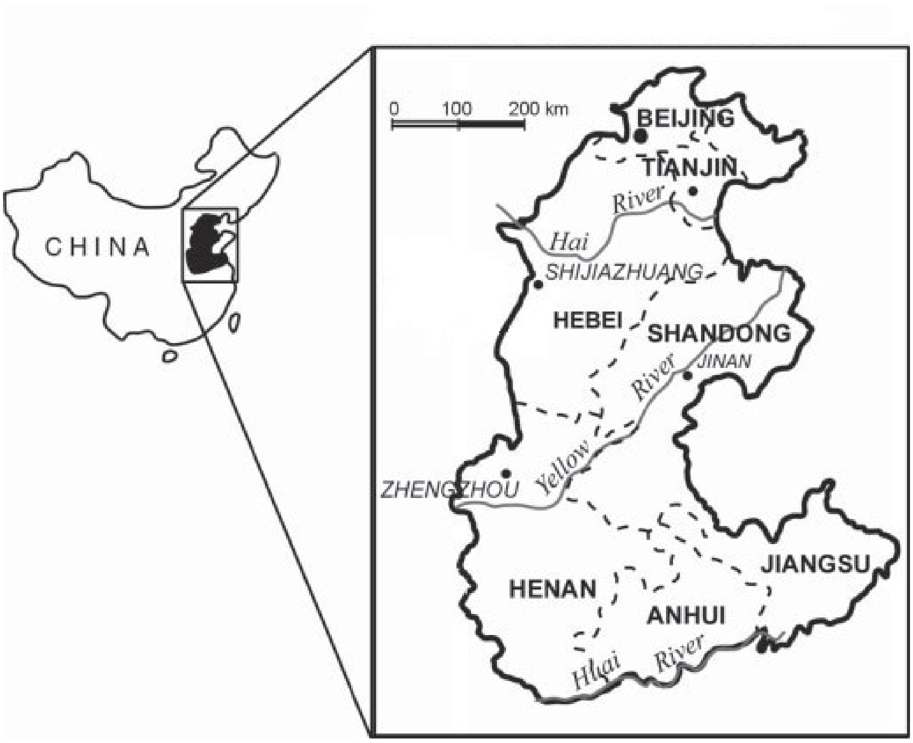
Introduction

1.1 Background information

The world population was around three billion in the 1960s. Over the next 50 years, the figure more than doubled and reached seven billion. This annual growth rate of 1.7% has been outpaced by the rise of total agricultural output at 2.3% per year, which has helped to reduce the proportion of people suffering from hunger (Wik et al., 2008). In the beginning, the growth in agricultural output has been largely due to the increase of input use, which includes resources such as land and water, as well as labor, capital and chemicals. During the 10 year period from 1960, the rise in input contributed 82% of the output growth with the rest coming from improvement in total factor productivity. The importance of these two components shifted over the years. The contribution of input dropped to 64% in the 1970s and 1980s, and reduced further to 29% over the following 20 years, with an increase in productivity accounting for the bulk of agricultural output growth (Fuglie, 2010). This trend is however not uniform throughout the world. According to the 2012 Global Food Policy Report by the International Food Policy Research Institute (IFPRI), the switch from input intensification to productivity growth took place around 1980 in high-income countries, which helped to maintain output level despite the decrease in resource use. The growth in labor productivity also outpaces that of land productivity following the drop in agricultural labor and the rise in average farm size. The switch comes later for many developing countries at around 2000, but China and Brazil have managed to maintain high productivity growth for the past two decades (Fuglie and Nin-Pratt, 2013).

Fan (1991) separates the growth promoting factors of Chinese agriculture into three components, which are input, technology, and efficiency. He finds that from 1960s to mid 1980s, 58% of the output growth is due to the increase in input use, especially chemical fertilizer. Technological advancement and greater efficiency account for 16% and 26% of the growth, respectively. Fan and Pardey (1997) extend the study period to mid 1990s and include more components, such as research and development, into consideration. In this case, input intensification accounts for 46% of output increase, with almost half of it coming from fertilizer alone. Agricultural research is responsible for 20% of growth, while the contributions from institutional and market reforms amount to 18%. Lin (1987), Lin (1992), and Young (2000) provide more explanation on the process of change in the Chinese agricultural institutions. For the topic of increasing agricultural input use in China, especially chemical fertilizer and its impact, more studies can be found in Huang and Rozelle (1995), Wang et al. (1996), and Zhen et al. (2006). Other than the research done at the country level, Fuglie and Nin-Pratt (2013) find that productivity growth can vary quite a bit even within a country itself. For example, they find that the growth in total factor productivity has been very strong along the coast in Northeast, East, and Southeast China. However, the performance is weaker in the interior parts of the country.

When agricultural growth began to take off in China in the 1980s, the region with the highest grain output growth was the North China Plain (NCP) at 55.5%, followed by the Northeast at 53.2%. Fertilizer application in that region also almost doubled from 1980 to 1990. Comparatively, southwestern China had a lower increase in fertilizer use at about 60% (Zhang and Carter, 1997) over the same time period. NCP is located in the eastern coastal region of China and covers a big part of the provinces of Hebei, Henan, Shandong, and the northern parts of Jiangsu and Anhui provinces. It is one of the most important agricultural regions in China, contributing to a quarter of the total grain yield of the country, with the main crops being summer maize and winter wheat (Zhen and Routray, 2002). Due to the intensification of agriculture and the increasing demand for irrigation, the decline of groundwater level has been a serious problem in this region (Sun et al., 2011). From 1983 to 1993, the average water table lowers by 0.429 meter per year from 7.23 meter to 11.52 meter beneath the surface (Liu et al., 2001). In addition to water shortage,

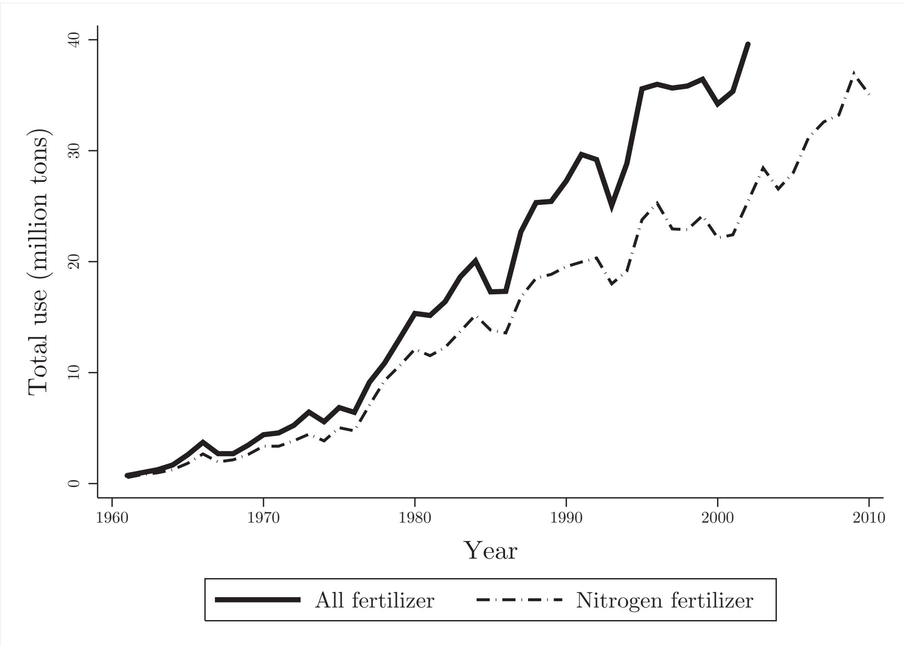


Source: Kendy et al. (2004)

Figure 1.1: Location of the North China Plain

the degradation of water quality is another problem faced by the region. In a comprehensive five-year study conducted by the China Academy of Geological Sciences from 2006 to 2011, a total of 7,451 groundwater samples were collected in the NCP and tested. The results show that only 25% of the samples are safe for direct human consumption, which is lower than the national average of 45% (Jiang and Jiang, 2013). One of the causes is the overuse of chemical fertilizer, as Chen et al. (2005) and Hu et al. (2005) show that nitrate pollution in groundwater is a problem in the region. In a case study conducted by Zhen et al. (2005) in a county of the NCP, 16 out of the 20 well water samples and 19 out of the 20 vegetables samples collected contain a higher nitrate concentration than the maximum level deemed safe for human consumption. The authors also find significant and positive correlation between the amount of nitrogen fertilizer used and the nitrogen concentration in groundwater. This contamination of both food and drinking water could be dangerous to the people living in the region, as the review of evidence by Fraser et al. (1980) indicates that nitrate ingestion could be a factor that raises gastric cancer rate.

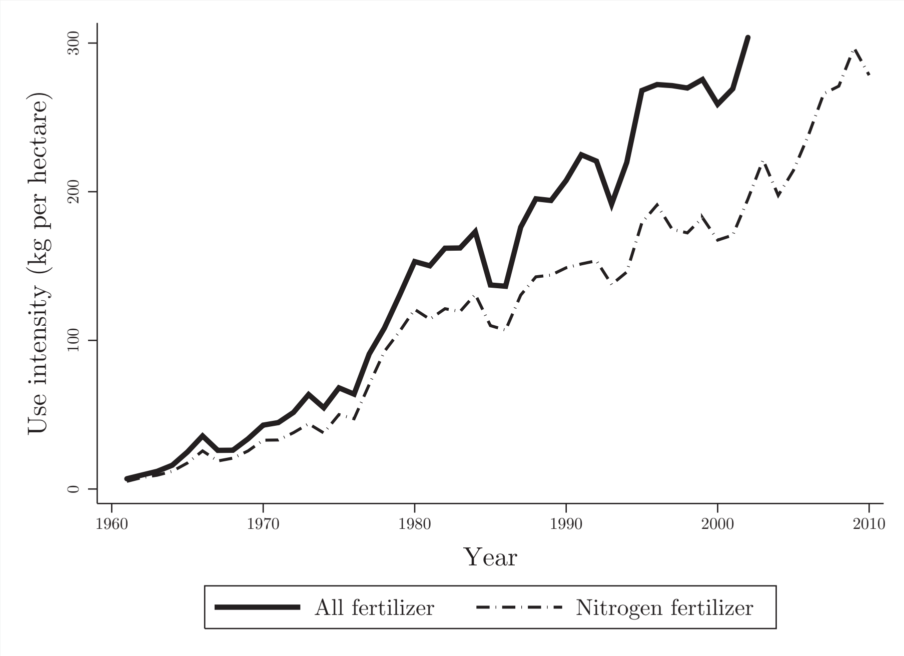
As mentioned by Fan (1991), chemical fertilizer was a huge factor in the fast agricultural growth up to the 1980s. Its impact has however diminished greatly since then. Tian and Wan (2000) shows that in the mid 1990s, even though the output elasticity of fertilizer was still quite high in wheat production with a value of 0.3, the impact on maize was already very small at 0.035. In a review of other studies by Chen et al. (2003), we can see that the marginal effect of fertilizer is quite small or negative, while Zhen et al. (2006) find that nitrogen use is not a significant factor in determining crop yield. Piotrowski (2009) comes to the conclusion that the marginal effect of fertilizer is not statistically significant in wheat production. This is contradictory to the earlier finding by Tian and Wan (2000) on wheat. However, the study by Piotrowski was conducted in mid 2000s, a difference of 10 years from that of Tian and Wan. Thus, it is possible that fertilizer has since lost its marginal effectiveness in wheat production as well. Despite the reduction in the impact of fertilizer, the use intensity of this input remains very high in China. As illustrated in



Source: FAO (2011)

Figure 1.2: Total fertilizer use in China from 1960 to 2010

Figures 1.2 and 1.3, other than a few short-term dips in some years, both total fertilizer use and fertilizer intensity per unit of land are on a growing trend from 1960 to 2010. This rise applies to nitrogen fertilizer as well as the sum of all fertilizer.



Source: FAO (2011) and own calculation

Figure 1.3: Fertilizer use intensity in China from 1960 to 2010

A reason for this high application rate is the favorable policy towards fertilizer producers that helps to drive the price down and encourages fertilizer usage. There is no direct subsidy to farmers for fertilizer use. However, according to a report on the real cost of nitrogen fertilizer in China, both the energy and transportation costs of fertilizer manufacturers are subsidized. In the case of transportation, these manufacturers pay on average 70% less than those from other chemical industries. They are also not required to pay the value added tax, which has a standard rate of 17%. In a cross-country comparative study, the same report also mentions that there are almost 1,000 different manufacturers of nitrogen fertilizer in China, with an annual average production of 20,000 tons. Among them, only 26 are big manufacturers who produce more than 300,000 tons, while there are 800 of them who produce less than the industrial average of 20,000 tons per year. In comparison, other big producing countries such as Russia has about 35 nitrogen fertilizer manufacturers in total and USA has about 50. Their average annual production levels are 400,000 tons and 300,000 tons, respectively. The favorable conditions for the fertilizer manufacturers in China mean that even the small-scale producers who have low expertise and are inefficient can also survive in the industry (Cheng et al., 2010). In addition, the big number of manufacturers makes quality control of the products at markets even more difficult.

1.2 Fertilizer quality

In the first six months of 2011, the Chinese authority found USD 23.5 million worth of fake or poor quality agricultural inputs such as seeds, pesticides, and fertilizers in the country (Wang, 2011). There are signs that the problem has worsened, as in 2012, the value was at USD 47.22 million from the first half of the year (Deng, 2012). On the level of household survey, Boeber et al. (2009) analyzed 14 samples of fertilizer from five villages in the southern part of Hebei province. They find that 12 of them have less nitrogen than that labeled on the package with the average reduction at about 20%. We conducted a survey ourselves in the same province in 2012, collected fertilizer samples from the households, and had the samples tested in a laboratory. Figure 1.4 shows the test results in an ascending quality order. They correspond to 86 surveyed households. As we can see, the fertilizer from most of the surveyed households

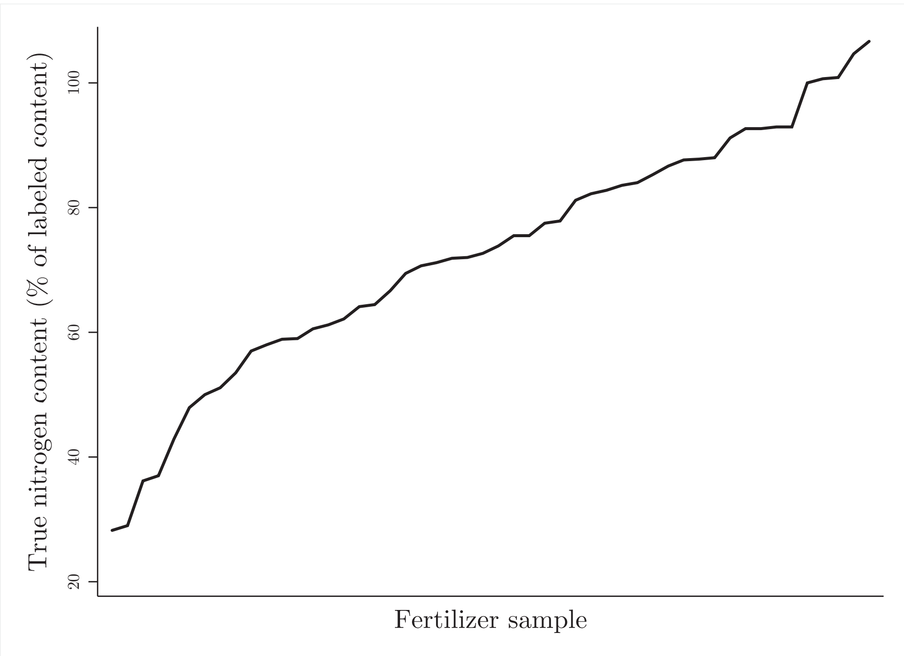


Figure 1.4: Percentage of labeled nitrogen content that is found in the fertilizer of Disituan, Hebei province

does not have the full nitrogen amount as labeled on the package. The average sample contains only 71% of the labeled nitrogen, which means that 29% of the nitrogen content is missing.

This fertilizer quality issue is not confined to China alone and the same incident has been reported in other countries of various regions as well. According to a study by the Soil Research Development Institute in Bangladesh, the percentage of questionable fertilizer in the country ranges from almost zero for urea to a very high 87% for the nitrogen-phosphorus-potassium (NPK) composite fertilizer (Zahur, 2010). In Tanzania, the Ministry for Agriculture, Food Security and Cooperatives found fertilizer samples that have been mixed with cement and salt. The costs of cement and salt are five to more than ten times lower than that of fertilizer, thus it is a lucrative business for the counterfeiters (Mwakalebela, 2012). A country-wide inspection in Vietnam uncovered substandard fertilizer in 45 provinces. There were 1,390 violation cases across the country and 917 tons of fertilizers were confiscated in the first half of 2012 (Phien, 2013). Similar problems on fertilizer quality have also been found in Cambodia (Hamaguchi, 2011), Kenya (Waitathu, 2013), Nigeria (Liverpool-Tasie et al., 2010), and Zambia (Mwebantu New Media, 2012).

1.3 Conceptual framework and outline of the dissertation

In view of the widespread issue, this dissertation research focuses on agricultural input quality, notably fertilizer, and its effects on efficiency, wealth, and use intensity.

Research topic 1. *Efficiency*

Question 1.1. How does fertilizer quality affect the estimation of production function and output elasticity of fertilizer?

Question 1.2. What is the impact of fertilizer quality on technical efficiency?

Research topic 2. *Wealth*

Question 2.1. How does the difference in wealth level among the farm households affect their fertilizer use decisions?

Question 2.2. What is the impact of fertilizer quality on this wealth effect?

Research topic 3. *Use intensity*

Question 3.1. What is the link between the perceived fertilizer quality by farmers and the true nutrient content?

Question 3.2. How do these two different measurements of fertilizer quality affect use intensity?

Section 1.1 of this chapter explains how efficiency contributes to agricultural growth, which then leads to economic growth in general (Fan et al., 2003). This emphasizes the importance of our first research topic, the study on efficiency. Regarding the second topic, there are studies showing that income inequality in rural China is increasing, and has worsened in the second half of 1990s (Benjamin et al., 2005; Ravallion and Chen, 2007). However, Rozelle (1994) and Ravallion and Chen (2007) find that the growth of the agriculture sector has helped to reduce income inequality. Being able to identify the direction of wealth effect in fertilizer use is important for the research on equity. For example, if the wealth effect is positive, it means that the rich is using more of the input than the poor. Assuming that a higher level of input leads to greater output and income, this increases the gap between the rich and the poor. Thus, there is a rise in income inequality, or in other words, a reduction in equity. Finally on the topic of environment, Section 1.1 mentions the leaching of fertilizer into groundwater causes nitrate pollution and health issues. There are also studies showing the negative impact of fertilizer overuse on the environment in China (He et al., 2007; Zhang et al., 2008a,b; Shen et al., 2009; Liu et al., 2013). Therefore, the three aspects that we look at - efficiency, wealth, and use intensity - form a part of the ideal of economic growth, equity, and environmental protection. The conceptual framework is summarized and illustrated in Figure 1.5. Among the different types of agricultural inputs, recent news reports indicate that besides fertilizer, there are problems with the quality of other purchased inputs as well, such as seed (Wang, 2011; Tambwe, 2013) and pesticide (Fishel, 2009; Henshaw, 2011). Even though we focus on fertilizer in our analysis, some of the methodology presented here can also be used to study the impact of questionable quality in other inputs.

For each of the three topics of our research, we start by constructing a theoretical model that captures the problem at hand, and postulates empirically

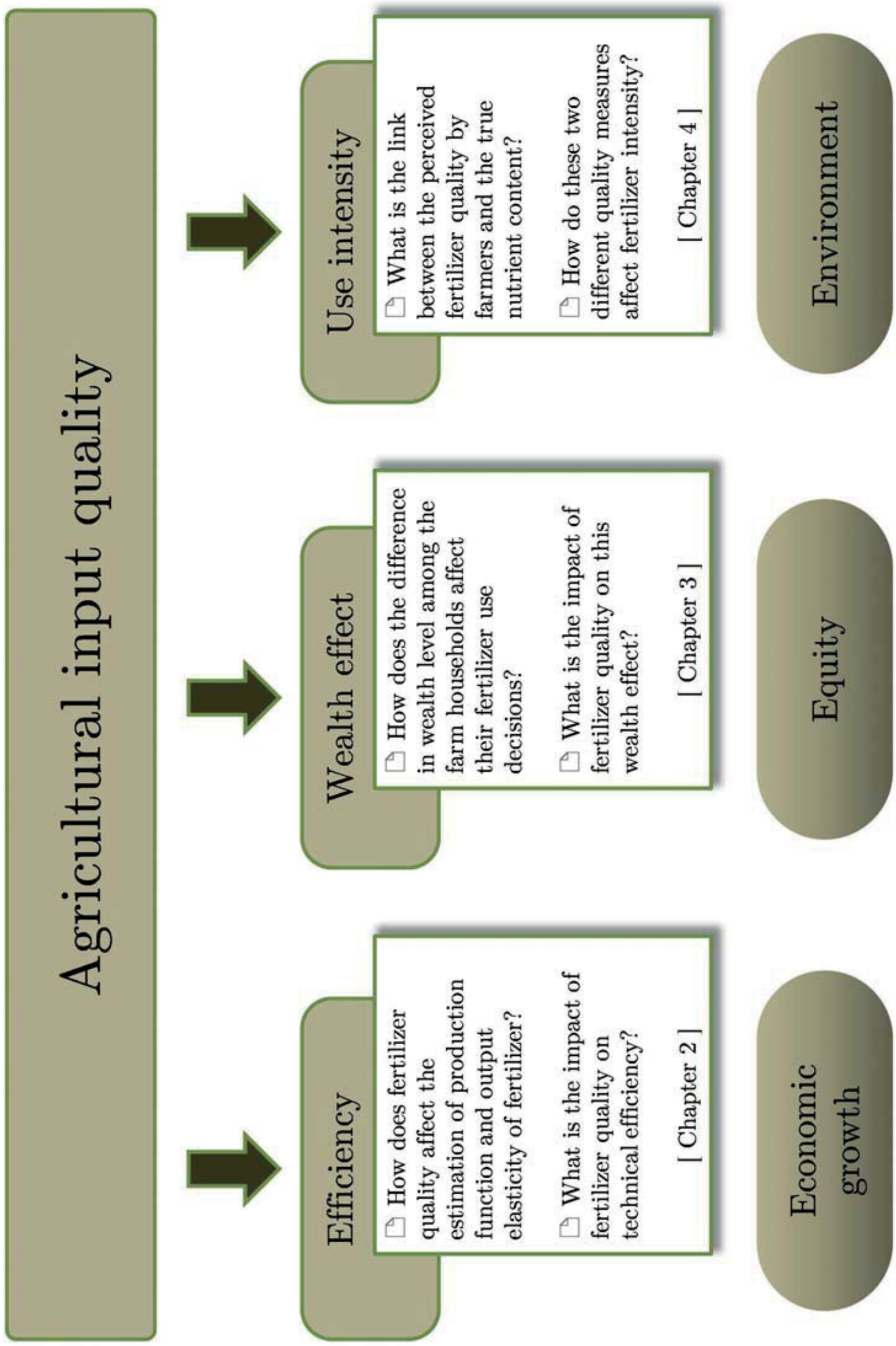


Figure 1.5: Conceptual framework of the dissertation

testable hypotheses. These models are based on theoretical work by others but with elements added to reflect the situation of our study. We then construct an econometric model to test the theory-driven hypotheses. Both the theoretical derivation and empirical results help to further our understanding of the issue. There are two main datasets for the empirical section of our research. The first is a panel dataset of a household survey in Hebei province conducted by the Research Center for Rural Economy (RCRE) of China. It covers a period of five years from 2004 to 2008 (Ministry of Agriculture, 2010). The second is a survey that we conducted in 2012 in the Quzhou county of Hebei province.

On the issue of efficiency, we are interested in the question on how the reduction in fertilizer quality affects both the estimation of output elasticity for fertilizer, as well as technical efficiency of the production as a whole. In Chapter 2, we incorporate the fertilizer quality term into the stochastic frontier model of Aigner et al. (1977), and derive an expression that captures the estimation bias in output elasticity and technical efficiency if we were to ignore the lower fertilizer quality. For the empirical analysis, we apply the method by Battese and Coelli (1995) on the RCRE data to estimate a maize production function of Hebei province. As the RCRE dataset does not have information on fertilizer quality, we use Monte Carlo simulation to generate the quality variable for different scenarios, such as whether the distribution of fertilizer quality is household-specific over the years or totally random. We then examine the impact of fertilizer quality on output elasticity and technical efficiency under each of these scenarios.

Analysis of how the wealth levels of farmers affect their fertilizer use decisions is a common theme in the literature (Kaliba et al., 2000; Lamb, 2003; Abdoulaye and Sanders, 2005; Ariga et al., 2008). However, the direction of this wealth effect is not clear, as some studies find that the effect is positive (Lamb, 2003; Abdoulaye and Sanders, 2005), while others conclude that it is insignificant (Kaliba et al., 2000) or negative (Ariga et al., 2008). We analyze this issue in Chapter 3 from another, new angle, by including uncertainty into the decision making. Where does the uncertainty come from? In our research region where fertilizer use is very common, this uncertainty could be due to the true content of fertilizer not matching that labeled on the package. Poor quality fertilizer creates uncertainty because farmers are not sure whether the fertilizer they use is good or bad. In other places with less widespread fer-