ESSAYS ON FOOD SECURITY

BY

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DISSERTATION

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ABSTRACT

My three dissertation essays explore food security questions in Ethiopia, Philippines and India. Specifically, I estimate how food security responds to (1) land degradation in Ethiopian highlands, (2) domestic marketing policies in Philippines, and (3) trade protection policies in India. In my first paper, I merge environmental maps with geographically coded farmer survey data in Ethiopian highlands to estimate the effect of land degradation on the value of agricultural production. Because land degradation may be endogenous to agricultural production choices, this analysis explicitly controls for endogeneity using bequests and type of energy used for cooking as instrumental variables. I find that land degradation reduces agricultural value by 4 percent, which is smaller than when endogeneity is not accounted for. I also generate a differential impacts map based on the estimates from the spatial weighted regression. By identifying those regions or sectors of Ethiopia most at risk of losing agricultural value from land degradation, this paper provides important information for targeting conservation measures. My second paper examines the effect of government grain procurement and distribution in the Philippines. I use a structural Vector Autoregression model to estimate impacts of policy shocks on market prices and then use the estimates simulate 'no policy' prices. I compare the simulated 'no policy' prices with actual historical prices. I find that government activities have a very small impact on rice price levels and variability. Specifically, I find that the government's activities only impacted food prices during the small number of years when the country was self-sufficient in production. Finally, in my third paper, I examine how trade policies, specifically export bans, affected domestic rice and wheat market integration in India. I verify that Indian markets maintain segmented equilibria by testing for and finding thresholds in a Threshold Vector Error Correction Model. More specifically I find that export bans may have had have had unintended consequences of increasing domestic price differences thereby resulting in the lack of domestic market integration. Since the decisions to use these blunt instruments are taken by domestic governments worldwide, studying the domestic effect of these policies has the potential to affect the use of these policies by other countries in the future.

To God be the glory.

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Chapter 1

INTRODUCTION

"The quest for food security can be the common thread that links the different challenges we face and helps build a sustainable future." – José Graziano da Silva, United Nations Food and Agriculture Organization (FAO) Director-General

Food security[1] is a stated objective of agricultural policy in many countries – be they rich, poor, importer or exporter. FAO projections show increasing pressure on the environment from increased population and food production demands (FAO, 2000). Furthermore, increased environmental constraints have induced food price volatility, spurring increasingly interventionist commodity policies (SOFI-FAO, 2006). My research clarifies the roles of environment and policy as drivers of food insecurity at a time when environmental crisis have heighted awareness of sustainability concerns and food price volatility has encouraged policy based market distortions.

My three dissertation essays explore food security questions in Ethiopia, Philippines and India. Specifically, I estimate how food security responds to (1) land degradation in Ethiopian highlands, (2) domestic marketing policies in Philippines, and (3) trade protection policies in India.

Examining the three very different kinds of issues and dimensions of food security broadens the scope of my work. In addition, these countries have different levels of food insecurity. The typology of food security (Yu, You and Fan, 2010), classifies Ethiopia as lowest

[1] Food security refers to a household's or country's ability to provide future physical and economic access to sufficient, safe, and nutritious food that fulfills the dietary needs and food preferences for living an active and healthy lifestyle (FAO Agricultural and Development Economics Division, 2006). The three facets of food security are food availability, food access and food use (World Food Summit, 1996).

food security, India as low food security and Philippines as lower middle food security. This is consistent with the rankings of FAO's SOFI (2011). The differences in the natural resources and government policies through food price controls and trade protection means they may respond differently to food price shocks. Thus, the diversity of rankings of undernourishment in these countries plus the biophysical, economic and political environment strengthens the information this study provides.

A large proportion of the hungry are concentrated in areas that are highly vulnerable to environmental degradation and climate change (FAO, 2006). Agricultural extensification in most developing countries is caused by population pressure and food scarcity. Farmers are driven to overgraze fragile rangelands and forest margins, threatening the very resources upon which their livelihood depends. In my **first paper**, I estimate the effect of land degradation on the value of agricultural production in Ethiopian highlands. Ethiopia's population largely relies on agriculture as its primary source of income and the country has one of the highest rates of soil erosion in the world. While land degradation is widely recognized as reducing agricultural potential, few studies have explicitly measured its effects on the value of agricultural production. This study integrates a fine resolution environmental map with a geographically coded farm household survey to compare production, farm characteristics, and an index of land degradation that captures soil, water and ecological quality. Unlike much previous work, I explicitly control for potential endogeneity and account for the spatial nature of the land degradation process. I also use the estimates from the regression to generate a map of differential impacts of land degradation. By identifying regions of Ethiopia most at risk of losing value of agricultural production from land degradation, this paper provides important information to policy makers to target soil conservation measures.

A large literature emphasizes the role of policy, rather than the environment, in exacerbating food insecurity (Andersen, 2012). In the Philippines, rice is the most important food crop, and thus, the government has made numerous attempts to influence its price. In 1972, the Philippine government established the National Food Authority (NFA) to ensure continuous supply of rice at stabilized prices through domestic stocks and import controls. The NFA's activities have received criticism but there has been little empirical work on its effectiveness. My **second paper** provides a better understanding of the past impact of the NFA and also informs the debate about an appropriate future role for the NFA. I estimate the effects of the NFA on rice prices using a structural vector autoregression (VAR) model and monthly data from January 1990 to January 2013. While I provide exclusion restrictions to make the model identified, I also verify my restrictions through a data-determined approach using PC algorithm and Directed Acyclic Graphs. I use the estimates from the regression and simulate price paths for the counterfactual (i.e. prices had there been no NFA intervention) and compare with historical prices. By doing so be able to determine how much the NFA's price setting activities have impacted market prices.

Agricultural export restrictions have been seen by many as worsening food price volatility, and pushing up world prices, to the detriment of poor consumers in developing countries (Anania, 2013). At the same time, others have argued that these measures can help safeguard domestic food security. In my **third paper**, I empirically estimate how the Indian export ban affected the integration within the domestic market. Threshold cointegration model is used to characterize integration between selected wheat and rice markets in India over the period of trade protectionist policies. Since the decisions to use these blunt instruments are taken by domestic governments worldwide, I believe that studying the domestic effect of these policies has the potential to affect the use of these policies by other countries in the future.

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Chapter 2

MAPPING THE DIFFERENTIAL IMPACTS OF LAND DEGRADATION ON VALUE OF AGRICULTURAL PRODUCTION IN ETHIOPIAN HIGHLANDS

2.1 Introduction

Land degradation is a major constraint to growth and development, particularly in low-income countries (Rosegrant and Ringler, 1997; Raina et al., 1991). Land degradation is defined as a decline in the productive capacity of the land which includes not only the soil resource, but also the water, vegetation, landscape, biodiversity and microclimatic components of an ecosystem needed to produce environmental services (Scherr and Yadav, 1996). Productivity on up to three-quarters of the world's agricultural land is reduced due to land degradation (IFPRI, 2000).

Ethiopia has the highest rate of soil depletion in sub-Saharan Africa with 42 tons per hectare eroding each year on cultivated land (Stoorvogel and Smaling, 1990; Pender et al., 2001). A substantial literature explores the causes of land degradation in Ethiopia. The causes include climatic effects such as soil desertification due to reoccurring droughts, unsustainable farm practices such as deforestation, overgrazing and extensification, lack of investment capacity, delayed returns on investment, and lack of inputs and information (Viste et al., 2012; Descheemaeker et al., 2011). The source of household cooking energy is another important factor in land degradation. While the use of fuel wood for cooking energy has led to deforestation, the use of dung and crop residues reduce organic matter and soil cover which eventually impacts soil fertility (Gebreegziabher et al., 2006 & 2008). Land degrading activities may also be exacerbated by the changing patterns of land ownership among ethnic groups (Berry

2003). Frequent land redistribution leads to tenure insecurity thereby reducing the incentive to engage in land conservation practices.

Estimates of the cost of loss of soil and essential nutrients in Ethiopia range from $139 million to $7 billion annually (Bojo and Cossells, 1995; Suttclife, 1993; Berry, 2003; Sonneveld 2002). Even the lower estimates amount to 3-4 percent of agricultural GDP, which is a substantial income effect in a country where 85% of the rapidly growing population depends on agriculture (Berry 2003). Dreschel and Gyiele (2001) estimate a range of losses from soil degradation using nutrient studies in areas of high and low nutrient loss. The estimated total loss per hectare per year varies from 400 birr ($46) in areas of low nutrient loss to 4,736 birr ($544) in areas of high soil nutrient loss. In the regions most affected by soil erosion, this loss amounts to about 10 to 12 percent of the agricultural GDP. The costs of land degradation are not only financial. Land degradation also leads to reduced biodiversity and stream sedimentation affecting water quality, storage and marine resources (Scherr and Yadav, 1996). The wide range of estimates reflects substantial uncertainty of the impact of land degradation on agricultural production.

In contrast to previous studies, I find that land degradation reduces agricultural value by 4 percent, which is smaller than previous studies for three reasons. First, I account for farmer's behavior. The previous studies rely on crop simulations with limited data on farm and farming practices and only measure the direct costs of soil erosion on yield which likely overestimate the effect of land degradation since they assume farmers will not respond to deteriorating soils by choosing new crops or new technologies. Second, unlike much previous work, this study recognizes the endogeneity of land degradation; which if not addressed, potentially leads to biased estimates of the effect of land degradation (see Nkonya et al., 2008; Lipper and Osgood, 2001 for an exception). Finally, I account for heterogeneity by merging the large and comprehensive cross-sectional farm-level data with a fine resolution environmental map enables me to represent the vast agroecological and socio-economic diversity of Ethiopia (Deressa, et al., 2008). Previous authors use more aggregate scales of data at the county or state level (Schlenker, et al., 2006; Mendehlson et al., 1994), despite there being substantial farm-level variation in productivity and returns (Kirwan, 2007).

To further improve the efficiency of the estimates, I account for the spatial nature of the land degradation process in the regression and project the differential impacts on a map based on the parameter estimates (Anselin, 1988). The results are valuable to policy makers in developing site-specific plans to target aid or extension to areas where value of agricultural production is most at risk of decline due to land degradation. This paper not only provides a new estimate of the effect of land degradation for Ethiopia but also demonstrates the feasibility of a method matching comprehensive environmental characteristics to farm survey data that can be applied to other countries as well.

2.2 Literature Review

Large simulation models are often used to predict the effect of the environment on crop growth and agricultural productivity. Examples of large-scale simulation models include Decision Support System for Agro-technology Transfer (DSSAT) by Nelson (2009), Agro-PEGASUS by Deryng et al. (2009) and Future Agricultural Resources Model (FARM) by the Economic Research Service of the Department of Agriculture. DSSAT simulates the impact of climate change on global food availability and malnutrition while Agro-PEGASUS simulates growth as a function of temperature, soil moisture and fertilizer level. FARM, on the other hand, projects the effects of rainfall and temperature on agricultural productivity through a computable general equilibrium (CGE) model of the world agricultural economy. The advantage of the biophysical crop growth simulation approach is that the crop varieties and fertilizer applications can be fixed and the productivity effects can be simulated to generate large-scale estimates with little data. A limitation of this approach is that these models assume that farmers do not change their crop and technology choice in response to changes in resource availability or climate (Hertel and Rosch, 2010). Moreover, crop simulation relies on data from agronomic experiments which may not be replicable on a country-wide scale. Mendelsohn et al. (1996) stress that since agronomic experiments are set up in a controlled environment, they fail to account for farmer adaptation leading to overestimation of the sensitivity of crops to environmental changes.

An alternative to the crop simulation method is to estimate statistical relationships between crop yields and environmental changes such as temperature, rainfall and/or soil erosion either based on cross-sectional, time series or panel data. This method can be readily implemented for large geographic areas, implying that it can be applied at a national or global spatial resolution (Hertel and Rosch, 2010). However, in most regions of the world, time series on yields and climate are limited in length. The limited data results in large standard errors and significant uncertainty about the likely impacts of environmental changes on yields.

Attempts have been made to analyze the vulnerability of Ethiopian farmers to environmental shocks in studies using panel datasets. For example, Dercon (2004), Dercon et al. (2005), Dercon and Krishnan (2000) and Skoufias and Quisumbing (2003) analyze vulnerability of Ethiopian farmers using a repeated household level survey in 15 villages. However, longitudinal data are hard to find and researchers often end up with a small sample. Deressa et al. (2009) stress that while these studies are informative and methodologically sound, the use of a small data set reduces the ability to represent the vast agroecological and socio-economic diversity of Ethiopia and limits the ability to compare vulnerability of specific regions.

Mendelsohn et al. (1994) propose a Ricardian Approach which uses cross sectional data to estimate a hedonic model of farmland pricing. This model is based on the notion that a tract of land capitalizes the discounted value of all future profits or rents that can be derived from the land (Mendehlson et al., 1996; Schlenker et al., 2006). The advantage of the Ricardian method is that it relies on cross sectional variation to estimate the effect of climate on future land rents, while allowing for the implicit choices of landowners regarding the allocation of their land among competing uses instead of directly modeling farmer decisions.

However, in most developing countries land markets are not well developed and the observed land value may not reflect future agricultural productivity. For example, Ethiopia's long history of land redistribution may reduce willingness to pay for land, leading to an underestimate of land value (Ahmed et al., 2002; Holden and Yohannes, 2002; Jayne et al., 2003). Land rights and security may also influence land management and productivity by affecting farmers' access to credit (Place and Hazell 1993; Pender and Kerr, 1998). For this study, instead of land values, I measure the effects of land degradation on the value of agricultural production per hectare. I calculate the value of agricultural production from crop yields, livestock and forestry timber production expressed in average market prices regardless whether the household consumed the agricultural produce, held back the output for future seeding purposes or sold the produce in the market.

2.3 Theoretical Framework of Agricultural Value of Production

Given the nature of household agriculture production, this paper assumes that farm households in Ethiopia are likely to be both consumers and producers. Thus, I assume that farmers maximize the net value of their agricultural production, $V_{h,k}$, rather than profits directly. Optimal land management will require a farmer to consider returns to each activity and the competing demands that they place on the land (Graff-Zivin and Lipper, 2008).

Suppose that production function in any given period is equal to a function of inputs (x), environmental characteristics (e) and land degradation (d): $f(x,e,d)$. Farmers choose the combination of inputs that maximizes their potential returns given their production function, and that production function is altered by land degradation. Let p_a represent the market price per unit of agricultural output. For simplicity, I will also assume that this price represents the per unit value of agricultural output consumed by the farmer.

The value of agricultural production associated with the k^{th} use of land $(k=1,...,N_k)$, in household *h*, can be expressed as,

$$V_{h,k} = p_a.f(x,e,d) - C_{h,k} = \tilde{\pi}_{h,k}(p_a,\omega_i,e,d,y_h) - C_{h,k} \qquad (2.1)$$

where $C_{h,k}$ represents the fixed costs of production and the term $p_a.f(x,e,d)$ represents the profit for all the farm produce had they sold everything in the market, $\tilde{\pi}_{h,k}(p_a,\omega_i,e,d,y_h)$.

The value of agricultural production depends on several factors which include a vector of output prices $(p_1,...,p_{nk})$, a vector of input prices ω_i , a vector of costs $C_{h,k} = (C_{h,1},...,C_{h,nk})$ and exogenous environmental quality e and the variable of interest d. Farm and farmer characteristics, y_h, such as distance to market and other facilities, land tenure characteristics (Pender et al., 2003; Huffman and Fukunaga, 2008; Berry, 2003), farmer's education, gender, assets and income (Weir, 1999; Kiome and Stocking, 1995; Molua, 2011; Liverpool and Winter-Nelson, 2010) also affect value of agricultural production.

Neighboring farms could affect a farm household's practices (Evenson, 1989; Bantilan and Davis 1991). I employ a theory-driven approach in incorporating the neighborhood effects of farming (Anselin, 2002). Past literature has used the spill-over effects as a structure for this kind of spatial correlation (Durlauf, 1994; Borja, 1995; Glaeser et al, 1996). I modify equation (2.1) to take into account the characteristics of nearby farmers, in as much as they are likely to affect the agricultural productivity of their neighbor. Spatial spill overs can be incorporated by including a spatially lagged dependent variable as an additional predictor or by premultiplication of spatial weights matrix W to the variable of interest.

$$V_{h,k} = \tilde{\pi}_{h,k}\left(p_a, \omega_i, e, d, y_h\right) - C_{h,k} + W\left[V_{h,k}^{-1}\right] \qquad (2.2)$$

where $V_{h,k}^{-1}$ denotes the neighboring farms. Equation (2.2) represents the returns associated with the k^{th} use of land for a given farm household and includes the term $W\left[V_{h,k}^{-1}\right]$, the spatially lagged dependent variables with weights matrix *W,* denoting neighboring farms.

2.4 Identification Strategy

In equation (2.2), one might expect land degradation, d, to be endogenous. The quality of the environment is influenced by the choice of agricultural inputs and farm investment decisions. Moreover, agricultural input and farming decisions are a function of the socio-economic situation of the farmers, and in turn the socio-economic situation of farmers depends on crop output. This effect represents the "complicated feedback loop" between farm production and resource quality (Lipper and Osgood, 2001). To estimate this measure, I use an instrumental variables approach detailed in the following section.

One might also expect that input and investment choices are also endogenous. Choices such as what to plant, what inputs to use and whether to adopt soil conservation measures may depend on unobserved farmer and plot characteristics. In this paper, I adopt the assumption made in Ricardian models that farmers put their land to its best, or most profitable use. Typically farmers know environmental characteristics of specific fields such as soil type, slope, elevation and temperature among other things as given and adjust their inputs and farming practices accordingly. Moreover, I recognize that farmers likely face credit constraints or other barriers, but as long as all farmers in the sample face similar constraints, the approach should lead to unbiased estimates. To consider this problem I examine the range of agricultural technologies used in the sample and compare it with the Atlas of Ethiopian Rural Economy. I find that the vast majority of farms use the same technology, indicating that if credit or other constraints affect farm production choices, those constraints appear to affect all farmers equally.[2] Because of

[2] The statistics from the farmer survey are consistent with the Atlas of Rural Ethiopian Economy, which indicates that my sample is representative of farm practices in Ethiopia. The IFPRI farmer survey data show very little variation in crop and technology choice. The vast majority (92.44%) of farm households plant cereals and grains i.e. barley, maize, millet (mashilla), wheat (duragna), teff and sorghum; whereas the Atlas reports that cereals and pulses are the main crops. I also observe very little variation in production technology in the survey. The vast majority of farms (95%) are rain-fed and only 26 out of 1,000 households have water pumps. Atlas reports that agriculture is mainly rainfed with minor use of a gravitational irrigation system. The IFPRI survey shows that farm tools and machinery do not greatly differ across farms. Only 14

the great homogeneity in production choices and potential endogeneity of technology, I do not include specific crop and technology choices in the analysis.

2.4.1 Instrumentation for Endogenous Land Degradation

Very few studies of land degradation use an instrumental variable approach because finding a good instrumental variable for land degradation is often difficult. A few studies use terms of trade weighted by agricultural production (Lipper and Osgood, 2001), land ownership and ethnicity (Pender et al., 2003) and the type of land contracts (Huffman and Fukunaga, 2008). In this paper, I explore intergenerational bequest and the farm household's main source of household energy as possible instrumental variables.

I argue that if the farmer inherited his land from his ancestors, he is more likely to want to pass it along to his children, and to pass it along in good condition. Other authors show that in Ethiopia, corporate and rented farms tend to use up soil faster than intergenerational family farms because of greater incentive for soil conservation (McConnell 1983; Rola and Coxhead 2001). Thus, I explicitly use the interaction of number of children and dummy variable whether the farmer inherited the land from their ancestors as the bequest variable.

In Ethiopia, household cooking energy sources include the use of fuel wood, animal dung, LPG, kerosene or electricity. The use of fuel wood leads to deforestation and land degradation. The lack of nearby fuel wood sources causes many households to switch from fuel wood to animal dung for cooking and heating purposes. However, this substitution strips away nutrients and disturbs the topsoil which can cause land degradation as well (Gebreegziabher et al., 2006). I

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farm households out of 1,000 own heavy machinery, i.e. tractors, ploughs and trailers. According to the Atlas, 83% of the farmers use of maresha with oxen as the preferred draft animal for soil cultivation and 94.16% do not use any improved seed variety. Approximately 83.93% of farmers have already adopted soil conservation practices in their farm. These practices include fanya ju (terraces) and any combination of soil, stone and wood bunds. The combination of fertilizer and chemicals does not vary much either. Fertilizer use is characterized by the use of urea, manure and DAP (Diammonium Phosphate). Nine out of 10 (91.8%) of farmers use 2-4D herbicide. Thus, the assumption of homogeneity of farmers is supported by the survey data and consistent with the published Atlas of Rural Ethiopia.

posit that farm household's source of energy for domestic use directly affects land degradation but not agricultural value of production.

In finite samples, the results of estimation with weak instruments can be more biased than ordinary least squares (Deaton, 1997). I test the relevance of the excluded instruments (Bound et al., 1995). I also further test the validity of my restrictions by comparing the OLS and IV models using the Hausman (1978) specification test and I investigate the robustness of the regression results to estimation by OLS, IV and reduced form (RF) approaches.

2.4.2 Challenges to the Identification Strategy

One might be concerned that intergenerational bequest may be directly related to the value of agricultural production. Farmers who have tenure security may have more incentives and access to credit to invest in technologies that reduce land degradation. To resolve this issue, I explicitly control for land tenure in the second stage estimation. In addition, I explicitly control for number of children in the estimation as well, thus using only the interaction term as my instrument. Second, one might be concerned that those households who use fuel efficient cook stoves are wealthier, thus that my instrument might pick up a wealth effect. To control for wealth, I include a measure of current value of assets including farms tools and machinery and other measures of wealth such as value of livestock, gift income and aid received separately in the regression.

2.4.3 Addressing Spatial Patterns in the Data

Finally, in my conceptual framework, I argue that land degradation is spatial in nature and spatial autocorrelation should be accounted for. I test for the presence of spatial autocorrelation using the Moran's I Index (Anselin, 2002). It is worth noting that spatial autocorrelation should be included only after endogeneity is corrected. If the spatial autocorrelation is due to unobserved variables, then this is a valuable technique to improve parameter estimates.

2.5 Data Sources and Description

This study is based on two data sets: the Global Land Degradation Information System (GLADIS) data provided by Food and Agriculture Organization (FAO) and household survey in Ethiopia from International Food Policy Research Institute (IFPRI). These two data sets are combined based on spatial location.

I extract soil type, slope, irrigation intensity, and land degradation data from GLADIS. In GLADIS, the geographic areas are divided into fine resolution grids of 0.05 degrees, or 5 arc minute km per grid cell (9x9 km). I generate dummy variables for certain types of soil. Slope is a continuous variable. Irrigation intensity represents increasing categories of intensity of irrigation: 1 if 0 to 2 percent of the land is irrigated, 2 if 2 to 16 percent of land is irrigated, and 3 if 16 percent or more of the land is irrigated. Data on land degradation are normalized from 0 to 1 and represent the average value for years 1981-2003, where 0 is the ideal no land degradation scenario.

I extract demographics, farm characteristics and socio-economic data from IFPRI farm household survey. The household survey was carried out in the Nile basin within Ethiopia by the International Food Policy Research Institute (IFPRI) for the 2004-2005 crop year. In addition to the farmer survey, I obtained average rainfall data and temperature for 2004-2005 from the IFPRI water research team's Climate Research Unit of East Anglia database.

The survey covered five major regions. Amhara is the biggest region in the Nile basin of Ethiopia, covering 38 percent of the nation's total land area, followed by Oromiya (24 percent), Beneshangul Gumuz (15 percent), Tigray (11 percent), and Southern Nation, Nationalities and People's Region (SNNPR) (5 percent) (Ethiopian Ministry of Water Resources, 1998; Kato et al, 2009). The final dataset contains 1,000 households. Each household is geocoded, a feature of these data that has not previously been used.

I generate the value of agricultural production variable using IFPRI data instead of yield because some plots may produce more than one crop, feed livestock or have forest. Thus, estimation of a single measure of production is difficult. This approach of aggregating all earnings from crops, livestock and forest products on a plot into a single measure of value of crop production has been used in many previous studies in Ethiopia and sub-Saharan Africa (Kato et al, 2009; Pender et al, 2001; Nkonya et al., 2008). Value of agricultural production is the sum of the total production regardless of whether the produce is consumed at home, sold in the market or held back as seed for next year's crop. To get total farm production, I add all of these uses and subtract the post-harvest and pest losses and then multiply the result by the market price farmers faced divided by the total hectares of land devoted for that purpose.

I also derive the instrumental variables from the IFPRI survey. Intergenerational bequest variable was generated by interacting a dummy variable for inherited land and the number of children. I generate a dummy variable for the use of an extracting cooking energy, valued at 1 if the households use fuel wood or animal dung as a source of cooking energy, and 0 otherwise. Table 2.1 presents the summary statistics and definition and sources for all the variables used in the study. More descriptive details on each dataset are found in the appendix.

While I believe the GLADIS data hold great potential for analyses of this sort, these data come with two limitations. First, although the 9x9 km grid size used was relatively fine, the information for that grid may have been derived from larger polygons. An examination of the raw data shows that there is variation in the level of land degradation relative to the spatial distribution of the respondents. The mean arc distance between neighbors is about 5.07 km, with a minimum distance of 0 km and maximum distance of 30.22 km. And about one-third of the sample is more than 9 km apart, implying they must be in different grids. Moreover, using 9x9 km grids is still an improvement from previous studies that use county-level scale environmental data (example Schlenker et al, 2006; Mendelsohn et al, 1994, 1996, 2004). Second, while GLADIS provides detailed cross-sectional geographic information, by its nature, it prevents time-series analysis. Panel data may have been favorable, but I argue that in my case, cross sectional variation is sufficient to isolate expected changes in the value of agricultural production from the variation in soil degradation, which itself is a long-run phenomenon.

I also note a limitation in the IFPRI survey data. While the survey only covers the major agricultural regions in the highlands of Ethiopia, the highlands constitute about 44 percent of the total land area, 45 percent of the total crop area including 88 percent of the total population at an average density of 144 per km^2 and supports 70 percent of the livestock population of the country (Deressa et al, 2008). Thus, I argue that the survey captures some of the key variation within the agricultural sector of Ethiopia. Moreover, the data allow me to conduct my analysis at the farm household level, thus, allowing me to capture spatial heterogeneity and help control for farm household level covariates. Combining the two datasets yields a total sample size of 828. 172 households were dropped because of missing GPS information or incorrect GPS codes lying outside the map of Ethiopia.

2.6 Results and Discussion

Table 2.2 shows regression results: OLS for value of agricultural production per hectare without correcting for endogeneity in first column, OLS for land degradation in the second column (equivalent to first stage of 2SLS) and Instrumental Variable regression for value of agricultural production per hectare in the third column (equivalent to second stage of 2SLS). I calculate the Moran's I statistic to verify whether spatial correlation is present in my data. This model includes a spatially-lagged land degradation variable in the regression, which represents the average land degradation of the four nearest neighboring plots. The spatially weighted IV regression results are in the fourth column.

Without correcting for endogeneity, the estimated effect of land degradation on value of agricultural production is 43.2 Ethiopian Birr or about 8.9% of the average value of agricultural production and is significantly different from zero (1st column, Table 2.2).[3] Note however, that this coefficient might be biased due to endogeneity. The test for endogeneity reveals a Wu-Hausman F statistic of 0.0537, which implies that land degradation is indeed endogenous in the system. Thus, I use instrumental variables.

The second column of Table 2.2 presents the results of estimating land degradation on all the covariates of farm and farmer characteristics. The coefficients on the two chosen instrumental variables (bequest and cooking energy) are significantly different from zero satisfying not only the partial correlation requirement for validity of IVs, but also validating what has been found in the literature. I obtain a Sargan statistic of 0.183 with a chi-square statistic of

[3] Average value of agricultural production per hectare is 482 Ethiopian Birr.

0.7726, which shows that the instruments are statistically valid. The Pagan-Hall test for heteroskedasticity suggests that the disturbance term is homoskedastic[4].

The factors that affect the agricultural value of production are presented in the 3rd column of table 2.2. After controlling for endogeneity, the coefficient on land degradation is -17.18 Ethiopian Birr or about 3.56% of the average value of agricultural production. Compared to the 8.9% result from the OLS regression, the IV results suggest that not accounting for endogeneity will overestimate the impacts of land degradation to value of agricultural production. Unobservables are correlated with both land degradation and value of agricultural production.

If all of the agricultural lands are degraded, the loss for the country as a whole is approximately $262 Million[5]. While much smaller than the upper bound estimate of $7 billion from the crop simulation model, this amount is almost twice the lower bound estimate of $139 million.

Environmental characteristics that significantly affect the value of agricultural production include the Entisol soil type (decrease value of agricultural production), rainfall (increases value of agricultural production) and temperature (decreases value of agricultural production). None of the coefficients on the land tenure characteristics were significant in directly determining agricultural value. The positive impact of access to information through extension agent visits implies that farmers who are more exposed to new ideas and concepts provided by extension agents are able to adjust their production which eventually increases the value of their production (Nkonya, 2008). Farmer demographics that significantly affect value of agricultural production include livestock ownership (increases value of agricultural production), and asset index (increases value of agricultural production).

[4] Test Statistic: 13.923; Chi-Sq P-Value: 0.3793

[5] FAOSTAT Average Value of Agricultural Production in 2004-2005 is $7,483,834,000.

2.6.1 Do neighboring farms affect others value of agricultural production?

I next control for spatial correlation in the value of agricultural production and land degradation. The Moran's I statistic valued at 0.6923 in Figure 2.1 shows the cluster maps and significance map of value of agricultural production which verifies the presence of a spatial correlation. My likelihood ratio test for spatial dependence confirms a positive spatial correlation or a spatial lag model where the value of agricultural production on one farm affects another through land degradation, thus exhibit a "spill-over effect".

In the last column of table 2.2, to deal with the simultaneity of land degradation on own and neighboring farms, I include an instrumented spatially-lagged land degradation variable in the regression, which represents the average land degradation of the four nearest neighboring plots. Note that in this regression, I predict land degradation from the first stage to correct for endogeneity. Including variables about neighboring farms' characteristic does not substantially change my finding that land degradation decreases the value of agricultural production. The marginal effect taking spatial lag into account is 16.75 Ethiopian Birr. However, taking spatial lag into account improves the efficiency of my estimates. Hence, the results for the similar variables in IV regression are the approximately the same but notice that most of the standard errors were reduced increasing the confidence in the new estimates.

The result implies that land degradation not only affects the value of agricultural production directly, but also indirectly by influencing the neighboring farms' value of agricultural production. However, it's not just the externality issue but also the spatial heterogeneity across a landscape. In other words, it matters that slope changes over space, as well as soil type and land cover. Thus, by including spatially weighted characteristics, I can observe both the direct and indirect effects of land degradation.

2.6.2 Robustness Tests

I estimate several model specifications to explore the robustness of my findings. First, one might be concerned about input costs. Average value of agricultural production might be too small if the fixed costs of production are huge, thus, possibly inducing a bias into the estimates. As a robustness check, I run the same regression using net income per hectare as the dependent variable. I find that the estimates did not vary much from the use of agricultural value of production. The marginal effect of land degradation on net income is -17.42 or about 3.61% of the average value of agricultural production per hectare. Second, one might be concerned how land tenure might affect adoption of soil conservation measures so I ran models which include and exclude land tenure measures to see how my variable of interest, land degradation, changes. I find that none of the specifications yield significant coefficients on land tenure variables. Moreover, land degradation coefficients were significant in both equations with very little change in their magnitude. I also include and exclude current value of assets and livestock as one might be concerned that it may influence land degradation. I find that livestock ownership is highly significant in all specifications and the adjusted R squared significantly increases after adding these variables. The coefficient on the variable of interest, land degradation, remains largely unchanged.

Appendix Tables A1 and A2 present the key estimation results for my robustness tests. The different estimation procedures and model specifications did not result in significant changes in land degradation, the variable of interest. I can therefore conclude that the results are generally robust across different models. In all models, I tested for multicollinearity and found it not to be a serious problem for almost all explanatory variables (variance inflation factors <5). The variance inflation factors for each model are presented in Appendix Table A2. Estimated standard errors are robust to heteroskedasticity and clustering (nonindependence) of observations from different plots for the same household.

2.6.3 Differential Impact Maps and Policy Implications

The left panel of figure 2.2 shows the map of differential impacts of land degradation on the value of agricultural production. While the right panel shows markers on which respondents in the IFPRI sample has adopted soil conservation practices. The differential impacts map basically maps the predicted value of agricultural production after running the spatially weighted regression to represent the predicted loss in value of agricultural production from land degradation. This process is similar to multiplying each covariate characteristic's average value with their estimated coefficients. These estimates are then mapped by woreda (district) using ArcGIS by spatially joining the grids to the nearest feature. The map represents the predicted loss in value of agricultural production from land degradation. The darker areas represent those areas where the value of agricultural production is most affected by land degradation. By visual examination, I can clearly see the 'hotspots'. Notice that the small pockets of high impact areas are the also the areas that do not adopt soil conservation practices based on the IFPRI survey data. The differential impacts map allows me to identify regions or sectors in the community that are more susceptible to losses in value of agricultural production due to land degradation and where land degradation has the potential to cause the greatest economic harm. These results can help inform policy makers to target aid, extension and policy to those who need it most.

Since the figure indicates a large degree of heterogeneity in the value of agricultural production lost to land degradation, I deduce that the benefits of conservation policy would be larger with spatial targeting. I estimate land degradation by region and find substantial differences in marginal effects of land degradation by region. Table 2.3 summarizes the marginal effects of land degradation per region. Table 2.4 shows land degradation regressions by region to identify the source of land degradation in each region, so that appropriate soil conservation policies could be designed. Soil types are significant for regions of Amhara, Oromiya and BG suggesting appropriate complimentary input for each soil type. Population density and irrigation are significant for Oromiya and BG. Thus, the results suggest policies to provide subsidies for complimentary inputs such as fertilizers, irrigation projects and provide more agricultural extension to highly populated regions. Moreover, the significance of the instrumental variable on source of energy used in cooking stoves suggests a two-pronged policy to stem deforestation and to disseminate more efficient stove technologies.

2.7 Conclusion

My study estimates the impact of land degradation on the value of agricultural production in Ethiopia using a cross section of farm household data matched to detailed environmental data from a fine-resolution environmental characteristics map to account for farmer's behavioral response and heterogeneity. I use an instrumental variable approach to control for the endogeneity of land degradation.

Controlling for farmer's behavior endogeneity and heterogeneity, I find that land degradation reduces value of agricultural production by 3.56% or 17.18 Ethiopian Birr per hectare. While much smaller than the upper bound estimate of $7 billion from the crop simulation model, this amount is almost twice the lower bound estimate of $139 million. Where 85% of the population depends on agriculture, this loss is substantial.

I also find that the type of fuel used in cooking stoves and bequest variables are good instruments for land degradation. The significance of type of energy used in cooking stoves suggests a two-pronged policy to stem deforestation and to disseminate more efficient stove technologies. The positive bias suggests that unobservables are correlated with both land degradation and value of agricultural production.

This result is consistent with the story that poorer farmers may have more degraded land to begin with and are most at risk from losing from land degradation. To account for the spatial nature of the problem of land degradation, I control for spatial autocorrelation and found significant clustering or spill-over effects. The estimation efficiency was substantially improved by the inclusion of neighboring characteristics increasing the confidence in my estimates.

A limitation of the study is that I cannot take into account the time component of the land degradation process. Nevertheless, the paper demonstrates the vast possibility of analysis one could generate by geographically combining datasets.

The spatial cross sectional analysis of the data implies that the strategies to reduce land degradation's effect on agricultural value of production must be location-specific. The map of differential impacts of land degradation on the value of agricultural production and region wise regressions show substantial heterogeneity in the effect of land degradation, implying that when designing aid and extension, it is important for policy makers to know the areas that are most degraded and areas where agricultural value is at risk to losses in value of agricultural production from land degradation. Moreover, interventions might enjoy greater success if they are tailored to addressing those local characteristics of the land and behavior that induce land degradation.

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2.9 Tables

Table 2.1 Variable Definitions and Summary Statistics

Variable Name	Definition	Source	Mean	Std	Min	Max
Value of Agricultural Production	continuous variable, sum of the total produce regardless of whether the produce is consumed at home, sold in the market or held back for farming purposes less the post harvest and pest losses multiplied by the market price farmers faced in 2004-2005 divided by the total hectares of land devoted for that purpose; Ethiopian Birr/ha	IFPRI	482.414	741.245	0	9325.153
Land Degradation	continuous variable, represents the degree of land degradation, normalized from 0 to 1	GLADIS	0.55844	0.16446	0.06287	0.7502422
Candidates for Instrumental Variables						
Bequest = Inheritance*Children	Interaction term between inheritance as the source of ownership dummy and number of children	IFPRI	1.19203	2.10615	0	10
"Bad" Cooking Energy	=1 if source of energy is animal dung, fuel wood or both, =0 otherwise (LPG, kerosene, electric)	IFPRI	0.65942	0.47419	0	1
Environmental Characteristics						
Aridisol Soil (useless without irrigation)	=1 if Aridisol Type of Soil, =0 otherwise	GLADIS / USDA	0.20531	0.40418	0	1
Entisol Soil (useless without fertiizer)	=1 if Entisol Type of Soil, =0 otherwise	GLADIS / USDA	0.26208	0.44003	0	1
Mollisol Soil (most unproductive soil, dry and sand-like)	=1 if Mollisol Type of Soil, =0 otherwise	GLADIS / USDA	0.23068	0.42152	0	1
Slope	continuous variable in %	GLADIS	4.46981	2.08937	0	8
Elevation	continuous variable in MASL units	IFPRI	2586.62	7836.39	0	220274
Rainfall	continuous variable, Mean Rainfall in 2004-2005, in mm	IFPRI	932.322	201.144	211.142	1216.208
Temperature	continuous variable, Mean Temperature in 2004-2005, in degrees Celsius	IFPRI	19.0347	2.685	14.0061	24.75047
Socio-Environment Characteristics						
Population Density	continuous variable, number of inhabitants per kebele's area	IFPRI	148.368	314.986	0	2578.857
Access to Basic Facilities	continuous variable, average distance in kilometers of farm to roads and bridges and market where they sell output, in kilometers	IFPRI	5.68279	3.90851	0.05	45
Access to Information	continuous variable, number of visit times of entension agents (2004-2005) cropping season	IFPRI	2.14476	4.61522	0	48
Farm Characteristics						
Irrigation Intensity	increasing categories of intensity of irrigation, (1-0 to 2%, 2-2 to 16%, 3->16%)	GLADIS	1.48913	0.99144	0	3
Distance of farm from home	continuous variable, distance of farm from home in kilometers	IFPRI	1.0431	0.69926	0.20263	10.1579

Continued Table 2.1 Variable Definitions and Summary Statistics

Variable Name	Definition	Source	Mean	Std	Min	Max
Land Tenure Characteristics						
Inheritance Dummy	=1 if source of ownership is through inheritance; =0 if government redistribution	IFPRI	0.33213	0.47126	0	1
Land Certified Dummy	=1 if land is certified; =0 not certified	IFPRI	0.18599	0.38933	0	1
Rent Dummy	=1 if land is rented; =0 not rented	IFPRI	0.08454	0.27837	0	1
Sharecrop Dummy	=1 if hh is practicing sharecropping; =0 otherwise	IFPRI	0.28019	0.44937	0	1
Farmer Demographics						
Big Ethnic Group	=1 if member of Oromo or Amhara, =0 otherwise	IFPRI	0.64493	0.47882	0	1
Children	number of children	IFPRI	3.94203	2.24799	0	12
Male headed hh	=1 if male; =0 female	IFPRI	0.89734	0.30369	0	1
Farming Years	continuous variable, number of farming years	IFPRI	23.5664	13.0183	1	68
Asset Index	continuous variable, total current value of assets (i.e. farm tools and machineries)	IFPRI	-0.0462	1.17731	-3.0821	4.827992
Livestock Ownership Dummy	=1 if household owns livestock, =0 otherwise	IFPRI	0.49638	0.50029	0	1
Regional Fixed Effects						
Tigray Region	=1 if household is in the region, =0 otherwise	IFPRI	0.17874	0.38337	0	1
Amhara Region	=1 if household is in the region, =0 otherwise	IFPRI	0.35507	0.47882	0	1
Oromiya Region	=1 if household is in the region, =0 otherwise	IFPRI	0.22585	0.41839	0	1
Benishangul Gumuz Region	=1 if household is in the region, =0 otherwise	IFPRI	0.17995	0.38438	0	1
SNNP Region	=1 if household is in the region, =0 otherwise	IFPRI	0.06039	0.23835	0	1
Neighbor's Characteristics						
Neighbor's Land Degradation	continuous variable, represents the degree of land degradation, normalized from 0 to 1	GLADIS	0.55898	0.1628	0.06288	0.75024

Table 2.2 Regression Results

	OLS without correcting for endogeneity	*First Stage Regression*	*Instrumental Variable Approach*	*Spatially Weighted Regression*
	Value of Agricultural Production per hectare	Land Degradation	Value of Agricultural Production per hectare	Value of Agricultural Production per hectare
Land Degradation	-43.2*		-17.18***	-16.75***
	(23.70)		(9.44)	(7.61)
Candidates for Instrumental Variables				
Bequest	-35.0	-0.00299**		
	(22.91)	(0.0013)		
"Bad" Cooking Energy	-80.8	0.0245**		
	(82.33)	(0.0110)		
Environmental Characteristics				
Aridisol Soil	-124.1	-0.337***	-411.1	-411.1
	(168.20)	(0.0191)	(1058.00)	(1047.00)
Entisol Soil	-298.4**	-0.0985***	-293.12**	-293.12**
	(123.80)	(0.0162)	(123.80)	(119.40)
Mollisol Soil	0.0	-0.234***	-194.1	-194.1
	(155.50)	(0.0191)	(737.80)	(730.10)
Slope	30.4	0.0732***	91.5	91.5
	(35.11)	(0.0039)	(229.60)	(227.20)
Elevation	0.001	-8.06E-08	0.000	0.000
	(0.00)	(0.0000)	(0.00)	(0.00)
Rainfall	-0.2	-7.79e-05**	-0.338	-0.338
	(0.24)	(0.00003)	(0.31)	(0.31)
Temperature	-75.95***	0.0479***	-30.63**	-30.63**
	(24.66)	(0.0028)	(17.50)	(14.00)
Socio-Environment Characteristics				
Population Density	0.152*	-3.30e-05***	0.1	0.1
	(0.08)	(0.000011)	(0.13)	(0.13)
Access to Basic Facilities	4.2	-0.00163**	2.217	2.217
	(6.09)	(0.0008)	(7.94)	(7.85)
Access to Information	11.45**	-0.00317***	8.802*	8.802*
	(5.48)	(0.0007)	(6.10)	(5.98)
Farm Characteristics				
Irrigation Intensity	62.65*	-0.0101**	56.77*	56.77*
	(33.48)	(0.0045)	(47.28)	(41.28)
Distance of farm from home	1.2	0.00376	1.5	1.5
	(34.61)	(0.0046)	(35.86)	(35.48)
Land Tenure Characteristics				
Inheritance Dummy	119.1	0.016	-6.1	-6.1
	(100.70)	(0.0135)	(53.67)	(53.10)
Rent Dummy	31.6	0.0516***	-80.4	-80.4
	(89.68)	(0.0118)	(186.70)	(189.50)
Sharecropped Dummy	-52.5	-9.47E-04	-55.4	-55.4
	(55.71)	(0.0075)	(56.16)	(55.57)
Land Certified from Govt	81.5	-0.0397***	40.3	40.3
	(72.02)	(0.0096)	(146.10)	(144.50)

Continued Table 2.2 Regression Results

	OLS without correcting for endogeneity	*First Stage Regression*	*Instrumental Variable Approach*	*Spatially Weighted Regression*
	Agricultural Value of Production	Land Degradation	Agricultural Value of Production	Agricultural Value of Production
Farmer Demographics				
Big Ethnic Group	-51.4	-0.0269**	-80.9	-80.9
	(102.30)	(0.0137)	(130.90)	(129.50)
Number of Children	5.5	0.0128***	-5.7	-5.7
	(13.12)	(0.0018)	(11.40)	(11.28)
Male head	-6.1	0.0211**	16.9	16.9
	(79.65)	(0.0107)	(103.70)	(102.60)
Farming Years	-2.4	-0.000555**	-3.1	-3.1
	(1.91)	(0.0003)	(2.69)	(2.66)
Livestock ownership dummy	488.3***	-0.00934	478.9***	478.9***
	(48.36)	(0.0065)	(57.92)	(57.31)
Asset Index	41.65*	-0.00467	42.72*	42.72*
	(23.37)	(0.0031)	(27.58)	(27.29)
Regional Fixed Effects				
Tigray Region	344.8**	-0.142***	203.1**	223.6**
	(173.50)	(0.0227)	(156.00)	(141.00)
Amhara Region	-28.0	-0.0908***	-63.3	-63.3
	(157.90)	(0.0209)	(367.50)	(367.50)
Oromiya Region	-182.5	-0.00345	-158.1	-158.1
	(136.60)	(0.0183)	(138.00)	(138.00)
Benishangul Gumuz Region	-712.4***	0.200***	-524.1***	-489.3***
	(186.20)	(0.0240)	(123.80)	(117.80)
Neighbor's Characteristics				
N's Land Degradation				-27.3***
				(14.09)
Constant	-1,085*	1.426***	-1293.4*	-1293.4*
	(597.00)	(0.06)	(453.00)	(440.10)
Observations	828	828	828	828
R-squared	0.2370	0.7250	0.2330	0.2425
Underidentification test			1.057[a]	0.222[a]
Chi-sq(2) P-val			0.148	0.9891
Overidentification test			0.183[b]	0.322[b]
Chi-sq(2) P-val			0.7726	0.8873

[a] Anderson Canonical Correlation LM Statistic
[b] Sargan Statistic
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2.3 Marginal Effects of Land Degradation by Region

Region	Marginal Effect of Land Degradation
Tigray	-12.06*
	(10.5)
Amhara	-14.30**
	(12.37)
Oromiya	-19.87**
	(15.62)
BG	-15.92*
	(13.1)
SNNPR	-21.06
	(35.09)

Standard errors in parentheses

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

Table 2.4 Regression Results by Region

	Region Tigray *Land Degradation*	Region Amhara *Land Degradation*	Region Oromiya *Land Degradation*	Region BG *Land Degradation*
Candidates for Instrumental Variables				
Bequest	0.00463	-0.011**	-0.00875*	-0.00104**
	(0.0076)	(0.0011)	(0.0019)	(0.0009)
"Bad" Cooking Energy	0.131*	0.0201	0.0564**	-0.0215**
	(0.0624)	(0.0032)	(0.0056)	(0.0118)
Environmental Characteristics				
Aridisol Soil	-0.0126	-0.00843	0.0688**	0.689***
	(0.2050)	(0.0096)	(0.0296)	(0.1930)
Entisol Soil	0.0512	-0.0166**	0.0355*	0.386***
	(0.1560)	(0.0073)	(0.0201)	(0.1120)
Mollisol Soil	0.0209	-0.0270***	0.0674***	0.315
	(0.1790)	(0.0089)	(0.0244)	(0.2310)
Slope	0.0114	0.00540***	-0.0171***	-0.146***
	(0.0302)	(0.0020)	(0.0055)	(0.0434)
Elevation	0.00000793	1.97E-08	0.000000603	-0.00000238
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Rainfall	0.000166	2.40e-05	1.29e-05	-0.000502
	(0.0004)	(0.0000)	(0.0000)	(0.0003)
Temperature	0.00608	0.00235*	0.00482**	-0.00533
	(0.0211)	(0.0013)	(0.0024)	(0.0368)
Socio-Environment Characteristics				
Population Density	0.000022	0.00000455	0.000192**	0.00429***
	(0.0000)	(0.0000)	(0.0001)	(0.0011)
Access to Basic Facilities	0.00168	-0.000124	-0.00109	7.77e-05
	(0.0022)	(0.0003)	(0.0008)	(0.0002)
Access to Information	0.00206	-0.0000589	0.00143	0.000879
	(0.0030)	(0.0002)	(0.0018)	(0.0007)
Farm Characteristics				
Irrigation Intensity	-0.00109	-0.00334**	0.00298	0.122
	(0.0205)	(0.0016)	(0.0061)	(0.0370)
Distance of farm from home	0.00993	0.000765	0.00147	0.0188***
	(0.0091)	(0.0016)	(0.0026)	(0.0036)
Farmer Demographics				
Big Ethnic Group	0.0148		0.0242*	0.00424
	(0.0636)		(0.0135)	(0.0026)
Number of Children	-0.0018	0.00107	-0.000947	0.000203
	(0.0028)	(0.0006)	(0.0012)	(0.0006)
Male head	-0.00422	0.00372	-0.00334	0.00248
	(0.0153)	(0.0042)	(0.0062)	(0.0048)
Farming Years	-0.000649	-0.0000487	0.000245	0.0000142
	(0.0005)	(0.0001)	(0.0002)	(0.0001)
Livestock ownership dummy	0.0097	0.00248	-0.00111	0.000468
	(0.0110)	(0.0023)	(0.0043)	(0.0022)
Asset Index	0.00973*	0.000426	-0.000468	-0.00193*
	(0.0050)	(0.0012)	(0.0021)	(0.0011)

Continued Table 2.4 Regression Results by Region

	Region Tigray *Land Degradation*	Region Amhara *Land Degradation*	Region Oromiya *Land Degradation*	Region BG *Land Degradation*
Land Tenure Characteristics				
Inheritance Dummy	-0.0213	0.00564	0.00245	0.000112
	(0.0291)	(0.0054)	(0.0081)	(0.0039)
Rent Dummy	0.000000729	-0.0000037	-0.0000327	0.0000172
	(0.0001)	(0.0000)	(0.0000)	(0.0000)
Sharecropped Dummy	0.00253	-0.00286	-0.00536	-0.00288
	(0.0125)	(0.0024)	(0.0053)	(0.0040)
Land Certified from Govt Dummy	-0.00214	-0.00196	-0.0023	-0.0154***
	(0.0292)	(0.0028)	(0.0095)	(0.0044)
Constant	-0.173	0.0171	0.154**	0.609
	(0.4530)	(0.0260)	(0.0650)	(1.1920)
Observations	148	294	187	149
R-squared	0.6480	0.7994	0.6940	0.8620

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

2.10 Figures

Figure 2.1 Cluster and Significance Maps of Land Degradation induced decline in Value of Agricultural Production and Moran's I-statistic

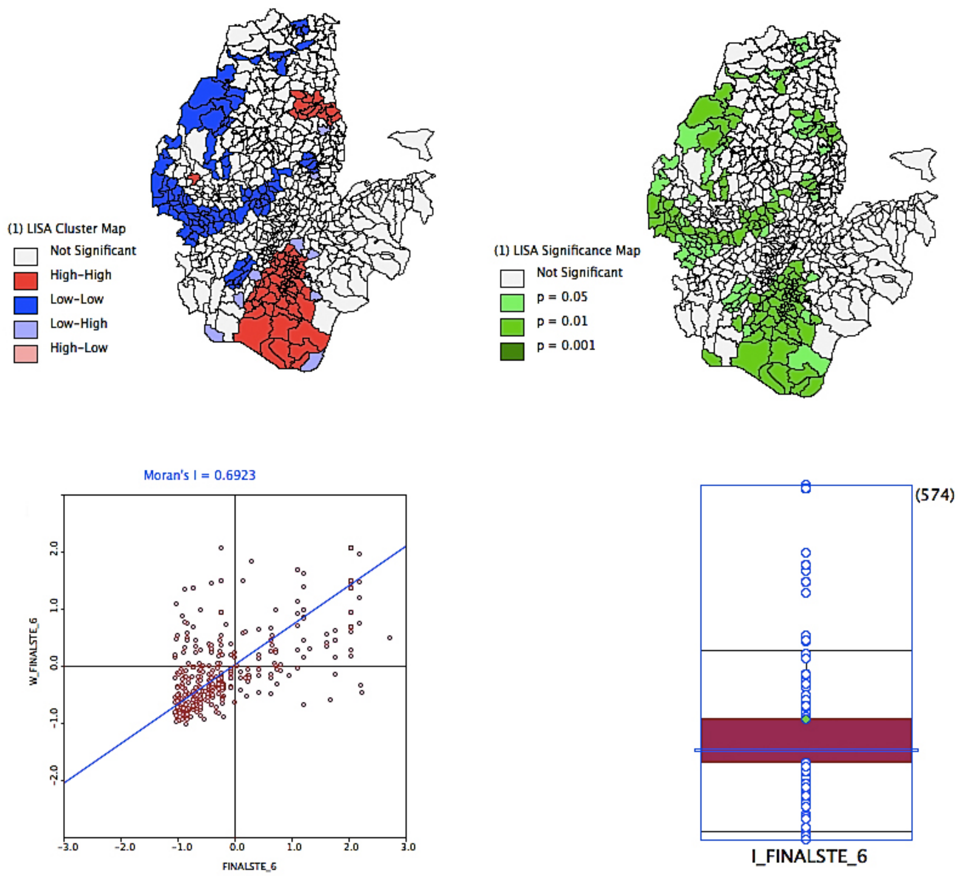
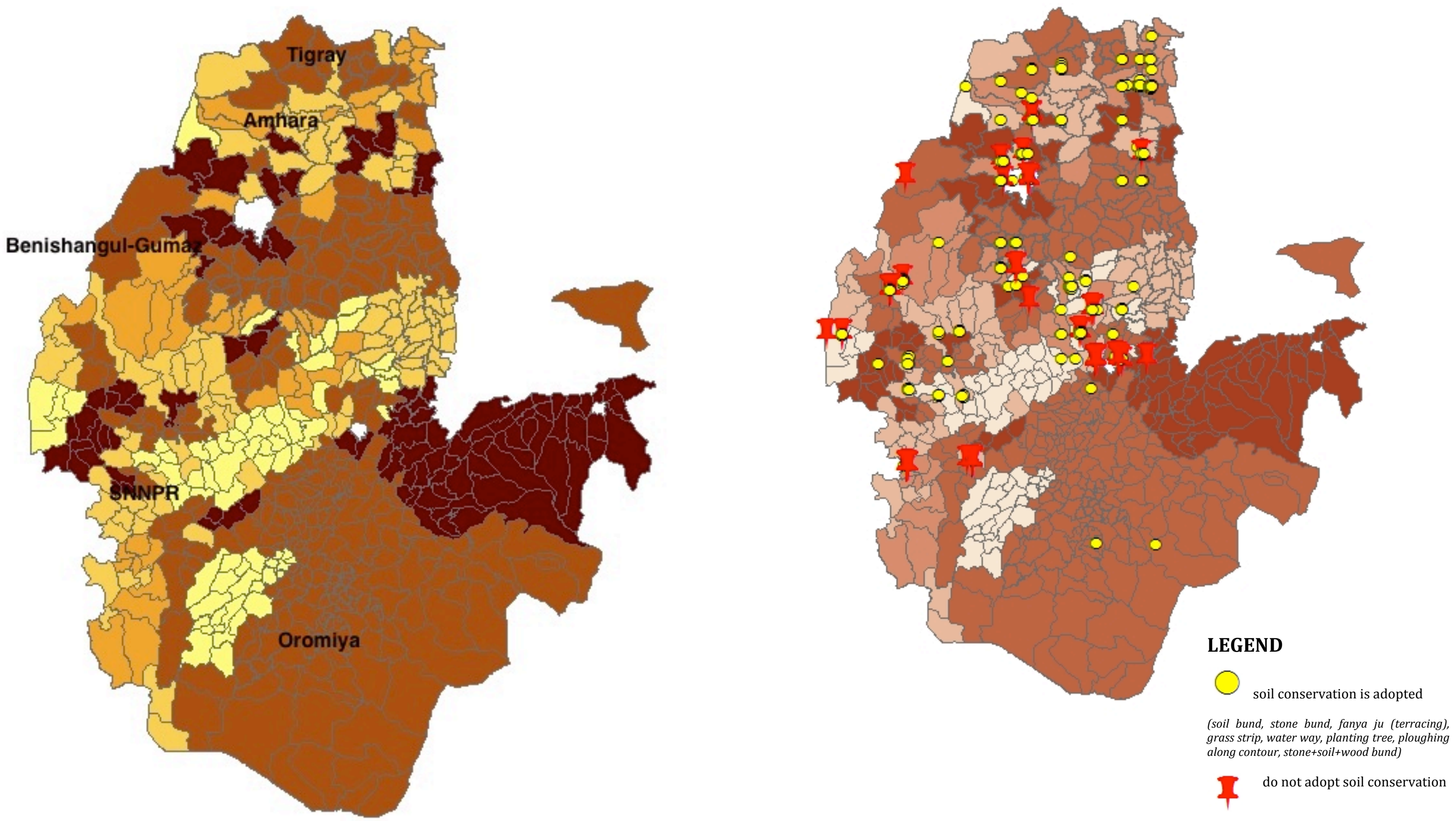


Figure 2.2 Differential Impacts of Land Degradation on the Value of Agricultural Production



Chapter 3

DOES PHILIPPINE PROCUREMENT AND DISTRIBUTION IN THE RICE MARKET MATTER?

3.1 Introduction and Motivation

Rice is the staple food in the Philippines. It accounts for 1/3 of the total food consumption (in terms of domestic utilization in metric tons)[6] and is grown on about 4 million hectares of the total 13 million hectares of arable land (Glipo, Vibal and Cainglet, 2002). Since rice is the most important food crop, the government has made numerous attempts to influence its price. In 1972, the Philippine government established the National Food Authority (NFA) to ensure continuous supply of rice at stabilized prices through domestic stocks and import control. The agency procures and sells rice at administratively determined prices and stores and maintains rice stocks as a contingency against future shortages.

However, variability in rice production and consumption results in periodic regional surpluses or deficits (Rufino, 2011). Furthermore, the problem is exacerbated by market inefficiencies such as poor rural and market infrastructure (Goletti et al 1995; Moya et al 2002), fragmented markets (Dawe et al, 2008; Intal and Ranit, 2001), inefficient distribution, poor transportation (Intal and Ranit, 2001) and exogenous supply shocks such as extreme weather.

Since 1972, the private sector marketing channel has operated alongside the NFA. Prices in the private sector are set by supply and demand conditions, while the NFA purchases and sells at administratively set prices; therefore it is not clear how the NFA's marketing activities affect the level and variability of rice prices.

[6] http://www.bas.gov.ph

Because of this, the NFA has been criticized. (Jha and Ramaswami, 2010; Jha and Mehta, 2008; Tolentino, 2006; Intal and Garcia, 2005; Esguerra et al., 2001; Subbarao et al., 1996; Unnevehr, 1985) But there have been few academic studies on the matter (Umali et al., 1992; Shively et al., 2002; Yao et al., 2005 as an exception). Umali et al. (1992) concluded that increased market integration during the period of 1983-1986 was attributable to declining levels of government intervention in the marketing system. Shively et al. (2002) used trends, seasonal terms, and deviations from trend output variables to analyze rice price changes in the Philippines. They found that the buffer stock program had little influence on rice prices. Yao et al. (2005) used seemingly unrelated regressions to examine effectiveness of the program. Yao et al. (2005) found that the NFA successfully increased producer prices in 5 of 13 regions through stock accumulation and paddy rice purchase at floor prices. However, NFA stock releases did not correlate strongly with retail prices in their study.

Given that the previous literature is mixed regarding whether or not NFA interventions have had an effect on Philippine rice market, I hope to address the issue using a novel approach. I differentiate producing regions and consuming regions as well as major intervention regions (with high distribution and procurement). I expect the high distribution and consuming regions are most affected by the NFA program.

This paper uses a structural vector autoregression (VAR) approach similar to Jayne et al. (2008) and Mason et al. (2013) and monthly price data from January 1990 through January 2013 to estimate the impacts of the NFA's pricing decisions on private sector rice price levels and variability. However, an important method which makes this study differ from Jayne et al. (2008) and Mason et al. (2013) is that I verify the exclusion restrictions set for model identification through a data determined approach using PC algorithm and Directed Acyclic

Graphs. The structural VAR allows for a set of underlying supply, demand, and policy shocks to influence market prices. I use the structural VAR results to evaluate the effects of NFA policy shocks on market prices using impulse response analysis. Finally, I use the estimated models to simulate the counterfactual path that market prices would have taken in the absence of NFA activities. The level and variability of these simulated prices compared to the realized historical prices demonstrate the effects of the NFA on rice market prices.

This paper makes an important empirical policy analysis contribution to the agricultural economics literature. The findings provide better understanding of the impact of NFA policies and inform the debate about an appropriate future role for the NFA in Philippine rice markets. Results showed that the NFA buying price premiums had a significant effect in the major producing region and the major procurement region in the following month. While for the major distribution region, the NFA sell price premiums take longer to respond to changes in price policy suggesting that market prices were tracking the world prices. Finally, comparing historical price data to simulated prices with no NFA activities show that the interventions had a very small impact on both rice price levels and variability. NFA's impact in raising food prices occurred primarily during self-sufficient years and had little or no effect at all in importing years.

3.2 Government Price Stabilization Policy and the Philippine Rice Market

A stated goal of the NFA is to support farm gate prices and reduce the retail price of rice (NFA website[7]). To accomplish this, the NFA sells rice through accredited retailers at a fixed margin on the sale, while at the same time, offers to buy raw rice from farmers at a support price based on the average domestic cost of production plus an administratively determined mark-up.

[7] http://www.nfa.gov.ph/

It holds buffer stocks equivalent to 30 days of consumption plus 15 days of emergency holdings by buying paddy during peak harvest; then the NFA sells rice from its stocks at strategic times when prices are at seasonal highs in order to reduce the retail price (Intal and Garcia, 2005; Yao et al., 2005).

The private marketing channel operates along side NFA. In the private channel, prices are set by supply and demand forces, while the NFA purchases and sells at administratively set prices. The two marketing channels are interrelated because farmers can decide to sell their rice to private markets or the NFA.

Apart from the price setting function, the NFA can also influence market process through stockholding[8] policies and monopolizing importation[9]. However, Mason et al (2013) and Jayne et al (2008) show that the effect of price setting activities on market prices is similar to effect of stockholding activities. Furthermore, they show that the effect of government activities are well captured by the price premium alone because the extent to which the government is building or reducing stocks is tied so closely to the size of the buy and sell price premiums. In this paper, I only focus on the effects of the official price setting process of the NFA, while indirectly incorporating the effect of importation. I assume that the NFA influences market prices in two main ways: by changing the size of the buy price premium (difference between the NFA buy price and the farmgate market price in surplus producing regions) and by changing of the sell

[8] The NFA Council sets the level of stocking based on the recommendation of the National Inter-Agency Committee (Intal and Garcia, 2005). The NFA's regional and provincial offices manage approximately 296 warehouses with a combined storage capacity of more than one million metric tons of grains (NFA website, www. nfa.gov.ph).

[9] Historically, the NFA has also controlled the importation of rice through quantitative restrictions. Prior to 1996, the NFA was the country's sole rice importer. In 1996, with the enactment of the Agricultural Tariffication Act, private enterprises gained the rights to import minimal quantities of rice. In 2003, substantial amount of imports was still through the NFA amounting to 75% of total rice importation (Intal and Garcia, 2005).

price premium (difference between the NFA sale price and retail market price in consuming regions).

3.3 Methodology

I take a structural vector autoregression (VAR) approach (Sims, 1980; Bernanke, 1986; Shapiro and Watson, 1988) to estimate the effects of NFA marketing activities on private sector rice prices. VAR models have proven useful for estimating policy effects in the presence of limited data and uncertainty about the correct structural model of the underlying data generating mechanism (Myers et al., 1990).

I segment the VAR into blocks of prices $\mathbf{y}_t$ and policy variables $\mathbf{p}_t$. A general dynamic model of the relationship between the variables is specified:

$$\mathbf{B}y_t = \sum_{i=0}^{k} \mathbf{B}_i y_{t-i} + \sum_{i=0}^{k} \mathbf{C}_i p_{t-i} + \mathbf{A}^y \mathbf{u}_t^y \qquad (3.1)$$

$$\mathbf{D}p_t = \sum_{i=0}^{k} \mathbf{G}_i y_{t-i} + \sum_{i=0}^{k} \mathbf{D}_i p_{t-i} + \mathbf{A}^p \mathbf{u}_t^p \qquad (3.2)$$

where $\mathbf{B}, \mathbf{B}_i, \mathbf{C}_i, \mathbf{A}^y$ and $\mathbf{D}, \mathbf{D}_i, \mathbf{G}_i, \mathbf{A}^p$ are matrices of unknown parameters, k is the number of lags, and $\mathbf{u}_t^y$ and $\mathbf{u}_t^p$ are vectors of mutually uncorrelated structural error terms.

A distinct feature of VAR models is that they are unrestricted (equations 3.1 and 3.2) (Sims, 1980). That is the $\mathbf{A}^y$ and $\mathbf{A}^p$ matrices allow the error terms from one equation to enter other equation, so that the error terms within each of these vectors are not mutually uncorrelated (Bernanke and Mihov, 1998). In order to estimate the dynamic response of market variables to a policy shock (i.e. in order for impulse response analysis to have a causal, ceteris paribus interpretation), a set of identifying restrictions needs to be imposed on contemporaneous interactions among the variables.

In particular, I set restrictions on $\mathbf{C}_0, \mathbf{G}_0, \mathbf{B}, \mathbf{D}, \mathbf{A}^y$ and $\mathbf{A}^p$ (Bernanke, 1986; Fackler, 1988). I follow Jayne et al. (2008) and Mason et al. (2013) in their approach to identify the model.

First, I set $\mathbf{C}_0 = 0$ which implies that there is no contemporaneous response of market changes to NFA policies. In other words, the rice market variables $(\mathbf{y}_t)$ depend on current and past values of $\mathbf{y}_t$ but only on the past values of the policy variables $(\mathbf{p}_t)$. This assumes market variables respond to lagged policy changes but not contemporaneously. This may seem like a restrictive assumption because it implies rice sellers and buyers respond to a change in the NFA price premiums after a full period before they become fully aware of the change and start altering their behavior. In most developing countries like the Philippines access to information can be sporadic and incomplete. Hence, it takes time for buyers and sellers to become aware that premiums have changed. Also, even when market participants become aware of premium it may be too costly to alter their marketing channel because of adjustment costs. If $\mathbf{C}_0 = 0$, the effect of a policy shock on market variables is independent of $\mathbf{B}$ and $\mathbf{A}^y$ parameter matrices (Bernanke and Blinder, 1992; Bernanke and Mihov, 1998). Thus, there is no need for any identification restrictions on the market variables $(\mathbf{B} \text{ or } \mathbf{A}^y)$.

However, with $\mathbf{C}_0 = 0$, the system is still not identified. The policy effect is still sensitive to restrictions set to identify $\mathbf{D}$, $\mathbf{G}_0$ and $\mathbf{A}^p$ in policy block, i.e. alternative orderings of the policy variables (buy price premium and sell price premium). Choleski factorization is the most common identification scheme used in VAR models which imposes a recursive ordering among variables (Sims, 1980). If $\mathbf{C}_0 = 0$, Choleski decomposition requires $\mathbf{A}^p$ to be a diagonal matrix, $\mathbf{D}$ to be lower triangular with ones on the principal diagonal and $\mathbf{G}_0$ left unrestricted. Defining $\mathbf{D}$ in this way imposes a recursive ordering on the policy variables, $(\mathbf{p}_t)$. In the context of this paper, I place the buy price premium first and the sell price premium next because I assume that NFA determines its buy price premium based on how much rice is being delivered and then sets the sell price premium based on what was obtained. But sensitivity of impulse response function to orderings of policy variables are also presented in the diagnostic section.

I verify the validity of these identification restrictions using Directed Acyclic Graph Analysis which I describe in detail in section 3.5. After estimating the model, impulse response analysis can be used to trace out the dynamic response of a given market variable to a one-time random shock to one of the policy variables, ceteris paribus. That is $\frac{\partial \mathbf{y}_{i,t+s}}{\partial \mathbf{u}^p_{j,t}}$, where $\mathbf{y}_i$ is a price variable and $\mathbf{u}^p_{j,t}$ is the structural error policy variable. And because structural error terms are orthogonal, the impulse response functions have a causal interpretation.

Finally, given the estimated VAR, I simulate the counterfactual values of the variables if there had been no NFA activities. This is accomplished by setting all of the random shocks to market variables or the market variables error terms $\mathbf{u}^y_t$ to their estimated historical values and constructing a new series of policy shocks $\mathbf{u}^{*y}_t$ and $\mathbf{u}^{*p}_t$ so that the buy premiums and sell premiums are zero. The latter results in simulated price paths that would have occurred had buy premiums and sell premiums been zero. I compare the simulated paths of the market variables to the historical in terms of mean, standard variation and coefficient of variation to inform whether the NFA has affected market price levels and stability.

3.4 Data

I use monthly data from January 1990 through January 2013. The farmgate and retail prices by region are from Bureau of Agricultural Statistics website (http://www.bas.gov.ph). All prices are expressed in Philippine peso per kilogram (Php/kg). The NFA price, sales and purchase data were acquired directly from the NFA. The NFA purchase and sale prices were pan-territorial and pan-seasonal (i.e. uniform throughout the country and remain fixed during the marketing season, except for some years when they were revised in the middle of the year as a response to crop supply forecasts and weather shocks). Computing for the price premium is straightforward by calculating the spread between NFA prices with Central Luzon and ARMM prices. Summary statistics for all the variables used in the study are reported in Table 3.4 and the series are depicted in Figures 3.1 and 3.2.

From Figure 3.1, it seems like the sell premium does not change frequently and appears to be set administratively. While buy premiums seem to be determined in response to market conditions. This makes sense because NFA would base their buy price premium on how much is being delivered or produced which is more exogenous and then the NFA would base the sell price premium on how much NFA obtained.

3.5 Application of VAR Method to Philippine Rice Market and DAG Verification

For the market variables, I include the major producing and consuming regions and regions where there is considerable NFA intervention. In particular, the market variables, $\mathbf{y}_t$, include wholesale prices for Central Luzon (a major producing region), ARMM (a major consuming region), Mimaropa and NCR (high procurement and distribution regions). I also include world prices since NFA still imports substantial amount as seen in the difference of procurement and distribution quantities[10].

Table 3.1 presents annual per capita consumption of rice by region from 2008-2009 and Table 3.2 presents average palay area harvested by region from 1990-2012. Table 3.3, on the other hand, summarizes average annual palay procurement and distribution of rice per region from 2000-2012.

For the policy variables, $\mathbf{p}_t$, I include variables that represent the operation of the Philippines' rice price policy. I include the buy price premium in the major producing region of Central Luzon and the sell price premium in the major consuming region of ARMM. Both these policy variables can be positive, zero or negative and if both are set to zero then the market would be operating without the NFA influence[11].

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10 Including other market variables such as trade flows, consumption levels, private storage, transportation costs, etc., might provide more information but data on these variables are not available.

11 Other potential variables that might have been included in the policy vector are how much the NFA was actually selling and buying at administratively determined prices and measure of tariff rate the government imposes on rice imports. Positive net purchases indicate the government is adding to their stocks while negative net purchases indicate they are running down stocks. However, as shown by Jayne et al. (2008) and Mason (2011), the effects of stocks and price premiums are the same. Thus, this suggests that the effects of the NFA on market prices is well captured by price premiums alone because the extent to which the NFA is building or reducing stocks is tied closely to the size of their buy and sell price premiums and discounts. On the other hand, the measure of tariff rate the government imposes on rice imports changed very infrequently over time making it not suitable for linear VAR

While setting exclusion restrictions is a possible way to achieve an identified system, Etienne (2013) noted that this may have an element of subjective judgement of the researcher. To reduce this problem, I follow Swanson and Granger (1997) to verify the exclusion restrictions using a data determined approach based on conditional and unconditional correlations among reduced-form VAR structural innovations. I employ PC algorithm of Spirtes, Glymour and Scheines (2000) of Directed Acyclic Graphs (DAG) of Demiralp and Hoover (2003) embedded in Tetrad IV software. PC algorithm starts with a completed undirected graph connecting the n innovations or structural errors (n=number of variables) from the reduced form VAR. Edges between the variables are removed based on either zero unconditional or conditional correlations based on Fisher's z test. I use 10% significance level as recommended by Spirtes, Glymour and Cheines (2000) based on their Monte Carlo simulation for different sample sizes.

Figure 3.3 reports the pattern from TETRAD IV's application of the PC Algorithm to the reduced form VAR model. The result conforms to my proposed exclusion restrictions presented in section 3.3. The market variables respond to lagged policy changes but not to contemporaneous policy changes, i.e. no significant contemporaneous correlation from UParmm, UPncr, UPcluz and UPmim to either UPsp or UPbp. Similarly, policy changes respond to lagged market variables but not contemporaneously, i.e. no significant contemporaneous correlation from UPsp or UPbp to any of UParmm, UPncr, UPcluz and UPmim. With this verification, I can then proceed to estimate the structural VAR model I specified in section 3.3.

framework. Moreover, the NFA plays a monopoly role in importation of rice and the levels of tariff they set are closely related to their local buy and sell price premiums as well.

3.6 Diagnostic Tests

I tested the data for unit roots. A summary of Dickey-Fuller and Phillips-Perron tests for unit roots are reported in Table 3.5 and the detailed results are in the Appendix Table B1. I tested for stationarity in levels and in differences. Also, the lag order k is determined using Akaike and Schwarz-Bayesian information criteria and likelihood ratio (LR) tests. In Dickey-Fuller regressions, the regressors were estimated with and without a time trend. Phillips-Perron tests were also applied as a consistency check, again both with and without time trend. The tests imply that all the wholesale price variables in levels exhibit unit root but were difference stationary. I then proceed to do VAR in differences of wholesale prices.

In addition, I test for serial correlation and autoregressive conditional heteroskedasticity effects. Given plots of the data in Figures 3.1 and 3.2, I suspect seasonality may be an issue. Domestic rice production in Philippines is seasonal, inevitably resulting in seasonal variation in the price of rice. That is the price of rice is lower during the harvest season and higher during the lean months. Because Philippines has two seasons, I control for seasonality by adding a seasonal dummy variable as an exogenous shock in the system without changing the identification assumptions and restrictions (Hylleberg et al., 1990; Saikkonen et al., 2000). Correlograms for both the price and policy variables displayed strong evidence of seasonality. Further, a VAR regression without seasonal dummy variables show significant evidence of autocorrelation (See Appendix B2). And a likelihood ratio test based on the determinants of the error variances and covariance from estimations with and without seasonal dummy variables reject the null hypothesis that the seasonal dummy variables are not necessary.

I also test for linear trends, and find that trend terms are not significant in any of the equations which was also confirmed by a likelihood ratio test. Thus, I do not model it explicitly in the regression. Enders (2008) also recommended not including trend terms in VARs so that the dynamic interrelationships between the variables remain as unrestricted as possible. (See Appendix B3)

3.7 Results

3.7.1 VAR Estimation Results

A seven variable VAR with seasonal dummies was estimated using lagged prices. The Akaike information criteria and Schwartz Bayesian criteria suggests two lags. However, Likelihood ratio test and Lagrange multiplier test for autocorrelation both suggest that four lags was sufficient to eliminate autocorrelation in the residuals in all the Dickey-Fuller regressions (See Appendix Tables B4 and B5). So a lag of four was chosen.

I also tested the residuals for autocorrelation using Ljung-Box Q statistics. Results from Ljung-Box Q statistics suggest four-lagged dependent variables. The same test applied to the squared residuals supports no autoregressive conditional heteroskedasticity (ARCH) in any residual series. Model specification tests for residuals are reported in Table 3.6. For stability conditions, I find that the eigenvalues lie within unit circle, and thus satisfy VAR conditions for stationarity (see Appendix B6). Hence I choose a lag length of four for the model.

The VAR results are presented in Table 3.7. Based on the VAR coefficients, I find that policy variables do not consistently affect the four regions. For a major producing region, Central Luzon, buy premiums coefficient is negative and significant in the second, third and fourth lag. While for ARMM, the region with the biggest per capita consumption, the sell premium is significant in the third lag. World prices are significant in all regions at one and two lags which suggest that local prices are highly responsive to world price shocks despite heavy government intervention. While the domestic markets do not appear to be responding to each other but driven much by action in the NCR as the first lag of NCR is highly significant in all price equations. Seasonality is highly significant in the regions where NFA intervenes the most suggesting efforts to dampen seasonal swings in price are not fully effective.

3.7.2 Impulse Response Results

As mentioned in the previous sections, the underlying dynamic interrelationships between rice prices and NFA premiums is that sellers and buyers of rice have two alternative marketing channels: either they can buy or sell through the private sector at prices set by forces of supply and demand or through the NFA at administratively set prices.

So if NFA raises its buy price in a producing region such as Central Luzon, then one might expect more supply entering the NFA channel and less in the private market. And as supply contracts, this should create an upward pressure on market prices in Central Luzon. Similarly, if NFA raises its sell price in a consuming region, i.e. ARMM, then I will expect people buying in the private market channel instead of buying from NFA. High demand could lead to increase in prices as well.

I investigate the dynamic response of market prices to changes in NFA buy and sell premiums using impulse response analysis. Impulse response analysis uses moving average representation of VAR to trace out the dynamic effect of a one-time shock to the system on each variable in the system. Here I am interested in the dynamic response of market prices to shocks to the NFA buy and sell premiums. Thus, I would expect positive shocks to the premiums to have positive effects on the market prices, with an effect being spread over time as a result of adjustment costs from moving between marketing channels.

While I verify the exclusion restrictions in section 3.3, the policy effects can still be sensitive to the alternative orderings for the policy variables. I derive orthogonal impulse response functions, which in this case correspond to selecting Cholesky decomposition for the contemporaneous affects matrix and are depicted in Figure 3.4. In Appendix Figure B1, I present impulse response functions for different orders or policy variables and find no difference at all.

The solid line in Figure 3.4 represents the impulse response function and the grey band is the 95% confidence interval for the IRF. As expected, positive shocks to the premiums have positive effects on the market prices, with an effect being spread over time as a result of adjustment costs from moving between marketing channels. However, none of the confidence intervals exclude zero, which indicates that they are not statistically significant. This is further support that the NFA policies are not significantly influencing market rice prices.

3.7.3 Simulated Effects of NFA marketing activities

I simulate prices in the absence of NFA market channel by: (1) recursively constructing a set of alternative policy scenario shock, i.e. $\mathbf{u}_t^{*y}$ and $\mathbf{u}_t^{*p}$, that generate zero values for NFA buy and sell price premiums over the entire sample period; (2) assuming that the shocks to the market variables remain at their estimated sample values over the sample period; and (3) constructing dynamic forecasts of the Central Luzon and ARMM price paths under the alternative policy scenario and actual market shocks.

The resulting estimated NFA price effects are tabulated in Table 3.8 and graphed in Figures 3.5-3.8. The effect of NFA over the entire sample period was very little. This is consistent with earlier findings by Shively et al. (2002) and Yao et al. (2005). Except for NCR, the effect of NFA was to raise the average prices in Central Luzon, ARMM and Mimaropa by approximately 0.85 to 1.56%. NFA also stabilize prices as seen by reduced standard deviations.[12]

Based on Figure 3.5-3.7, it was mostly felt only in the early 1990s and has little or no effect at all in the later years, with an exception during the price spike of 2008, which my results indicate would have been slightly worse had the NFA not been active. The differences are more prominent looking at the percentage differences of the prices in Figure 3.9. Recall that in the 1980s up to early half of the 1990s Philippines was self-sufficient (Intal and Garcia, 2005). Thus, it is mainly when in self-sufficient years that I observe significant differences between actual and simulated prices. Suggesting that as world markets have come to play a large role in the Philippine rice market, the NFA's ability to influence prices has diminished.

3.8 Conclusion

In 1972, the Philippine government established the National Food Agency (NFA) to ensure continuous supply of rice at stabilized prices through domestic stocks and imports control. The NFA procures rice at support price and sells rice at an affordable price to poor consumers. In addition, the NFA stores and maintains rice stocks as a contingency against future shortages. The NFA has received a lot of criticism but there has been little empirical work investigating effects of the NFA on private sector grain prices. Given the importance of rice in the Philippine

[12] It is worth noting that the simulations are based on time series when NFA exists. Thus, care should be taken in interpreting the simulation results. Ideally, I could use coefficient estimates of VAR from the time series when NFA does not exist but the data was not available.

economy, empirical research on the historical effects of the NFA activities will provide a better understanding of the past impact of these policies and also inform the debate about an appropriate future role for the NFA.

In this article, I use a structural vector autoregression (VAR) approach using monthly data from January 1990 through January 2013 to estimate the impacts of NFA's pricing decisions on private sector rice price levels and variability. I also use the VAR results to evaluate the effects of NFA activities on market prices using impulse response analysis and to simulate the path that market prices would have taken in the absence of NFA.

Results from the VAR show that NFA buying price premiums had a significant effect for major producing region. While for major distribution and consumption region, NFA sell price premiums had a significant effect in the third lag suggesting that market prices in these regions are most likely tracking the world prices and takes longer to respond to changes in price policy despite heavy government intervention. Impulse response function reveal that the effect of government policy shocks would impact prices in the short term. That is increasing the market prices abruptly and after about 4 months, the prices would then start to diminish and this process lasts for about a year. Finally, comparing historical price data and simulations of prices in the no NFA scenario show that NFA activities have a very small impact on both rice price levels and variability. NFA's impact in raising food prices occurred primarily during self-sufficient years and had little or no effect at all in importing years.

Islam and Thomas (1996) state that for a buffer stock program to be effective, the agency must be in control of the timing of the purchases and be able to make cost-effective purchases and sales. As in the case of the NFA's price stabilization program, operational inefficiency has been apparent. The deficits of the NFA accounted for 31% in 2002 and 43% in 2005 of the total deficit of all government corporations (Intal et al, 2012). The Coffrey International Development Report, in their review of the NFA's operational efficiency and effectiveness, reports poor financial management information system and lack of integrated logistics have led to ineffective monitoring of stocks and operations leading to losses. Also, overstaffing and government bureaucratic rules results in higher administrative costs than necessary. Finally, where transportation and warehousing infrastructure is not well developed, a calamity leads to private hoarding and possible drastic increases in the prices of rice which dampens the purpose of price stabilization. The results of the paper suggest that the government should leave a greater role for the private sector in stabilizing rice prices.

3.9 References

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3.10 Tables

Table 3.1 Annual Per Capita Consumption of Rice by Region in kilograms, 2008-2009

Region	Consumption in Kg	Rank
NCR	100.984	16
CAR	131.612	5
Ilocos Region	125.008	8
Cagayan Valley	122.356	11
Central Luzon	123.24	10
CALABARZON	112.736	14
MIMAROPA	136.344	3
Bicol Region	124.28	9
Western Visayas	133.692	4
Central Visayas	95.212	17
Eastern Visayas	127.244	7
Zamboanga Peninsula	109.096	15
Northern Mindanao	115.7	12
Davao Region	113.152	13
SOCCSKSARGEN	136.5	2
Caraga	128.128	6
ARMM	144.664	1

Source: Bureau of Agricultural Statistics, bas.gov.ph

Table 3.2 Average Palay Area Harvested by Region in hectares, 1990-2012

Region	Area Harvested in ha	Rank
NCR	-	17
CAR	96,509.05	16
Ilocos Region	358,784.11	4
Cagayan Valley	476,805.53	3
Central Luzon	587,023.79	1
CALABARZON	123,158.74	13
MIMAROPA	250,631.95	7
Bicol Region	294,060.11	6
Western Visayas	572,604.32	2
Central Visayas	97,473.37	15
Eastern Visayas	236,122.79	8
Zamboanga Peninsula	141,763.89	10
Northern Mindanao	138,116.11	11
Davao Region	104,178.37	14
SOCCSKSARGEN	312,621.11	5
Caraga	124,987.16	12
ARMM	176,354.79	9

Source: Bureau of Agricultural Statistics, bas.gov.ph

Table 3.3 Average Annual Rice Procurement and Distribution by Region, 2000-2012, in bags of 50 kilos

Region	Procurement	Distribution
Philippines	4,152,497.00	26,843,037.00
NCR	-	5,681,376.00
CAR	34,935.00	544,756.00
Ilocos Region	389,693.00	2,005,111.00
Cagayan Valley	156,478.00	502,178.00
Central Luzon	164,298.00	2,374,580.00
Calabarzon	30,616.00	1,287,597.00
Mimaropa	2,357,274.00	867,707.00
Bicol	430,384.00	1,729,610.00
Western Visayas	392,968.00	1,146,200.00
Central Visayas	980.00	1,680,593.00
Eastern Visayas	19,172.00	1,388,614.00
Zamboanga Peninsula	7,159.00	1,401,444.00
Northern Mindanao	6,787.00	1,157,195.00
Davao Region	283,185.00	1,846,654.00
Soccksargen	85,041.00	1,074,093.00
Caraga	15,340.00	724,438.00
ARMM	54,308.00	560,146.00

Table 3.4 Summary Statistics of all the Variables used in the study, units and sources

Variable	Unit	Obs	Mean	Std. Dev.	Min	Max	Sources
Central Luzon Wholesale Price	Php/Kg	277	17.75162	6.351406	7.6	32.75	Bureau of Agricultural Statistics
ARMM Wholesale Price	Php/Kg	277	18.17177	6.625161	6.75	31.84	Bureau of Agricultural Statistics
Mimaropa Wholesale Price	Php/Kg	277	17.7896	6.781272	6.9	32.5	Bureau of Agricultural Statistics
NCR Wholesale Price	Php/Kg	277	17.82762	6.587463	7.57	35.29	Bureau of Agricultural Statistics
World Price of Rice	Php/Kg	277	13.65201	7.559923	4.99618	43.30185	Central Bank of the Philippines (Exchange Rate), Indexmundi.com (World Price)
NFA Selling Price	Php/Kg	277	14.40751	4.532838	6.25	25	National Food Authority
NFA Buying Price	Php/Kg	277	12.9235	5.062905	4.82	56.34	National Food Authority
NFA Selling Premium	-	277	-5.068159	4.765	-20.74	-0.2	National Food Authority
NFA Buying Premium	-	277	2.843863	5.674427	-7.31	47.32	National Food Authority
Wet Season Dummy	-	277	0.66787	0.4718298	0	1	Description from Philippine Atmospheric, Geophysical and Astronomical Services
Dry Season Dummy	-	277	0.33213	0.4718298	0	1	Administration

Table 3.5 Stationarity Summary of Variables used in the Study

Market	Including Constant and Trend	Including Constant but No Trend	Excluding both Constant and Trend
Central Luzon Wholesale Price	U	U	U
ARMM Wholesale Price	U	U	U
Mimaropa Wholesale Price	U	U	U
NCR Wholesale Price	U	U	U
World Price	U	U	U
NFA Buying Premium	U	U	U
NFA Selling Premium	U	U	U
diff Central Luzon Wholesale Price	S	S	S
diff ARMM Wholesale Price	S	S	S
diff Mimaropa Wholesale Price	S	S	S
diff NCR Wholesale Price	S	S	S
diff World Price	S	S	S
diff NFA Buying Premium	S	S	S
diff NFA Selling Premium	S	S	S
ln Central Luzon Wholesale Price	S	U	U
ln ARMM Wholesale Price	S	U	U
ln Mimaropa Wholesale Price	S	U	U
ln NCR Wholesale Price	S	U	U
ln World Price	S	U	U
ln NFA Buying Premium	S	U	U
ln NFA Selling Premium	S	U	U
diff ln Central Luzon Wholesale Price	S	S	S
diff ln ARMM Wholesale Price	S	S	S
diff ln Mimaropa Wholesale Price	S	S	S
diff ln NCR Wholesale Price	S	S	S
diff ln World Price	S	S	S
diff ln NFA Buying Premium	S	S	S
diff ln NFA Selling Premium	S	S	S

U indicates unit root, S is stationary

Table 3.6 VAR model Evaluation of Residuals

Test	Central Luzon	ARMM	Mimaropa	NCR	World	Buy Premium	Sell Premium
- AR(2)	0.2094	0.15062	0.13834	0.59959	0.04879	0.43935	0.12646
	(0.9006)	(0.9275)	(0.9332)	(0.7410)	(0.9759)	(0.8028)	(0.9387)
- AR(4)	0.32003	0.4418	0.54664	0.89581	3.2896	6.162	0.18008
	(0.9885)	(0.9787)	(0.9688)	(0.9252)	(0.5106)	(0.1874)	(0.9962)
- AR(6)	0.86624	6.6022	7.9957	3.635	10.687	18.782	2.2757
	(0.9902)	(0.3592)	(0.2384)	(0.7259)	(0.986)	(0.1145)	(0.8927)
- ARCH (2)	7.4577**	9.584***	2.5287	5.2486	8.611***	7.0376**	0.04346
	(0.0240)	(0.001)	(1.00)	(1.00)	(0.000)	(0.0296)	(0.9785)
- ARCH (4)	7.5345	2.727	2.6952	5.7616	6.344	7.0842	0.12145
	(0.1102)	(1.00)	(1.00)	(1.00)	(1.00)	(0.1315)	(0.9982)
- ARCH (6)	7.5612	3.4563	2.737	6.1763	3.966	7.3354	0.1412
	(0.2720)	(1.00)	(1.00)	(1.00)	(1.00)	(0.2909)	(0.999)

Notes: The AR (ARCH) residual tests are Ljung-Box Q tests for the relevant order autocorrelation in the residuals (squared residuals) of the series.

Table 3.7 VAR Results with Seasonal Dummies

VARIABLES	d.Central Luzon	d.ARMM	d.Mimaropa	d.NCR	d.World	d.BuyPremium	d.SellPremium
L.d.Central Luzon	-0.356***	-0.0927	-0.0167	0.0161	0.0846	0.704	-0.101
	(0.084)	(0.076)	(0.064)	(0.093)	(0.147)	(0.654)	(0.121)
L2.d.Central Luzon	-0.105	-0.0686	0.0121	-0.0862	0.0313	0.486	-0.0333
	(0.089)	(0.080)	(0.068)	(0.098)	(0.155)	(0.692)	(0.127)
L3.d.Central Luzon	-0.0357	0.161**	0.0569	-0.137	0.07	1.383**	-0.147
	(0.087)	(0.078)	(0.067)	(0.096)	(0.152)	(0.678)	(0.125)
L4.d.Central Luzon	-0.132	-0.086	-0.0772	-0.0763	0.00763	0.772	-0.0329
	(0.084)	(0.076)	(0.064)	(0.093)	(0.147)	(0.656)	(0.121)
L.d.ARMM	-0.0097	-0.00792	-0.0204	-0.104	-0.196	-0.99	-0.0456
	(0.083)	(0.075)	(0.064)	(0.092)	(0.146)	(0.651)	(0.120)
L2.d.ARMM	0.018	-0.11	0.0265	0.0242	-0.182	1.283**	0.0682
	(0.082)	(0.074)	(0.063)	(0.091)	(0.144)	(0.642)	(0.118)
L3.d.ARMM	-0.123	0.0811	0.0719	-0.0596	-0.0028	-0.377	-0.174
	(0.082)	(0.074)	(0.063)	(0.091)	(0.143)	(0.639)	(0.118)
L4.d.ARMM	0.13	-0.0733	-0.00535	0.0925	0.015	0.697	-0.0504
	(0.084)	(0.075)	(0.064)	(0.093)	(0.146)	(0.653)	(0.120)
L.d.Mimaropa	0.132	0.097	-0.0509	-0.0409	-0.259	0.359	0.0479
	(0.113)	(0.102)	(0.087)	(0.126)	(0.199)	(0.887)	(0.163)
L2.d.Mimaropa	-0.039	-0.0584	-0.0397	0.0464	-0.147	-0.184	-0.134
	(0.110)	(0.100)	(0.085)	(0.122)	(0.193)	(0.861)	(0.159)
L3.d.Mimaropa	0.0282	-0.0748	-0.176**	0.1	0.222	-0.432	0.123
	(0.106)	(0.096)	(0.081)	(0.117)	(0.186)	(0.827)	(0.152)
L4.d.Mimaropa	-0.289***	-0.00611	-0.115	-0.18	-0.232	0.12	0.198
	(0.100)	(0.090)	(0.077)	(0.111)	(0.175)	(0.781)	(0.144)
L.d.NCR	0.418***	0.196***	0.333***	0.134*	0.510***	-0.823	-0.116
	(0.071)	(0.064)	(0.055)	(0.079)	(0.125)	(0.558)	(0.103)
L2.d.NCR	-0.0797	0.00396	-0.071	-0.192**	-0.303**	-0.98	0.0955
	(0.078)	(0.070)	(0.060)	(0.086)	(0.136)	(0.608)	(0.112)
L3.d.NCR	0.0661	-0.0703	-0.0485	-0.0083	0.0534	-1.018*	-0.0707
	(0.078)	(0.070)	(0.060)	(0.087)	(0.137)	(0.610)	(0.112)
L4.d.NCR	0.0731	0.0626	0.0522	-0.118	-0.0718	-0.676	0.155
	(0.078)	(0.071)	(0.060)	(0.087)	(0.137)	(0.611)	(0.113)

Continued Table 3.7   VAR Results with Seasonal Dummies

VARIABLES	d.Central Luzon	d.ARMM	d.Mimaropa	d.NCR	d.World	d.BuyPremium	d.SellPremium
L.d.World	0.130***	0.0661*	0.0595*	0.111**	0.460***	-0.167	-0.114*
	(0.041)	(0.037)	(0.031)	(0.045)	(0.072)	(0.319)	(0.059)
L2.d.World	0.134***	0.140***	0.0805**	0.182***	-0.136*	0.143	-0.0743
	(0.043)	(0.039)	(0.033)	(0.047)	(0.075)	(0.333)	(0.061)
L3.d.World	0.0127	0.0433	0.0317	0.0203	-0.198***	-0.229	-0.136**
	(0.044)	(0.039)	(0.034)	(0.048)	(0.077)	(0.341)	(0.063)
L4.d.World	0.0732*	0.0461	0.0406	0.0604	0.175**	-0.144	0.0411
	(0.043)	(0.039)	(0.033)	(0.048)	(0.075)	(0.335)	(0.062)
L.d.BuyPremium	-0.0136	-0.00314	-0.00904	-0.0162*	-0.0153	-0.595***	0.000474
	(0.008)	(0.007)	(0.006)	(0.009)	(0.015)	(0.065)	(0.012)
L2.d.BuyPremium	-0.0180*	-0.000719	0.00119	-0.00823	0.00277	-0.439***	-0.00209
	(0.009)	(0.009)	(0.007)	(0.011)	(0.017)	(0.074)	(0.014)
L3.d.BuyPremium	-0.0145*	-2.33E-03	-4.30E-03	-0.00898	-0.00882	-0.242***	0.0135
	(0.009)	(0.008)	(0.007)	(0.010)	(0.016)	(0.073)	(0.014)
L4.d.BuyPremium	-0.0148*	-8.35E-04	3.17E-04	-0.0124	-0.00908	-0.140**	0.0054
	(0.008)	(0.007)	(0.006)	(0.009)	(0.014)	(0.064)	(0.012)
L.d.SellPremium	0.0489	0.0339	-0.0136	-0.0192	-0.00761	-0.397	-0.0632
	(0.050)	(0.045)	(0.038)	(0.055)	(0.087)	(0.388)	(0.072)
L2.d.SellPremium	-0.0114	0.00431	-0.0672*	0.00702	-0.0826	-0.142	0.0067
	(0.049)	(0.045)	(0.038)	(0.055)	(0.087)	(0.386)	(0.071)
L3.d.SellPremium	0.0128	0.0996**	0.0552	-0.00108	0.00435	-0.404	-0.142**
	(0.049)	(0.044)	(0.038)	(0.054)	(0.086)	(0.383)	(0.071)
L4.d.SellPremium	0.0287	-0.0217	-0.0117	0.0639	0.104	-0.00225	0.0143
	(0.049)	(0.045)	(0.038)	(0.055)	(0.087)	(0.386)	(0.071)
wetseason_dummy	-0.0845	-0.00556	-0.247***	-0.267**	-0.113	1.054	0.086
	(0.102)	(0.092)	(0.078)	(0.113)	(0.178)	(0.795)	(0.147)
Constant	0.116	0.0645	0.227***	0.270***	0.155	-0.762	-0.0554
	(0.083)	(0.075)	(0.064)	(0.092)	(0.146)	(0.651)	(0.120)
Observations	272	272	272	272	272	272	272
R-squared	0.3846	0.2933	0.4181	0.2955	0.3288	0.3124	0.2262

*, **, *** significant at 10%, 5% and 1% levels respectively

Table 3.8 Summary of NFA Effects on Central Luzon and ARMM wholesale rice prices

	Central Luzon Prices			ARMM Prices		
	Historical	**Simulated**	**% difference**	**Historical**	**Simulated**	**% difference**
Mean	17.83	18.01	-1.00%	18.29	18.45	-0.85%
Standard Deviation	6.33	6.47	-2.26%	6.53	6.67	-2.05%
Coefficient of Variation	35.48%	35.94%	-1.28%	35.69%	36.13%	-1.21%

	Mimaropa Prices			NCR Prices		
	Historical	**Simulated**	**% difference**	**Historical**	**Simulated**	**% difference**
Mean	17.90	18.18	-1.56%	17.97	18.24	-1.49%
Standard Deviation	6.72	6.81	-1.24%	6.49	6.59	-1.50%
Coefficient of Variation	37.57%	37.45%	0.32%	36.10%	36.10%	-0.01%

3.11 Figures

Figure 3.1 Monthly NFA Buying Prices and Selling Prices for 1990-2013

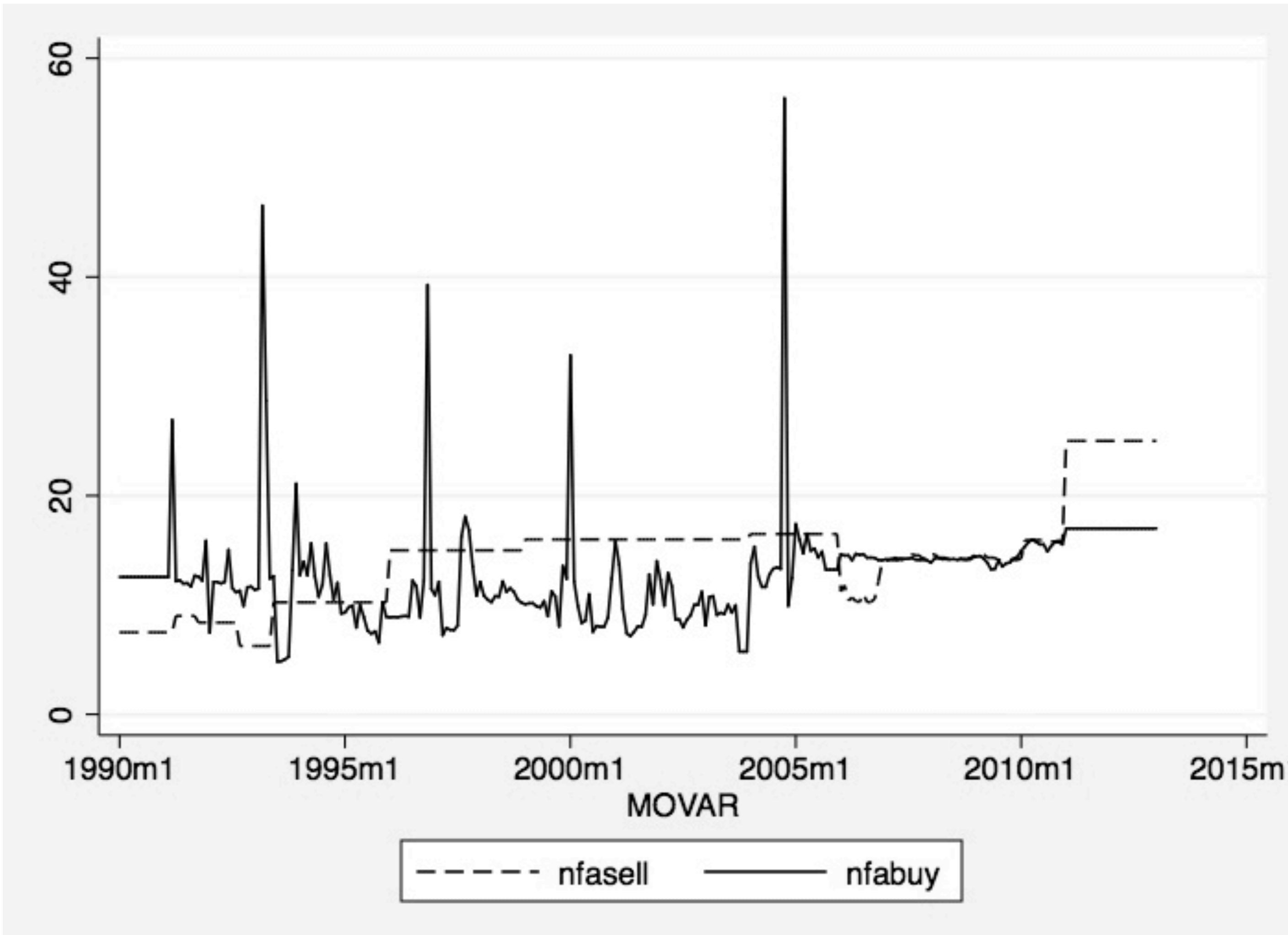


Figure 3.2 Monthly Rice Wholesale Prices for Central Luzon, ARMM, Mimaropa and NCR, 1990-2013

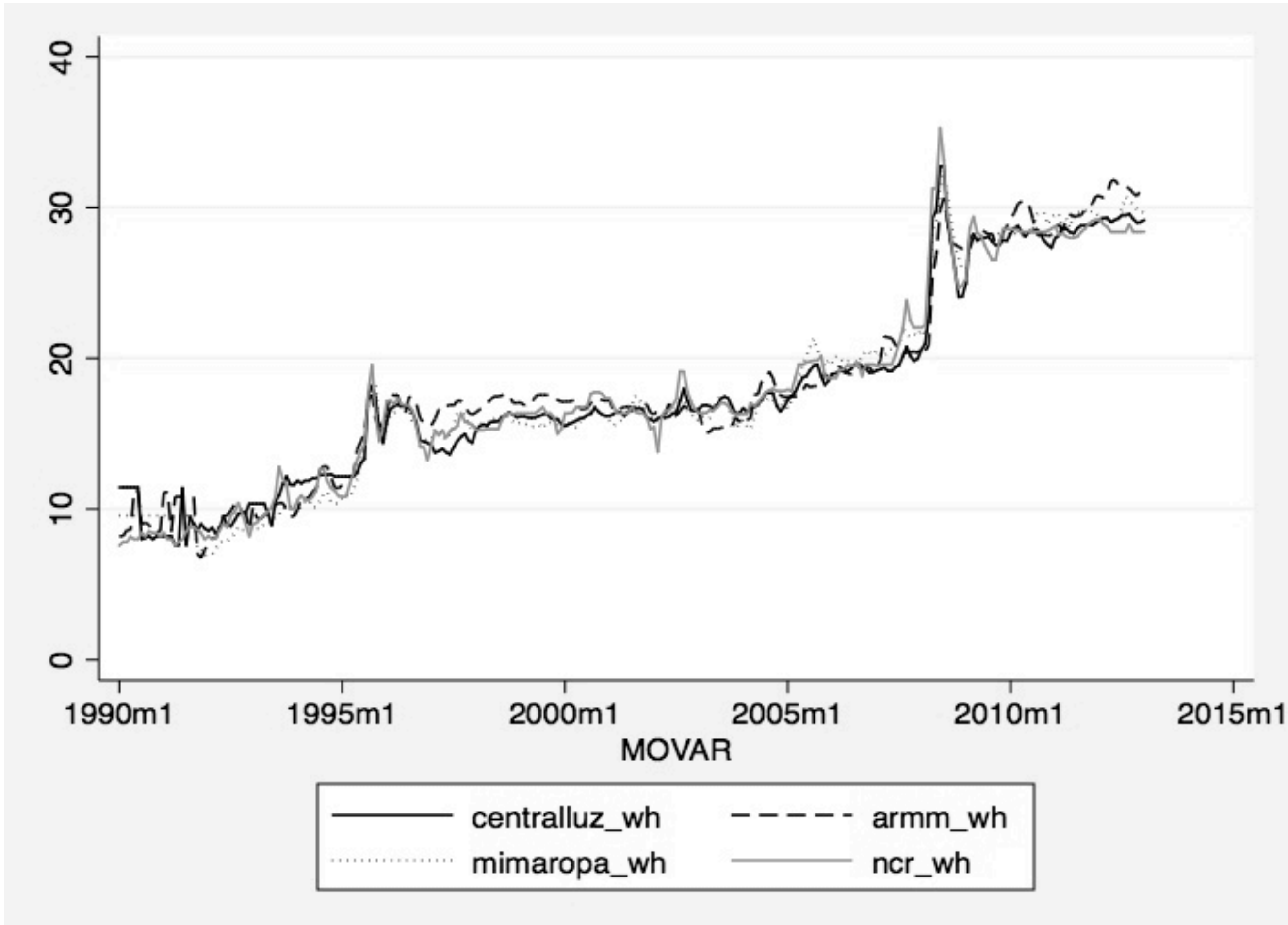


Figure 3.3   Contemporaneous Correlations Identified by the DAG

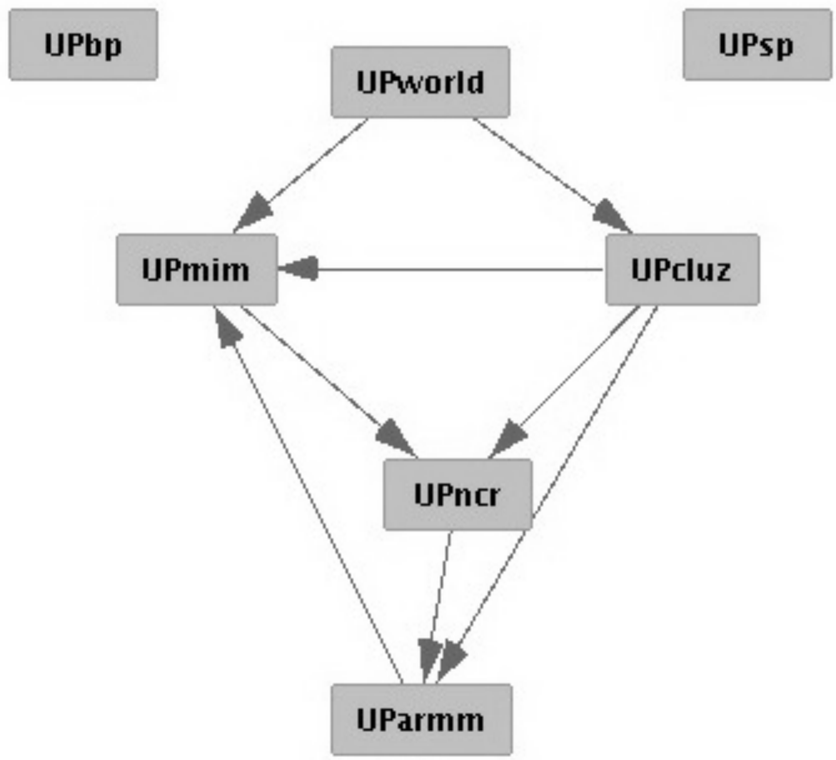


Figure 3.4 Impulse Response Functions

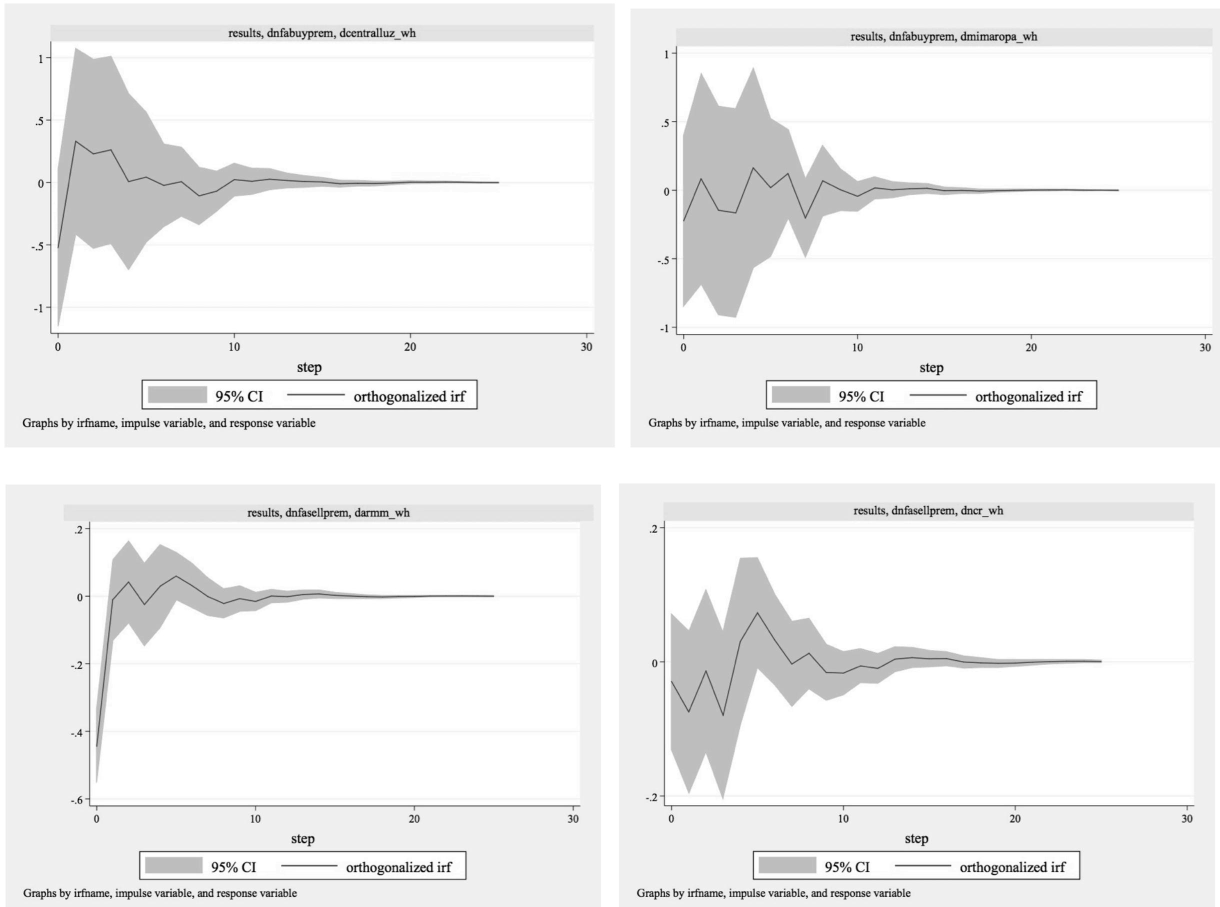


Figure 3.5 Historical and Simulated (No NFA) Prices for Central Luzon

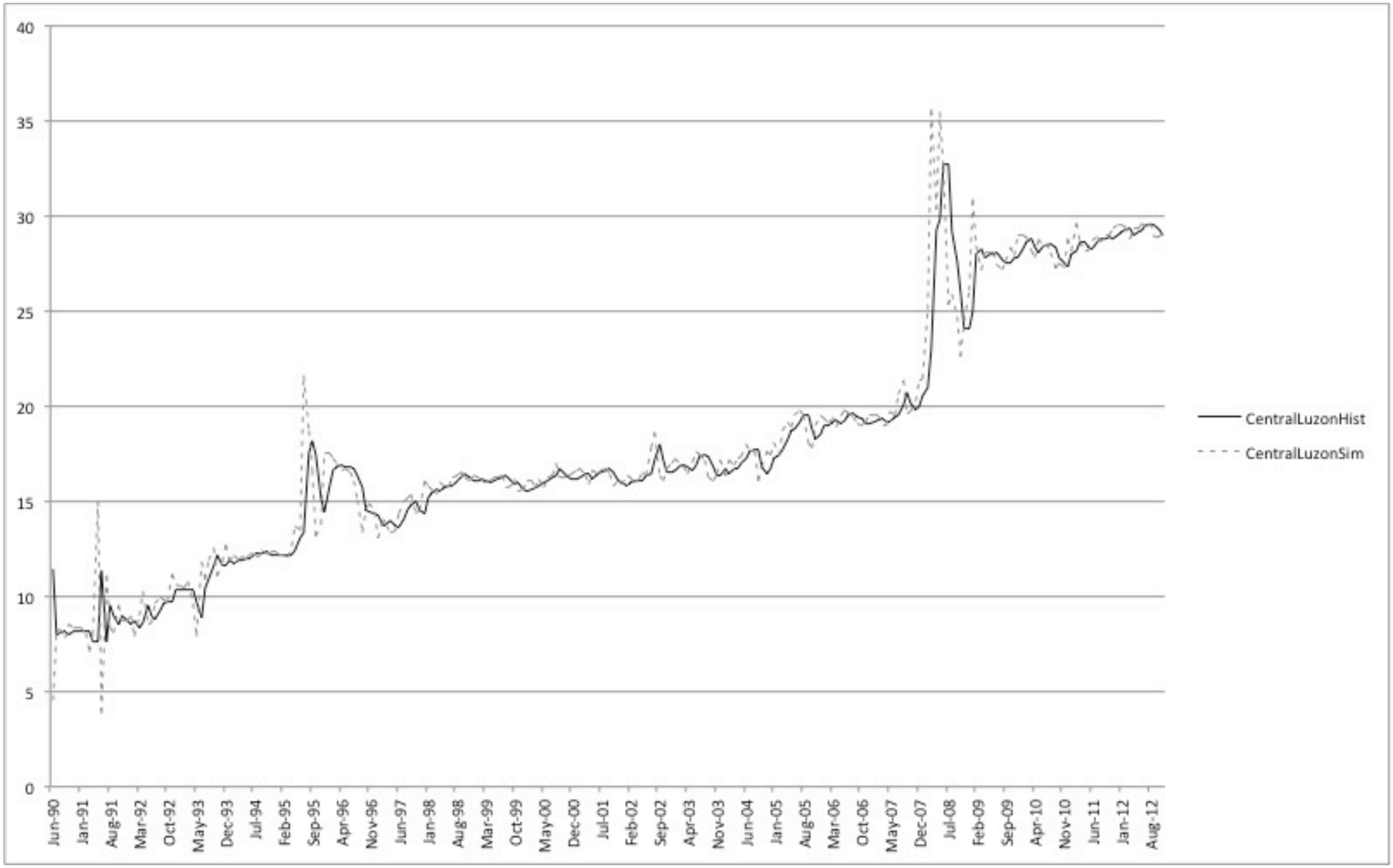


Figure 3.6   Historical and Simulated (No NFA) Prices for ARMM

Figure 3.7 Historical and Simulated (No NFA) Prices for Mimaropa

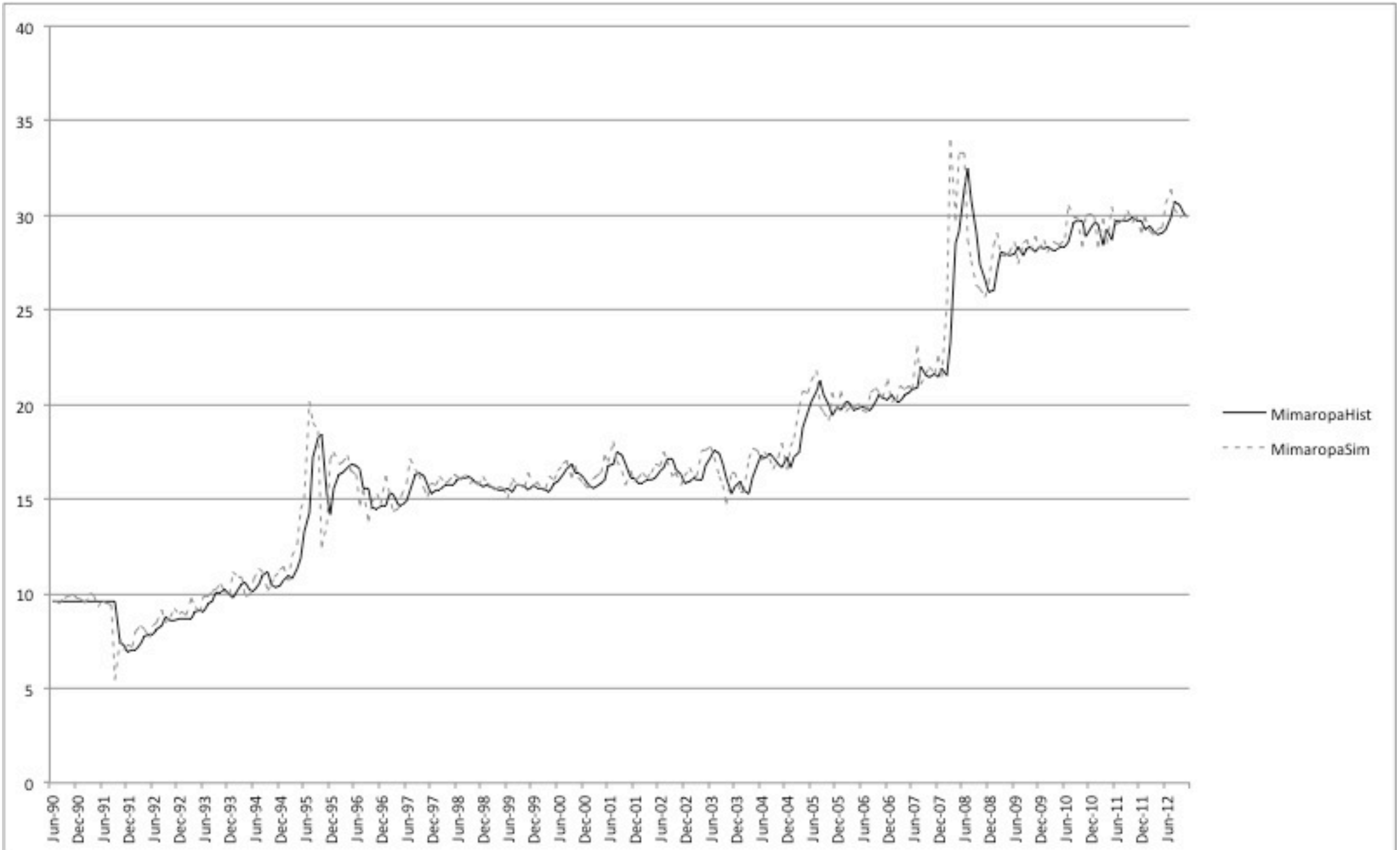


Figure 3.8 Historical and Simulated (No NFA) Prices for NCR

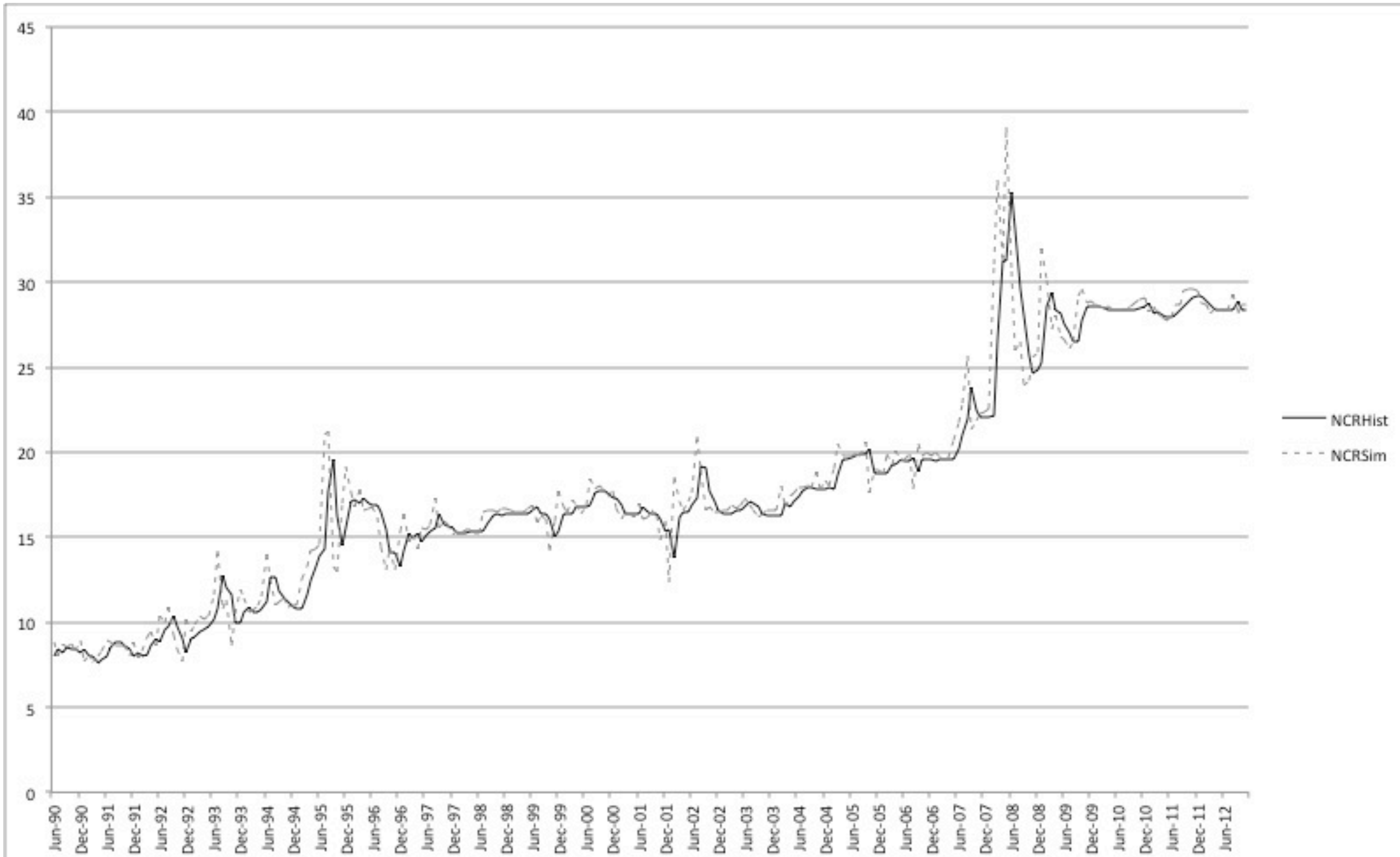
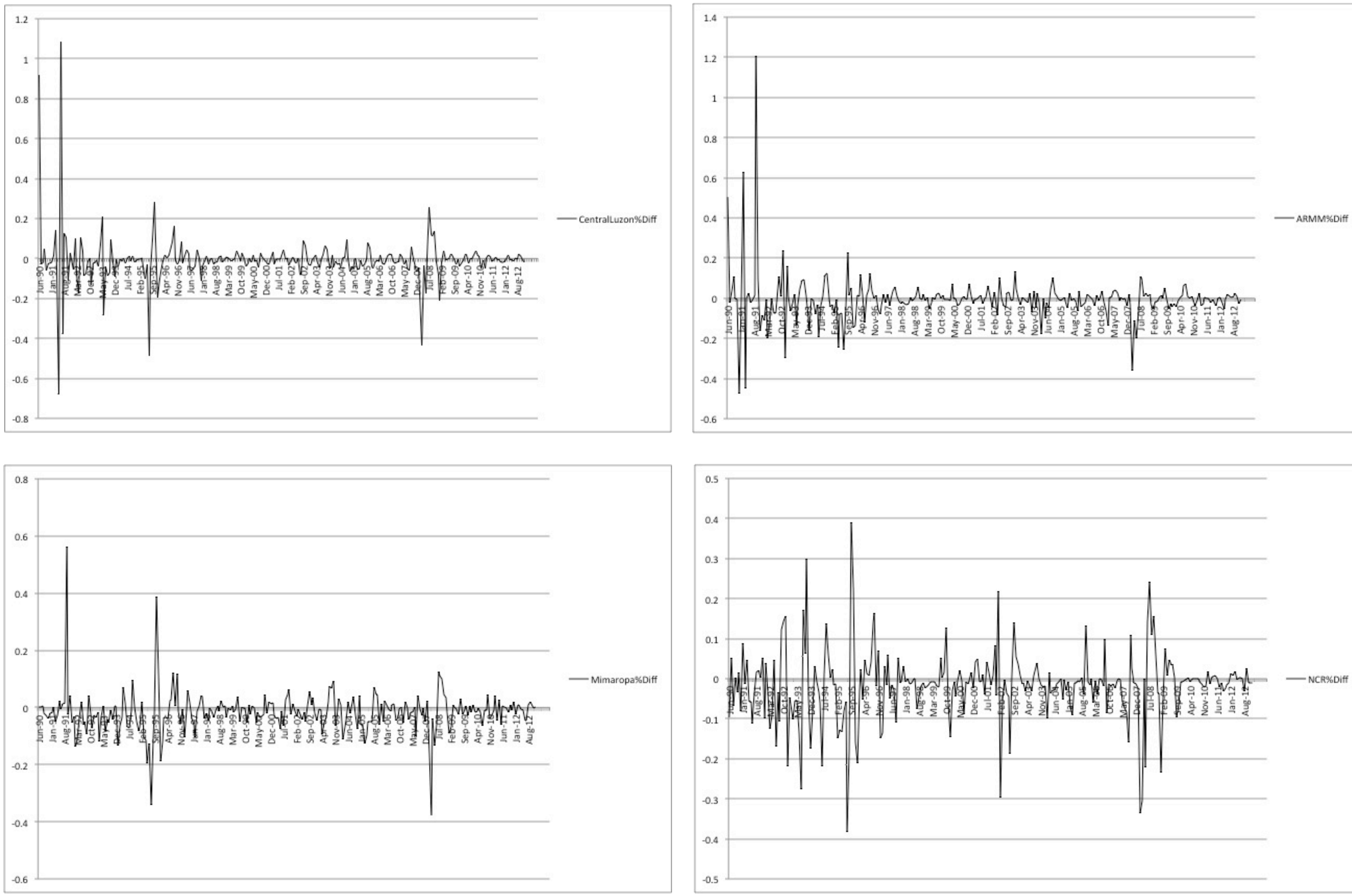


Figure 3.9 Percentage differences of the historical and simulated prices (ln historical/ln simulated)



Chapter 4

IMPACT OF THE WHEAT AND RICE EXPORT BAN ON INDIAN MARKET INTEGRATION

4.1 Introduction

In response to the dramatic increase in world grain prices in 2007 and 2008, many governments restricted exports to ensure sufficient domestic food supplies (Abbott, 2009; Abbott, 2010). In 2007, India, one of the world's largest grain exporters, banned exports of wheat and some varieties of rice, lifting the ban only four years later in September 2011 (Chand, 2009 and Chand et al, 2010). While a few papers explore the effect of export bans on world commodity prices (Gotz, Glauben and Brummer 2010; Abbott 2010; Liefert et al 2012; Martin and Anderson 2012; Welton 2011; Djuric 2009 and 2011), I empirically estimate how the Indian export ban affected not only the integration of the domestic market and the world market but the integration within the domestic market. Understanding the spatial effects of an export ban can better inform countries of the true costs and benefits of this form of blunt trade instrument on their own markets.

For domestic producers to benefit from international trade, markets need to be both open and spatially integrated (Gonzales-Rivera and Helfand, 2001; Asche, Bremnes and Wessells, 1999; Sexton, King and Carmen, 1991; Ravallion, 1986). In an integrated spatial market, prices are determined simultaneously in different locations (Liu, 2003). Large price spreads induce product movement from one location to another. However, in the absence of spatial market integration, price information may be conveyed inaccurately distorting decisions of economic agents, which could lead to inefficient product movements. In agriculture, geographic markets are relevant because most agricultural products are either bulky or perishable. Areas of production and consumption are generally separated; hence, large transaction costs exist. Thus, it is useful to know if and how government market interventions affect market integration and thus the efficiency of domestic markets.

Both wheat and rice are important grains for India. India is second largest producer of rice in the world accounting for 20% of world supply and the third largest producer of wheat accounting for 12% of world supply (Cagliarni and Rush, 2011). In terms of consumption, rice is the staple for the eastern and southern parts of the country while wheat is the staple for the northern parts of the country (Cagliarni and Rush, 2011). Because of the important role of these grains in local consumption and household food security, the Indian government has traditionally intervened when domestic markets face large price increases.

Countries impose export bans to insulate the domestic price from international price volatility and ensure availability in the domestic market at a lower than world price. Along with exacerbating the increase in world prices, export bans may have unintended consequences for the domestic market, such as increasing domestic price volatility due to the inability of the world market to mitigate against short run supply shocks and exacerbating existing market inefficiencies (Welton, 2011). If commodities cannot move freely within the country, export restrictions may increase price differentials (Porteous, 2012).

Furthermore, Indian agriculture is highly regulated by production and consumption subsidies, minimum export prices and domestic trade restrictions (Acharya et al., 2002; Kubo, 2011). According to Kubo (2011), given the already limited efficiency of domestic agricultural markets within India, the export ban might have further exacerbated market distortions.

In the case of India, the impacts of the export ban might differ between the two crops.

Prior to the 2007 export ban for wheat, the level of wheat exports was already quite low due to India's stagnant wheat yield and declining planted acres from 1996 to 2006. As a result, the Indian government actively imported wheat to slow the rising domestic prices in the wake of a production shortfall and widespread hoarding by traders (Western Australia Trade Office). The government even reduced the import tariff on wheat to zero to encourage the private sector to import wheat. Appendix Figure C4 presents imports and exports vis-à-vis wheat production from 1996-2013. Thus, there was a reversal of trade flows for wheat prior to the ban, raising the question of whether the ban was, in fact, binding. Conversely, rice was actively being exported right up to the moment of the ban.

Several authors find that market liberalization generally increases market integration (Goleti and Babu, 1994 for Malawi; Dercon, 1995 for Ethiopia; Alexander and Wyeth 1994 for Indonesia). Welton (2011) explicitly considers the effect of an export ban on domestic prices and price volatility in the case of Russia. Using a detailed description of the ban and following market changes, Welton (2011) finds that traders stored grain in expectation of the lifting of the ban, limiting the ban's immediate effect on domestic grain prices. Eventually, a supply response led to a sharp fall in domestic price and widened the price gap between domestic and world markets, prompting the government to end the ban. Thus, the Russian export ban led to short run price increases in both the domestic market and world market, and did not successfully isolate the domestic price from the world price in the short run (Welton, 2011).

Few studies analyze the Indian export ban, and those that do are largely descriptive and do not use extensive data (Woolverton and Kiawu, 2009; Dorosh, 2008; Slayton, 2009, Abbott, 2010; Martin and Anderson, 2011; Liefert, Westcott and Wainio, 2011; Clarkson and Kulkarmi, 2012). While Acharya et al. (2002) use farmgate and retail prices for several markets in India to quantitatively analyze the extent of price transmission for rice and wheat, the paper only uses a special reference to the world food crisis of 2007/08 and not the ban per se. They find that while domestic prices did increase during the global food crisis, the increase was considerably less than the increase in the world prices.

In this paper, I ask three research questions: What effect did the Indian export ban have on the integration of domestic markets with the world market? What effect did the export ban have on the integration within the domestic market? Did the export ban worsen the price effects of domestic supply shocks? I see several contributions of the paper. First, I analyze the effect of the export ban not just on the integration of the Indian market with the international market but integration among domestic markets. Not only do I differentiate between producing states and consuming states, I also consider the major port areas, which I expect to be most affected by an export ban. Given that other authors have found little market integration within India (Mallory and Baylis 2012; Sekhar, 2012), I want to differentiate and test for those markets most likely to be integrated with world prices. Second, unlike Acharya et al (2012) I develop a theoretical model to predict the effect of an export ban on price transmission, which incorporates trading regimes and discontinuity. Finally, I also test for the effects of domestic supply shocks on domestic prices during the export ban period. To my knowledge, this paper is one of the first to econometrically explore the domestic market effect of an export ban.

I begin by modifying a simple model of spatial price transmission from Fackler and Goodwin (2001), and deriving several testable hypotheses about the effect of the ban. I use a linear vector error correction model as a baseline analysis of spatial market relationships. Then I extend the linear framework by testing for thresholds.

A summary of my findings are as follows:

(1) The majority of port markets for rice and wheat are not integrated with the world market during the export ban, whereas a majority of port markets for rice and wheat are integrated with the world market during the open trade period. Moreover, thresholds between port markets and the world market increase during the export restriction. The increase in the price thresholds imply that transaction costs rose between the two markets when exports were restricted.

(2) Fewer port markets are integrated with domestic consuming markets for rice during the export restrictions, than during the open trade period. However, I find the opposite effect for wheat, where a greater number of domestic consuming and port markets are integrated during export restrictions. A plausible reason for this counterintuitive finding is that India actively imported wheat from 1996-2006 (Western Australia Trade Office, 2012).

(3) Fewer producing and consuming market pairs are integrated during the export restrictions as compared to the open trading period, and more producing and port markets pairs are integrated for both crops. This result is in contrast to my hypothesis. Furthermore, wheat thresholds between producing and consuming regions switch signs. Thus, a plausible cause for the unanticipated result in wheat producing and consuming markets is that production even in the supply regions was sufficiently low that they needed to import grains. This result is consistent with our finding for wheat for hypothesis 2 that consuming wheat markets became more integrated with port markets. On the other hand, the decrease in integration between consumer and producer markets and increase in integration between port and producer markets in rice can possibly be explained by active storage.

(4) Price differences between markets might be worsened due to the inability of the world market to mitigate against domestic supply shocks during the export ban. I also test for the impacts of domestic supply shocks on domestic market prices. I find that more producing and consuming markets have significant domestic supply shock effects when the export restrictions are in place compared to when it is not imposed.

4.2 Overview of India's Food Policy and Export Market

India faces long-run problems of domestic malnutrition and household food insecurity. In 2011, India has 224.6 million inhabitants who are undernourished (FAO-SOFI, 2011) and has one of the highest rates of child stunting in the world (Cagliarni and Rush, 2011). Concerns with food insecurity have led the Indian government to be heavily involved in domestic agricultural markets.

India's government food policy consists of two pillars: (1) government procurement of staple crops from farmers and (2) public distribution of these crops (Dorosh, 2009). The government directly purchases unmilled rice or wheat from farmers or traders at organized wholesale markets called *mandis*. In theory, the Food Corporation of India (FCI) and the procurement arms of state governments will purchase an infinite amount of paddy or wheat at the minimum support price (MSP), as long as the grain satisfies a minimum standard called "fair average quality (FAQ)". The MSP is set by the Ministry of Agriculture each year based on recommendations by the Commission on Agricultural Costs and Prices (CACP) based on a cost-plus basis using cost-of-cultivation estimates obtained through farm surveys. The government then distributes grain through the Public Distribution System (PDS) selling the milled grain at government run Fair Price Shops at Central Issued Prices (CIP). The government withholds some stocks of grain from the market as a buffer for food security.

In early 2000, agricultural policy was liberalized in India, including reforms in 2002 that improved mobility of grains across state lines. However, the trend toward liberalization reversed when global prices rose. The reported domestic wheat stock on July 1, 2006 was only 8.2 million tons, less than half of the 17 million ton norm. In that same month, the Indian government increased the level of grain procurement and distributed higher quantities of subsidized rice and wheat to the Fair Price Shops (Chand et al, 2010). To further enhance domestic supply in September 2006, the government reduced the import tariff on wheat to zero and the private sector was encouraged to import wheat.

In February 2007, the government placed an export ban on wheat (Acharya et al, 2012). [See Figure 1 for the timeline of the wheat policy.] The government also increased the MSP for wheat and began to actively import wheat. These efforts only increased the wheat stock slightly; so that by July 1, 2007 wheat stocks were still 4.2 million tons below the July 1 norm (Dorosh, 2009).

India also placed an export ban on non-basmati (ordinary) rice on October 9, 2007 [see Figure 2 for rice policy timeline]. Though the ban was lifted on October 31, 2007, it was replaced with a minimum export price[13] (MEP) of $425 per ton (Sharma, 2011). The MEP was subsequently raised and the export ban on non-basmati rice was reinstated on April 1, 2008 (Dorosh, 2009). In addition, on March 8, 2008, the month prior to the reinstatement of the non-basmati export ban, basmati rice's MEP was raised to $950/ton. Several adjustments were made

[13] Under a MEP, no export is allowed below the set minimum price. The MEP is often used together with an export tax. A low MEP may have little effect on domestic supplies in an implementing country and a very high MEP may result in an export ban. Some countries prefer an MEP to an outright export ban for revenue reasons when world prices are surging as well as to prevent under invoicing (Dorosh, 2009).

and the restrictive MEP for basmati rice continued as well (Sharma, 2011). Due to the export ban and government's active procurement, government's rice stocks grew dramatically, and by mid-2009 they were more than twice as large as the norm (Kubo, 2012). In July 2010 newspapers reported large amounts of rice and wheat rotting in FCIs storage facilities (Kubo, 2012). Despite these high stocks, the *non-basmati* rice export ban and wheat ban were not lifted until July 19, 2011 (Director General of Foreign trade, India government 2012[14]).

Because export ban imposition was not continuous, in this paper, I focus on export restrictions period instead, which started on February 2007 for wheat and October 2007 for rice. I examine domestic market integration prior and during the export restrictions period.

4.3 Data

I analyze domestic impacts of the export ban by using weekly data for major markets in producing states, major retail centers in consuming states and markets in major ports cities for rice and wheat as summarized in Table 4.1a. To capture crucial supply, consumption, and export regions, I select three primary wholesale market centers that supply 35-40% of the rice and wheat to major urban centers in India (Punjab, Uttar Pradesh and Haryana for Wheat; West Bengal, Andrha Pradesh and Uttar Pradesh for Rice). Density maps for major producing states are presented in Appendix Figure C1. I also choose major urban centers for each crop (Delhi, Mumbai and Kolkata for rice and Delhi, Mumbai and Patna for wheat) to take into account the effect of the ban on end consumers. Last, I choose three major ports listed on the 2005 India port report (I-maritime Research). Map of the major ports is presented in Appendix Figure C2. I also substituted closest markets due to data availability.

[14] http://www.aec-fncci.org/index.php?page=news&NewsID=110; http://timesofindia.indiatimes.com/business/india-business/Govt-lifts-ban-on-wheat-exports-Sharad-Pawar/articleshow/9246520.cms

I use local prices from January 2003 to December 2013 from AgMarkNet[15], and the Department of Agriculture website[16]. For the missing price data, I follow the multiple imputation procedure using the Amelia R Package[17] as in Mallory and Baylis (2012). Percentages of missing observations are also summarized in Table 4.1b.

Amelia performs multiple imputation, a general purpose approach to data with missing values. Multiple imputation has been shown to reduce bias and increase efficiency compared to listwise deletion and mean imputation. List-wise deletion requires one to delete an entire row of data even if only one data point is missing and thus could discard much valuable data. On the other hand, linearly interpolating or using mean conditional distribution can reduce the variance of the resulting sample thereby affecting inference (Friedman, 1962; King at al., 2001). Multiple imputation generates *m* completed datasets making random draws from the conditional distribution over the missing data. It also allows for smooth time trends and correlations across time and space (Honaker and King, 2010). The *m* completed datasets are the same for the observed data points, but the missing data are replaced by draws from the posterior density and hence incorporate the relevant level of uncertainty associated with those data points. Detailed graphs for observed and imputed values from Amelia are presented in Appendix Figure C3.

To analyze price transmission from international to domestic markets, I use the weekly world price for rice (Thai rice 5% broken[18]) and wheat (US, No. 2 HRW wheat) from FAO Economic and Social Division[19]. Using the prevailing Indian Rupee-ME $ exchange rate from

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[15] AgMarkNet is the website of the Indian Ministry of Agriculture, http://agmarknet.nic.in/

[16] Retail Price Info System, Directorate of Economics and Statistics, http://rpms.dacnet.nic.in/

[17] http://cran.r-project.org/web/packages/Amelia/citation.html

[18] Thai rice positively correlates with Vietnam rice prices. Overall sample correlation is 95.41% and correlation during the export restriction period is 90.86%.

[19] Food and Agriculture Organization (FAO). 2013. Economic and Social Development Statistics Division, http://www.fao.org/es/esc/prices

the Oanda weekly average exchange rates[20], world prices were converted to Indian Rupee per kilo equivalents. The weekly nominal price series were logarithmically transformed.

I also include rainfall data from the Indian Department of Meteorology for years 2005-2013 and Central Statistical Organization for years 2003 and 2004 to accommodate induced supply shocks in my analysis. Table 4.2 below summarizes the variables used, summary statistics and data sources. Figures 4.3-4.8 depict monthwise domestic price movements for the selected markets in Table 1 vis-à-vis world price and export quantities.

4.4 Conceptual Model for Empirical Strategy and Hypotheses

A simple theoretical model predicts the effect of an export ban on price transmission. I begin by dividing India's grain market landscape into three regions: a supply region (S) with local price P_s, a domestic consumption region (C) with local price P_c, and an export region (X) with local price P_x. The export region can be thought of as the area around the major ports.

From the port market, grains are sold into the world market (W), where they receive price P_w. The cost to move grain domestically, from the supply region to either the consumption or export region, is τ_d. The cost of exporting grain from the port to the world market is τ_w, where τ_w includes the monetary value of any export restrictions.

In this paper, I follow Porteous (2012) and model export ban as an increase in trade cost. My focus is on price differences rather than prices themselves in analyzing the mechanics of how these policies actually affect agricultural markets while avoiding potential endogeneity issues. Drawing on the spatial price analysis literature, I develop a theoretical model to show how export bans affect the total trade costs (unobservables) and how total trade costs determine price

[20] Oanda Average Exchange Rates, http//www.oanda.com/currency/average

differences (observables) across different markets. I argue that the timing of the export ban is plausibly exogenous to price differences. The Indian grain market landscape is illustrated in Figure 4.9.

A trader in a producing region can chose to sell to the domestic market or to the port market, where he will receive P_c less per unit domestic transaction costs τ_d, or P_x less per unit transaction costs τ_d, respectively. The trader in a producing region will chose quantities to sell to each market to maximize their profit:

$$\Pi\left(q_{ct}, q_{xt}\right) = P_{c,t+k} q_{ct} + P_{x,t+j} q_{xt} - \tau_d q_{ct} - \tau_d q_{xt} \qquad (4.1a)$$

Where q_{ct} is the quantity sold in the domestic market and q_{xt} is the quantity sold in the port market at time t and $P_{i,t+k}$ is the price received upon delivery in market i, k periods after *t*.

On the other hand, a trader in an port region can chose to sell to the domestic market or to the world market, where he will receive P_x less per unit domestic transaction costs τ_d, or P_w less per unit transaction costs $\tau_d + \tau_w$, respectively. The trader in a port region will chose quantities to sell to each market to maximize their expected profit:

$$\Pi\left(q_{ct}, q_{wt}\right) = P_{c,t+k} q_{ct} + P_{w,t+j} q_{wt} - \tau_d q_{ct} - (\tau_d + \tau_w) q_{wt} \qquad (4.1b)$$

Where q_{ct} is the quantity sold in the port market and q_{wt} is the quantity sold in the world market at time t and $P_{i,t+k}$ is the price received upon delivery in market i, k periods after *t*.

Taking first order conditions, the trader will chose the quantities to sell by equalizing the marginal profit in each market. In general, for any market pair, *a* and *b*, they will set the expected difference in discounted prices net of transaction costs to zero:

$$E_t = \left\{P_{a,t+k} - P_{b,t+j} + \tau_{a\rightarrow b}\right\} = 0 \tag{4.2}$$

where $\tau_{a\rightarrow b}$ is the total trade cost of moving the good from market *a* to *b*. The above relation implies that the difference in the prices for two markets is simply the cost of transporting the good (Fackler and Goodwin, 2001). The relationship in equation (4.2) relates to the Law of One Price model, which postulates that allowing for transporting cost τ, transporting commodity between two markets, the relationship between the prices is as follows:

$$P_{bt} = P_{at} + \tau \tag{4.3}$$

Following Baulch (1997) and Barret and Li (2002), I recognize that there may be different possible trading regimes and/or discontinuities based on relative magnitude of actual observed price difference, unobserved trade costs and domestic shocks. For any two market pairs, *a* and *b,* trading regimes are illustrated in equation (4.4).

$$P_{bt} - P_{at} = \tau + \varepsilon \begin{cases} \text{Case 1: } P_{bt} - P_{at} = \tau + \varepsilon & \text{Perfect Integration} \\ \text{Case 2: } P_{bt} - P_{at} < \tau + \varepsilon & \text{No incentive to trade} \\ \text{Case 3: } P_{bt} - P_{at} > \tau + \varepsilon & \text{Incentive to trade} \end{cases} \tag{4.4}$$

In case 1, markets exhibit perfect market integration. In other words, the grain is tradable between two markets and the price increases one for one with an increase in trade costs. In case 2, there is no incentive to trade because the price difference between the markets is smaller than the trade costs. In this case, prices are determined by local supply and demand, and price differences are unaffected by changes in trade costs. In case 3, the price difference is greater than the trade cost, thus it signals positive marginal profits to spatial arbitrage. For cases 1 and 3, the relationship between the trade costs and price differences is straightforward. Traders transport the grains according to expected price differences, but production shocks may cause those price differences to be larger or smaller; that is the error term maybe greater than or less than zero $(\varepsilon > 0 \text{ or } \varepsilon < 0)$. In case 2, when there is no incentive to trade, price movements between markets and within the transaction cost will be most likely unrelated. In other words, the markets will not be integrated.

Significant anecdotal evidence indicates that the Indian national border was porous even during the export ban, and export bans were never completely enforced over time (Kubo, 2011; Dorosh, 2009). Therefore, I expect the primary effect of the export ban to be reflected in prices at the port, where P_x should drop by the change in τ_w. Thus, the export ban increases the price difference between the world and the domestic markets. Given that prices include a stochastic component, this increased price wedge may lead to lack of market integration between world market and port markets. From this discussion, I obtain my first hypothesis.

Hypothesis 1: Fewer world and domestic market pairs exhibit integration during the export ban. Further, if the market pair exhibits threshold integration before and after the ban, the threshold will be larger when export ban is in place than when it is not in place.

Next, I explore how the ban might differentially affect prices within India. Assume that grain movement takes time, and that at the moment the export ban was imposed, some grain is sitting at port. The value of this stored grain is determined by the world price less the cost of exporting, $P_w - \tau_w$, and therefore the value of stored grain decreases with the imposition of the export ban given that I view export ban as an increase in transaction cost. Moving this grain to the domestic consumption region is not costless, and a trader will only ship the grain today if the expected price in the domestic market less the domestic cost of moving grain is higher than the expected discounted future world price less future export cost. Thus, the grain will only move if:

$$E(P_{c,t} - \tau_d) \geq E\delta^k(P_{w,t+k} - \tau_{w,t+k}) \quad (4.5)$$

As is the case of the Russian export ban on wheat, a trader may have the incentive to store the grain at the port instead of moving it to the domestic market if they expect the export ban to be lifted in the near future. At a minimum, the price in the consuming region has to be τ_d higher than the price at the port, P_x to induce the movement of grain from port. Thus, if grain movement takes time and prices are uncertain, the export ban may make domestic market prices more 'sticky'. Moreover, if τ_d is low enough to cause influx of supply in the domestic consuming market, I expect it to drive down Pc, but perhaps not to the same degree as it affects prices in the port market, P_x. Thus, the export ban increases the price difference between the port markets and domestic consuming markets, which will result in their lack of market integration.

Hypothesis 2: Fewer port markets and domestic consuming market pairs will be integrated during the export ban. Further, if the market pair exhibits threshold integration before and after the ban, the threshold will be larger when export ban is in place than when it is not in place.

After the imposition of the export ban, farmers will be less likely to ship grain to the ports with the increase in trade costs, making the domestic market their primary sales outlet.

Hypothesis 3: When the export ban is in place, more producing and consuming market pairs will be integrated, and less producing markets and port markets will be integrated. For market pairs which exhibit threshold integration before and after the ban, the threshold between producing and consuming market pairs will be smaller and the threshold between producing and port markets will be larger when export ban is in place than when it is not in place.

The amount of rainfall is significantly correlated with agricultural production in India (Cagliarni and Rush, 2011) as seen in Figure 4.10. Gulati et al. (2013) and Bhattacharya et al.

(2011), both emphasize domestic supply shocks through droughts and deficient rainfalls as one of the most important variables affecting food price inflation in India.

Hypothesis 4: When the export ban is in place, more domestic producing and consuming markets will have significant domestic production shocks coefficients than when it is not in place.

4.5 Methods

The estimation strategy can be summarized as follows: First, because the paper aims to test for impacts of the export ban and the export ban was not continuous, I divide the data into two periods: export restrictions period (ER) and open trade period (OT). I call it export restrictions period to take into account other trade policy changes during the export ban period (i.e. wheat export quotas for month of July 2009 and rice minimum export prices for months of November 2008-March 2009). On the other hand, the open trade period covers the weeks prior to the imposition of the ban[21]. However, for wheat, since exports are significantly reduced even before the export ban was in place (see Figure 4.1 and Appendix Table C3), I redefine export restrictions period as "effective" export restrictions period. So that open trade period for wheat includes weeks in between January 2003 to July 2005 and export restrictions period includes weeks in between August 2005 to August 2011. On the other hand, open trade period for rice includes weeks in between January 2003 to September 2007 and export restrictions period includes weeks in between October 2007 to August 2011. These cutoffs are based on timeline of export restrictions based on several publications and compilation of news articles (Appendix C1) and what I deem is "effective" export restrictions period for wheat (Figure 2.1 and Appendix Table C3).

[21] The post-ban period is too small to allow empirical analysis.

Second, I generate all possible market pairs for each crop (producing and consuming market pairs, producing and port market pairs, port and consuming market pairs, and port and world market pairs). The pairing results into 30 market pairs per crop.

Third, I perform both the linear and threshold cointegration tests for each market pair and synthesize the cointegration results by reporting the number of market pairs that were cointegrated. This was the most sensible way of presenting results from over 100 cointegration tests. In addition, I compare the thresholds estimates for market pairs which exhibit thresholds in both periods.

Finally, I compare the coefficients' significance of domestic production shock effects for ER and OT periods. Similar to integration results, I synthesize the result by reporting the number of producing and consuming markets with significant domestic supply shock effects.

4.5.1 Domestic Market Integration

I test my first, second and third hypotheses using market integration framework. In order to determine whether the market price series are stationary, standard Augmented Dickey-Fuller (ADF) unit root tests are used. I test for linear cointegration between markets price pairs using Johansen cointegration model. The tests were carried out for all possible market pairs.

Let $p_t = (p_1, p_2)'$ be a two-dimensional vector of price series for a price pair p_1 and p_2. The linear Vector Error Correction Model (VECM) of order l+1 can be written as follows:

$$\Delta p_t = \mu + \alpha w_{t-1} + \sum_{i=1}^{l} \Gamma_i \Delta p_{t-i} + u_t \qquad (4.6)$$

where $E_{t-1}(u_t) = 0$. The long run relationship is defined as

$$w_t = (1-\beta) p_t = p_1 - \beta p_2 \qquad (4.7)$$

which is stationary as discussed by Engle and Granger (1987). The term w_{t-1} represents the error correction term obtained from the estimated long-term relationship between the two price series. If $\beta = 1$, the long run relationship implies a one-to-one responses between the two price series. The mean-reverting behavior depends on the adjustment vector α in the linear VECM. If it is close to 0, the equilibrium error is likely to be persistent. The parameters are estimated by maximum likelihood under the assumption that errors u_t are iid Gaussian. I use the Johansen test to test the null hypothesis that there are at most *r* cointegration vectors in the system.

The concept of threshold cointegration was introduced by Balke and Fomby (1997) as a way of combining cointegration and non-linearity. In this paper, I use Hansen and Seo's (2002) bivariate two-regime, threshold vector error-correction model (TVECM) to test for non-linear cointegration among all market pairs. The two-regime TVECM allows one to characterize a trading environment in which trade between spatially separated markets only occurs when relative prices exceed some level of transaction costs. As in equation (4.4), trading regimes occur based on the relative magnitude of actual observed price differences and unobserved trade costs.

The representation of the VECM with a two-regime threshold is given as:

$$\Delta p_t = \begin{cases} \mu_1 + \alpha_1 w_{t-1} + \sum_{i=1}^{l} \Gamma_{1i} \Delta p_{t-i} + u_t & \text{if} \quad \mathrm{w}_{t-1} \le \hat{\tau} \\ \mu_2 + \alpha_2 w_{t-1} + \sum_{i=1}^{l} \Gamma_{2i} \Delta p_{t-i} + u_t & \text{if} \quad \mathrm{w}_{t-1} > \hat{\tau} \end{cases} \qquad (4.8)$$

The coefficient matrices α_1 and α_2 relates to the dynamics in the regimes. Values of the error correction term w_{t-1} could either be above or below the threshold parameter, $\hat{\tau}$. Except for the cointegrating parameter β, the system allows all coefficients including w_{t-1} to switch between the regimes.

Threshold effect exists if $0 < P\left(w_{t-1} \leq |\tau|\right) \leq 1$, otherwise a linear cointegration model is more fitting. This constraint is imposed assuming that $\pi_0 < P\left(w_{t-1(\beta)} \leq |\tau|\right) \leq (1-\pi_0)$ by setting $\pi_0 > 0$ as a trimming parameter equal to 0.05 in the empirical estimation. This value follows Hansen and Seo (2002) which implies that each regime is restricted to contain at least 5% of the observations. Assuming the errors, u_t, are iid Gaussian, the model is estimated by maximum likelihood.

A grid search algorithm is used to obtain MLE estimates of β and τ (Hansen and Seo, 2002). The grid search requires a region over which to search. Thus, two confidence intervals, $[\tau_L, \tau_U]$ and $[\beta_L, \beta_U]$, are constructed for τ and β respectively. Notation *L* and *U* represent lower and upper values. The grid search procedure over (τ, β) examines all pairs (τ, β) on the grids $[\tau_L, \tau_U]$ and $[\beta_L, \beta_U]$ subject to constraint $\pi_0 \leq P\left(w_{t-1} \leq \tau\right) \leq 1 - \pi_0$. In the empirical application the grid search procedure is carried out with 300 grid points as in Hansen and Seo (2002).

Once β and τ have been estimated, I proceed to test for the presence of threshold cointegration using the Lagrange multiplier (supLM) test provided by Hansen and Seo (2002) where the null hypothesis of linear cointegration is tested against the alternative of threshold cointegration. I also use the Sup-Wald test by Seo (2006), where the null hypothesis of no cointegration is tested against threshold cointegration using a bootstraped distribution.

4.5.2 Domestic Production Shocks

Similar to Loening at al. (2009), I use a high-frequency rainfall data transformation as a direct proxy for agricultural supply. Food crop agriculture in India is overwhelmingly rainfed so that conditional on planting decisions, yield variation is high and dependent on rainfall variation. .

To test my fourth hypothesis (i.e. domestic production supply shocks have more effect on prices in the production and domestic consumption regions during export restrictions period), I model rainfall variable as an exogenous variable in a Vector Autoregression (VAR) of all domestic prices.

The choice between VECM and VAR lies in the research question I am trying to answer. The foremost advantage of VECM is that it has nice interpretation with long term and short term equations. Thus, VECM is mostly used for cointegration analysis. On the other hand, VAR is commonly used for analyzing the dynamic impact of random disturbances on the system of variables (Enders, 2010). Thus, while I use VECM to test my first three hypotheses, I use VAR to test my fourth hypothesis.[22]

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[22] In Dave Giles blog on how to effectively randomize the choice of a VAR or VECM model, he finds that the practice of pretesting for cointegration can result in severe overrejections of the noncausal null, whereas overfitting results in better control of the Type I error probability with often little loss in power." (Clarke & Mirza, 2006, p.207.) Thus, he suggests in some cases, VAR is preferred over VECM in testing for causality.

4.6 Diagnostic Tests

I first test for the order of integration. I apply a number of tests, namely Augmented Dickey Fuller (ADF) test (Dickey and Fuller, 1979) and the $Zt - Z\rho$ tests by Phillips and Perron (1988).[23] Table 4.3 presents the summary for the unit root tests. The unit root statistics for all variables and both their levels and differences are presented in Appendix Table C2 (one that includes constant and trend, one includes constant but no trend and one that excludes both constant and trend). I perform the test for variables in levels, logarithmic transformation of the variables and variables in differences. The ADF test is performed by including up to 10 lagged terms of the differenced terms in the regression and I use the information criterion test that yielded the most conservative results. In my case, it is the Akaike Information Criteria (AIC) to choose the appropriate lag length by trading off parsimony against reduction in the sum of squares and a lag length where autocorrelation is not present. The ADF test statistics presented in Table 4.3 correspond to the regression that has the maximized AIC. On the basis of both ADF and Phillips and Perron tests, both with and without deterministic trend, I conclude that there is insufficient evidence to reject the null hypothesis of non stationarity for all price series. Moreover, both tests reject the null, indicating that all the price series are unit roots.

Knowing that the variables are integrated to the same order, I can proceed Johansen's cointegration tests to find cointegrating vectors that posit non-spurious long-run relationships among variables. Lag order for the test for each market pair were chosen by Akaike Information Criteria. But I also perform Lagrange multiplier test for autocorrelation and chose the lag that

[23] ADF is the most commonly used test, but sometimes behaves poorly in the presence of serial correlation. Dickey and Fuller correct for serial correlation by including lagged differenced terms in the regression, however, the size and power of the ADF has been found to be sensitive to the number of these terms. The Phillips and Perron tests are non parametric tests of the null of the unit root and are considered more powerful, as they use consistent estimators of the variance (Rapomanikis et al, 2003).

was sufficient to eliminate autocorrelation the in residuals. Results are presented in Tables 4.4a and 4.4b.

4.7 Estimation Results

4.7.1 Number of Integrated Market Pairs

In this section, I present the results of Johansen's cointegration rank tests and threshold cointegration tests. I summarize the results as the number of market pairs that are cointegrated for each pair type and crop in Table 4.5a and then list the integrated market pairs in Table 4.5b. More detailed results are in Appendix Table C4. So for example, in Table 4.5a, the first row of the second column means 0 of the 9 possible market pairs for producing and consuming regions are cointegrated during the export restrictions period.

Finding linear cointegration is supportive of the law of one price model, as in equation 4.3. On the other hand, finding threshold cointegration as opposed to linear cointegration is supportive of the segmented equilibrium model, as in equation 4.4. Lo and Zivot (2001) and Taylor (2001) suggest that linear modeling may induce misleading conclusions regarding cointegration if the data generating mechanism is not linear. Thus, I test for both linear and non-linear cointegration for both regimes and make cointegration conclusions based on the preferred model using Hansen and Seo test (2002) and Seo test (2006).

In this section, I also present plausible reasons for my observed results and consider the evidence for each of these plausible explanations when I discuss the relative prices in the following section.

Results from cointegration tests show that less port markets are integrated with the world market during the export restriction period than the open trade period (Table 4.5a's first row for each crop). This finding is consistent with the Hypothesis 1, i.e. that the export ban is likely to result in less integration between port markets and world markets.

Hypothesis 2 posits that the export ban results in a lack of market integration between the port markets and the domestic consuming markets. In table 4.5a, third row of each crop, I find that the hypothesis holds for rice but not for wheat.

Faced with an export ban a rice trader has two choices: (1) store grain stocks that are already at the port in anticipation of the ban being lifted which leads to leads to less integration or (2) move the grain back to the interior to sell to domestic markets, which could still manifest in integrated markets but with relative prices favoring grain flow in the other direction. Thus, if grain movement takes time and prices are uncertain, the export ban may make domestic market prices more ‘sticky’. Thus, the export ban could possibly increase the price difference between the port markets and domestic consuming markets, which will result in their lack of market integration.

On the other hand, a plausible reason for the contrary effect on wheat (more producing and port market pairs exhibit integration) is that grain movement flowed in the opposite direction with India’s active importation. From 1996-2006, India’s wheat yield remained stagnant and planted acres steadily declined (www.indexmundi.com). As a result wheat production lagged behind consumption from 2001-2006, resulting in beginning stocks dropping from a record 23.0 metric million tons in 2002/2003, to a 40 year low of 2.0 MMT by 2006 (Western Australia Trade Office)[24]. In February 2006, the Indian government announced a decision to import wheat to arrest rising domestic prices in the wake of a production shortfall and widespread hoarding by

[24] Western Australia Trade Office. January 2012. India Wheat Market Report. http://www.dsd.wa.gov.au/documents/India_Wheat_Market_Report_January_2012.pdf

traders (Western Australia Trade Office). Appendix Figure C4 presents imports and exports vis-à-vis wheat production from 1996-2013. Also, examining the actual relative prices show that wheat prices in the main Indian consuming regions are higher than the wheat world prices during the export restrictions period. On average, wheat world price during export restrictions period is 11.70 Rs/kilo while average prices in Delhi, Mumbai and Patna are 14.82, 19.12 and 15.57, respectively.

Finally, for the third hypothesis, i.e. more producing and consuming market pairs and fewer producing and port market pairs are integrated during the export restrictions period, I find the contrary result for both crops. During the export restrictions period, fewer producing and consuming market pairs are integrated and more port markets and producing markets are integrated for both crops as is shown in first two rows of Table 4.5.

A plausible explanation for the counterintuitive finding in rice is that since rice is a storable grain and the export ban was not instituted continuously, traders may have continued to move rice to the port despite the ban being in place in anticipation of port markets opening up. Examining the price differences between rice world market and rice consuming markets during the export restrictions period reveal a substantial difference in favor of the world prices. Thus, storage is a plausible story for rice. However, because wheat is being imported during the export restrictions period, wheat warrants more discussion by examining thresholds and relative prices.

4.7.2 Threshold Cointegration Results

To further assess hypotheses 1-3, I analyzed the threshold cointegration results by comparing the estimated threshold parameters before and after the ban in conjunction with comparing the relative prices of the market pairs. The estimated beta from the cointegrating vector, estimated thresholds, and proportion of weeks when there is incentive to trade consistent with the conceptual model and equation 4.4 are presented in Table 4.6.

The proportion of weeks in which there is incentive to trade was determined by counting the proportion of observations for which $\beta * P_{bt} - P_{at} > \tau$, where b is the destination market and a is origin market.

For instance, in Table 4.6a's first row, for a rice producing and consuming market pair, Burdwan and Delhi, the estimated beta from the cointegrating vector is 1.27 during the export restrictions period. There is no estimated threshold and thus no estimated proportion of weeks when there is incentive to trade during the export restrictions period since a linear model was preferred in this case.

During the open trade period, the beta from Burdwan and Delhi's estimated cointegrating vector is 0.89 with a threshold of -1.70. The proportion of weeks in which there is incentive to trade was determined by counting the proportion of observations for which ($0.89*P_{Delhi}-P_{Burdwan}>-1.70$), which is 93% in this case. The highlighted market pairs in Table 4.6 are those for which the threshold model is preferred to the linear model in both the ER and OT periods.

The sign on the threshold parameter provides some intuition as to the direction of trade flows between markets, particularly when the sign reverses between the open trade period and the export restriction period. In table 4.6, say for Ludhiana and Delhi for wheat, during the export restrictions period, the estimated threshold is -1.64 and the estimated cointegrating relationship is $w_t = P_{delhi}-0.66*P_{ludhiana}$. The sign of the threshold has switched from positive in the open trade regime to negative in the export restriction regime, suggesting that the incentive for grain to flow from Ludhiana to Delhi in the open trade period was reversed in the export restriction period. Here, 92% of the total observations occur when 0.66 times the market price in Ludhiana is more than 1.64 above the price in Delhi. This is the case where incentives are for grain to flow are from Delhi to Ludhiana, and is displayed in column 5 of table 4.6b. Conversely, 8% of the total observations occur when 0.66 times the market price in Ludhiana is more than 1.64 below the price in Delhi. This is the case where incentives are for grain to flow from Ludhiana to Delhi.

Hypothesis 1 states that for port and world market pairs where the threshold model was preferred to the linear model, the threshold would be larger in the export restriction regime than in the open trade regime. We find evidence in support of this hypothesis for one of the market pairs. The other market pairs either did not favor a threshold specification in one of the periods, or the estimated threshold was larger in the open trade regime. The evidence for the wheat market pair, Kachch and World is in table 4.6b. The threshold during the export restrictions period was larger than the threshold during the open trade period, which implies that the transaction cost between the two markets is higher during the export restrictions period. Consistent with increased transactions costs, we find that the proportion of weeks in which the relative prices indicate a possible incentive to trade between Kachch and world market is also higher in the open trade period than export restrictions period.

Hypothesis 2 could not be explored via the threshold models because none of the port and consuming market pairs for either crop exhibited thresholds both before and after the ban.

Hypothesis 3 states that for market pairs which exhibit threshold integration before and after the ban, the threshold between producing and consuming market pairs will be smaller during the ban and the threshold between producing and port markets will be larger during the ban than when it is not in place. In the case of rice, thresholds increased between producing and port markets during the export regime period. While in the case of wheat, thresholds decreased between producing and consuming market pairs during the export restrictions regime. Note also that the threshold sign for wheat during the export restrictions regime is negative.

One possible explanation for wheat producing and consuming markets is that production even in the supply regions was sufficiently low that they needed to import grains. This importation into producing regions could have plausibly led to more price integration between port and producing regions.

4.7.3 Robustness Tests

One might be concerned that the results of number of significant market pairs are driven by the nature of the imputed data. As a robustness check I look at market pairs with less imputed data, thus having fewer missing observations as in Table 4.1b, and find that thresholds exist in those pairs in much more frequency. For instance, during the ER period for rice, there were three market pairs which exhibit threshold integration, namely Mumbai-Burdwan, Mangalore-Bijnaur, Vadodara-Bijnaur. In all the three market pairs in the ER period for rice, the percentage of missing data range from 2.48% to 16.83%. For wheat during the ER period, with the exception of Kachch-World market pair, the market pairs exhibiting thresholds are those pairs with less imputation. I find the same story for both crops during the OT period.

Another concern is the close correlation in ports and consuming markets. To acknowledge this, I compare the population size[25] of the pseudo (or proxy) port markets and the

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[25] **Actual Intended Port Markets:** Managalore, Karanataka (484,785); Cochin, Kerala (601,574); Kandla, Gujarat (15,782); Haldia, West Bengal (200,762); As we could not find price data for these markets, we used

actual port markets. While I find that some of the counterintuitive results come from those pseudo port markets (proxy cities) that happen to have large domestic populations and therefore can be thought of as consuming markets (i.e. Mysore-World during OT period and Kachch-World during ER period), results from other market pairs were as expected, despite having large domestic populations.

4.7.4 Domestic Production Shocks Results

Increased price differences might be worsened due to the inability of the world market to mitigate against domestic supply shocks. I test for the impacts of short run supply shocks on the market prices and find that domestic supply shock effects in prices are mostly felt in producing and consuming states during ER period as compared to OT. A summary of results is reported in Table 4.7. I find that the results for both crops are consistent with the hypothesis.

4.8 Conclusion

During the global food crisis of 2007/2008, the Indian government intended to reduce the domestic impact of rapidly increasing world prices on the world and regional markets by implementing export ban on wheat and non-basmati rice in combination with domestic price policies and food grain procurement and distribution. By introducing these policy measures, the government was aiming to influence the supply of wheat and rice on the domestic market.

In the cointegration analysis, domestic markets are integrated with the world market during the open trade period, and were less integrated during export restrictions, as expected. Countries normally impose export bans to insulate the domestic market from international price

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nearby port markets instead: Ernakulam, Kerala (3,279,860); Vadodara, Gujarat (1,666,703); Kachch, Gujarat (2,092,371); Mysore, Karnataka (887,446); Malda, West Bengal (3,997,970) volatility and ensure availability in the domestic market at a lower than world price. However, my results suggest that domestic consumer and producer markets were less integrated during export restrictions period. Plausible explanations include active role of storage in the case of rice, and the export ban not being instituted continuously and domestic production shocks. For wheat, India actually imported grain during this period, increasing the integration between ports and consumer markets, but decoupling producing and consuming regions. Further, I find that the export ban may have exacerbated the price volatility arising from domestic supply shocks. Thus, the export ban in India, similar to the Russian export ban on wheat, may have had unintended consequences of increasing domestic price volatility.

Since the decisions to use these blunt instruments are taken by domestic governments worldwide, I believe that it is useful to know if and how government market interventions affect market integration and thus the efficiency of domestic markets. Moreover, studying the domestic effect of these policies has the potential to affect the use of these policies by other countries in the future.

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4.10 Tables

Table 4.1a Selected Markets for Rice and Wheat

Commodity	Primary Wholesale/Producing Markets	Primary Retail/Consuming Markets	Major Ports
Rice	Burdwan, West Bengal[1] West Godavari, Andrha Pradesh[1] Bijnaur, Uttar Pradesh[1]	Delhi, Delhi[2] Kolkata, West Bengal[2] Mumbai, Maharashtra[2]	Managalore, Karnataka[1] Ernakulam, Kerala[1] Vadodara, Gujarat[1]
Wheat	Unnao, Uttar Pradesh[1] Ludhiana, Punjab[1] Gurgaon, Haryana[1]	Delhi, Delhi[2] Patna, Bihar[2] Mumbai, Maharashtra[2]	Kachch, Gujarat[1] Mysore, Karnataka[1] Malda, West Bengal[1]
Source: 1-Agmarknet; 2-Department of Agriculture			

Table 4.1b Percentage of Missing Observations for Selected Markets

Market Type	Market	% Missing Obs (OT Period)	% Missing Obs (ER Period)
Rice Producing Markets	Burdwan, West Bengal	4.91%	4.95%
	West Godavari, Andrha Pradesh	47.68%	17.52%
	Bijnaur, Uttar Pradesh	21.68%	2.97%
Rice Consuming Markets	Delhi, Delhi	27.50%	20.69%
	Kolkata, West Bengal	11.61%	12.87%
	Mumbai, Maharashtra	17.50%	16.83%
Rice Major Ports	Mangalore, Karnataka	19.20%	4.95%
	Ernakulam, Kerala	5.80%	11.39%
	Vadodara, Gujarat	20.98%	2.48%
Wheat Producing Markets	Unnao, Uttar Pradesh	4.63%	0.91%
	Ludhiana, Punjab	25.93%	12.27%
	Gurgaon, Haryana	29.72%	24.09%
Wheat Consuming Markets	Delhi, Delhi	1.39%	1.36%
	Patna, Bihar	12.96%	0.91%
	Mumbai, Maharashtra	19.81%	16.82%
Wheat Major Ports	Kachch, Gujarat	5.09%	30.45%
	Mysore, Karnataka	6.94%	9.55%
	Malda, West Bengal	17.13%	35.45%

Table 4.2 Summary Statistics of Variables Used, Units and Sources

Variable	Obs	Mean	Std. Dev.	Min	Max	Units	Source
Rice Producing Market, Wholesale Prices							
Bijnaur, Uttar Pradesh	528	13.51	3.49	8.00	20.89	Rs/kg	Ag Marketing Information Network
Burdwan, West Bengal	528	14.29	3.70	9.47	25.50	Rs/kg	Ag Marketing Information Network
West Godavari, Andrha Pradesh	528	19.33	8.72	3.76	41.00	Rs/kg	Ag Marketing Information Network
Wheat Producing Markets, Wholesale Prices							
Unnao, Uttar Pradesh	528	9.80	2.49	5.52	15.85	Rs/kg	Ag Marketing Information Network
Ludhiana, Punjab	528	9.89	2.70	5.72	17.00	Rs/kg	Ag Marketing Information Network
Gurgaon, Haryana	528	10.19	2.40	5.98	18.14	Rs/kg	Ag Marketing Information Network
Rice Major Ports, Wholesale Prices							
Vadodara, Gujarat	528	16.93	5.57	4.34	26.82	Rs/kg	Ag Marketing Information Network
Mangalore, Karnataka	528	16.71	5.97	9.44	78.22	Rs/kg	Ag Marketing Information Network
Ernakulam, Kerala	528	18.88	7.05	0.36	73.36	Rs/kg	Ag Marketing Information Network
Wheat Major Ports, Wholesale Prices							
Kachch, Gujarat	528	10.99	3.17	6.06	19.51	Rs/kg	Ag Marketing Information Network
Mysore, Karnataka	528	15.30	4.74	7.52	26.13	Rs/kg	Ag Marketing Information Network
Malda, West Bengal	528	9.91	2.63	4.00	17.10	Rs/kg	Ag Marketing Information Network
Rice Consuming Markets, Retail Prices							
Delhi, Delhi	528	17.62	5.55	0.00	26.00	Rs/kg	Retail Price Info System, Directorate of Econ and Statistics
Mumbai, Maharashtra	528	18.90	6.41	7.35	34.50	Rs/kg	Retail Price Info System, Directorate of Econ and Statistics
Kolkata, West Bengal	528	16.05	5.40	2.88	28.55	Rs/kg	Retail Price Info System, Directorate of Econ and Statistics

Continued Table 4.2 Summary Statistics of Variables Used, Units and Sources

Variable	Obs	Mean	Std. Dev.	Min	Max	Units	Source
Wheat Consuming Markets, Retail Prices							
Delhi, Delhi	528	14.61	4.79	0.00	24.57	Rs/kg	Retail Price Info System, Directorate of Econ and Statistics
Mumbai, Maharashtra	528	20.38	7.33	11.40	37.58	Rs/kg	Retail Price Info System, Directorate of Econ and Statistics
Patna, Bihar	528	14.47	4.19	0.00	23.00	Rs/kg	Retail Price Info System, Directorate of Econ and Statistics
World Prices							
Rice World Price	528	16.60	7.79	6.65	34.06	Rs/kg	FAO Economic and Social Development Statistics Division
Wheat World Price	528	11.89	4.36	5.83	21.14	Rs/kg	FAO Economic and Social Development Statistics Division
Other Data							
Rainfall	528	115.63	112.20	2.13	382.10	mm	Meteorological Department, Govt. of India
Non-Basmati Rice Exports	528	456.31	507.00	7.23	2027.94	Rs Crore	Database on Indian Economy - Reserve Bank of India
Wheat Exports	528	171.18	337.37	0.00	1432.53	Rs Crore	Database on Indian Economy - Reserve Bank of India
Minimum Support Prices	528	8.40	2.27	5.60	11.10	Rs/kg	Ministry of Consumer Affairs, Food and Public Distribution, Govt of India
Central Issued Prices	528	8.30	0.00	8.30	8.30	Rs/kg	Ministry of Consumer Affairs, Food and Public Distribution, Govt of India

Table 4.3 Stationarity Summary for Logarithmic Transformation of Variables

Market	Wheat	Rice
Rice Producing Markets		
Bijnaur, Uttar Pradesh	U	U
Burdwan, West Bengal	U	U
West Godavari, Andrha Pradesh	U	U
Wheat Producing Markets		
Unnao Uttar Pradesh	U	U
Ludhiana, Punjab	U	U
Gurgaon, Haryana	U	U
Rice Major Port Markets		
Mangalore, Karnataka	U	U
Ernakulam, Kerala	U	U
Vadodara, Gujarat	U	U
Wheat Major Port Markets		
Kachch, Gujarat	U	U
Mysore, Karnataka	U	U
Malda, West Bengal	U	U
Rice Consuming Markets		
Delhi, Delhi	U	U
Mumbai, Maharashtra	U	U
Kolkata, West Bengal	U	U
Wheat Consuming Markets		
Delhi, Delhi	U	U
Mumbai, Maharashtra	U	U
Patna, Bihar	U	U
World Prices		
Rice World Pirce	U	U
Wheat World Price	U	U
Exogenous Supply Shock		
Rainfall	S	S

U indicates unit root, S is stationary, -- indicates no data

Note: Data are used are all logarithmic transformations, ran adf with lags; but no trend and with constant because that is how I am running the vars/vecm

Table 4.4a Lag order Selection for each Rice Market Pair for different periods based on AIC and LM test for Autocorrelation

Pair Type	Market Pair	Export restrictions Period		Open Trade Period	
		Lags based on AIC	Lags based on LM test for Autocorr	Lags based on AIC	Lags based on LM test for Autocorr
Producing and Consuming	Burdwan and Delhi	2	2	4	5
	Burdwan and Kolkata	5	8	4	4
	Burdwan and Mumbai	1	1	4	5
	Bijnaur and Delhi	2	3	5	6
	Bijnaur and Kolkata	3	3	4	5
	Bijnaur and Mumbai	1	1	5	5
	West Godavari and Delhi	2	3	5	6
	West Godavari and Kolkata	5	6	5	6
	West Godavari and Mumbai	4	4	5	5
Producing and Port	Burdwan and Mangalore	0	3	3	4
	Burdwan and Ernakulam	5	6	5	7
	Burdwan and Vadodara	1	1	1	4
	Bijnaur and Mangalore	0	2	5	6
	Bijnaur and Ernakulam	3	5	4	5
	Bijnaur and Vadodara	1	1	4	4
	West Godavari and Mangalore	4	4	5	6
	West Godavari and Ernakulam	5	5	5	6
	West Godavari and Vadodara	1	1	5	6
Port and Consuming	Mangalore and Delhi	2	4	5	6
	Mangalore and Kolkata	3	3	4	5
	Mangalore and Mumbai	2	3	5	6
	Ernakulam and Delhi	3	4	4	5
	Ernakulam and Kolkata	5	6	4	5
	Ernakulam and Mumbai	3	4	4	5
	Vadodara and Delhi	2	3	4	5
	Vadodara and Kolkata	5	6	3	4
	Vadodara and Mumbai	1	1	4	5
Port and World	Mangalore and World	5	6	5	6
	Ernakulam and World	5	6	5	6
	Vadodara and World	1	1	5	6

Table 4.4b Lag order Selection for each Wheat Market Pair for different periods based on AIC and LM test for Autocorrelation

Pair Type	Market Pair	Export restrictions Period		Open Trade Period	
		Lags based on AIC	Lags based on LM test for Autocorr	Lags based on AIC	Lags based on LM test for Autocorr
Producing and Consuming	Unnao and Delhi	1	1	4	4
	Unnao and Patna	1	1	4	4
	Unnao and Mumbai	1	1	4	4
	Ludhiana and Delhi	4	6	4	5
	Ludhiana and Patna	5	5	4	5
	Ludhiana and Mumbai	4	6	4	5
	Gurgaon and Delhi	2	4	5	5
	Gurgaon and Patna	2	4	4	4
	Gurgaon and Mumbai	2	5	4	5
Producing and Port	Unnao and Kachch	3	4	2	3
	Unnao and Mysore	5	8	4	5
	Unnao and Malda	1	1	5	5
	Ludhiana and Kachch	5	5	5	6
	Ludhiana and Mysore	5	6	5	6
	Ludhiana and Malda	4	6	4	4
	Gurgaon and Kachch	2	4	5	5
	Gurgaon and Mysore	3	4	4	4
	Gurgaon and Malda	2	4	5	5
Port and Consuming	Kachch and Delhi	3	3	5	6
	Kachch and Patna	3	3	4	5
	Kachch and Mumbai	4	5	4	4
	Mysore and Delhi	3	5	5	6
	Mysore and Patna	3	3	5	6
	Mysore and Mumbai	5	6	4	5
	Malda and Delhi	1	1	4	4
	Malda and Patna	1	1	4	4
	Malda and Mumbai	1	1	3	4
Port and World	Kachch and World	2	3	2	2
	Mysore and World	5	6	5	5
	Malda and World	1	1	3	3

Table 4.5a Number of Integrated Market Pairs by Pair Type and Crop

Pair Type Rice	Linear and Threshold Coint With ER	Linear and Threshold Coint OT
Producing and Consuming Markets	0/9	5/9
Producing and Port Markets	3/9	2/9
Port and Consuming Markets	0/9	2/9
Port and World Markets	1/3	3/3

Pair Type Wheat	Linear and Threshold Coint With ER	Linear and Threshold Coint OT
Producing and Consuming Markets	2/9	3/9
Producing and Port Markets	4/9	1/9
Port and Consuming Markets	5/9	3/9
Port and World Markets	1/3	2/3

Note: ER stands for export restrictions regime and OT stands for open trade regime.

Table 4.5b List of Integrated Market Pairs by Pair Type and Crop

Pair Type Rice	Linear and Threshold Coint With ER	Linear and Threshold Coint OT
Producing and Consuming Markets	none	Burdwan and Delhi, Burdwan and Kolkata, Bijnaur and Mumbai, West Godavari and Delhi, West Godavari and Mumbai
Producing and Port Markets	Bijnaur and Mangalore, Bijnaur and Vadodara, West Godavari and Ernakulam	Bijanur and Mangalore, Bijnaur and Ernakulam
Port and Consuming Markets	none	Mangalore and Delhi, Mangalore and Mumbai
Port and World Markets	Vadodara and World	Mangalore and World, Ernakulam and World, Vadodara and World

Pair Type Wheat	Linear and Threshold Coint With ER	Linear and Threshold Coint OT
Producing and Consuming Markets	Ludhiana and Patna, Ludhiana and Mumbai	Ludhiana and Delhi, Ludhiana and Mumbai, Gurgaon and Delhi
Producing and Port Markets	Unnao and Malda, Ludhiana and Mysore, Ludhiana and Malda, Gurgaon and Kachch	Gurgaon and Kachch
Port and Consuming Markets	Kachch and Patna, Mysore and Delhi, Mysore and Patna, Mysore and Mumbai, Malda and Mumbai	Kachch and Delhi, Mysore and Delhi, Malda and Delhi
Port and World Markets	Kachch and World	Kachch and World, Malda and World

Note: ER stands for export restrictions regime and OT stands for open trade regime.

Table 4.6 Proportion of Weeks where the estimated difference is more than the Threshold (i.e. Incentive to Trade)

Crop	Pair Type	Market Pair	Export Restrictions Period	Export Restrictions Period	Export Restrictions Period	Open Trade Period	Open Trade Period	Open Trade Period
			Estimated Cointegrated Vector, Beta	Estimated Thresholds, Tau	% Weeks when there is incentive to trade	Estimated Cointegrated Vector, Beta	Estimated Thresholds, Tau	% Weeks when there is incentive to trade
Rice	Consuming-Producing	Delhi-Burdwan	1.27	-		0.89	-1.70	93%
		Kolkata-Burdwan	0.65	-		0.52	-	
		Mumbai-Burdwan	0.64	3.47	10%	0.51	-	
		Delhi-Bijnaur	0.23	-		0.82	-1.31	93%
		Kolkata-Bijnaur	0.24	-		0.89	-1.94	93%
		Mumbai-Bijnaur	0.15	-		0.79	0.73	19%
		Delhi-West Godavari	0.79	-		0.98	-0.03	59%
		Kolkata-West Godavari	0.82	-		2.30	-	
		Mumbai-West Godavari	0.56	-		1.79	-	
Rice	Port-Producing	Mangalore-Burdwan	1.35	-		0.93	0.13	28%
		Ernakulam-Burdwan	1.06	-		2.95	-	
		Vadodara-Burdwan	-2.06	-		0.31	-	
		Mangalore-Bijnaur	0.82	1.15	7%	0.85	-0.93	75%
		Ernakulam-Bijnaur	0.54	-		0.76	-1.76	93%
		Vadodara-Bijnaur	0.73	3.25	1%	0.86	1.75	8%
		Mangalore-West Godavari	1.43	-		4.82	-	
		Ernakulam-West Godavari	1.31	-		-2.78	-	
		Vadodara-West Godavari	-0.68	-		1.02	1.38	15%
Rice	Consuming-Port	Delhi-Managalore	-4.17	-		0.95	-1.88	93%
		Kolkata-Mangalore	0.45	-		1.04	-1.95	91%
		Mumbai-Mangalore	3.90	-		0.53	-	
		Delhi-Ernakulam	0.01	-		0.17	-	
		Kolkata-Ernakulam	0.59	-		0.32	-	
		Mumbai-Ernakulam	0.09	-		-0.09	-	
		Delhi-Vadodara	-0.11	-		0.93	0.24	48%
		Kolkata-Vadodara	-0.63	-		1.74	-	
		Mumbai-Vadodara	0.34	-		0.89	1.05	27%
Rice	World-Port	World-Mangalore	4.52	-		1.24	-2.93	91%
		World-Ernakulam	5.89	-		1.36	-5.43	93%
		World-Vadodara	-0.23	-		1.19	1.71	23%

Continued Table 4.6 Proportion of Weeks where the estimated difference is more than the Threshold (i.e. Incentive to Trade)

Crop	Pair Type	Market Pair	Export Restrictions Period Estimated Cointegrated Vector, Beta	Export Restrictions Period Estimated Thresholds, Tau	Export Restrictions Period % Weeks when there is incentive to trade	Open Trade Period Estimated Cointegrated Vector, Beta	Open Trade Period Estimated Thresholds, Tau	Open Trade Period % Weeks when there is incentive to trade
Wheat	Consuming-Producing	Delhi-Unnao	0.66	-0.30	9%	0.98	-	
		Patna-Unnao	0.45	-		0.86	-	
		Mumbai-Unnao	0.17	-		0.72	-	
		Delhi-Ludhiana	0.66	-1.64	92%	0.76	0.21	89%
		Patna-Ludhiana	0.68	-1.60	98%	0.74	0.03	79%
		Mumbai-Ludhiana	0.49	-1.60	91%	0.51	0.16	31%
		Delhi-Gurgaon	0.43	-		0.91	-	
		Patna-Gurgaon	0.36	-		0.71	-	
		Mumbai-Gurgaon	0.12	-		0.85	-	
Wheat	Port-Producing	Kachch-Unnao	0.82	-		0.70	-	
		Mysore-Unnao	0.43	-		0.72	-	
		Malda-Unnao	0.99	0.96	0%	0.62	-	
		Kachch-Ludhiana	1.31	-		0.92	-0.08	62%
		Mysore-Ludhiana	0.68	-		0.73	-0.47	93%
		Malda-Ludhiana	2.47	-		0.96	0.35	31%
		Kachch-Gurgaon	0.91	-1.17	90%	0.80	-	
		Mysore-Gurgaon	0.47	-		0.81	-	
		Malda-Gurgaon	1.12	-		1.05	0.31	42%
Wheat	Consuming-Port	Delhi-Kachch	0.48	-		0.85	0.64	72%
		Patna-Kachch	0.45	-		1.02	-	
		Mumbai-Kachch	0.16	-		0.87	-	
		Delhi-Mysore	1.04	-2.40	95%	1.49	-	
		Patna-Mysore	1.04	-2.49	98%	1.17	-	
		Mumbai-Mysore	0.38	-		1.24	-	
		Delhi-Malda	0.31	-		0.81	-0.31	95%
		Patna-Malda	0.32	-		0.74	0.32	56%
		Mumbai-Malda	0.12	-		0.99	-	
Wheat	World-Port	World-Kachch	0.90	4.98	0%	1.04	1.05	45%
		World-Mysore	1.12	-		-2.88	-	
		World-Malda	0.10	-		0.97	0.29	57%

Table 4.7a Multivariate VAR Significance Results for the Domestic Production Shock Effects (ER Period)

	RICE			WHEAT		
	Producing	Consuming	Ports	Producing	Consuming	Ports
Rainfall	2/3	3/3	0/3	2/3	2/3	1/3

Table 4.7b Multivariate VAR Significance Results for the Domestic Production Shock Effects (OT Period)

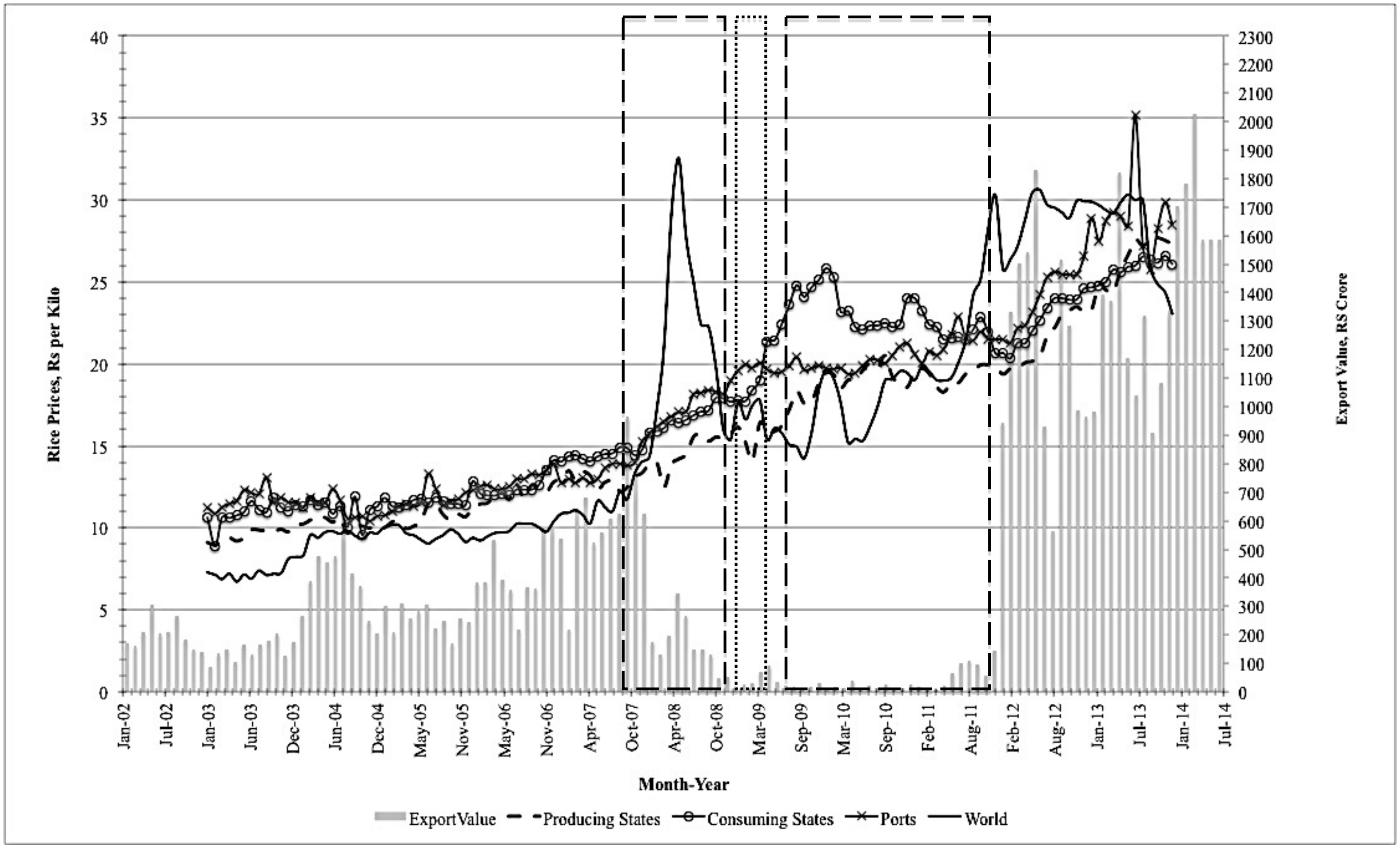
	RICE			WHEAT		
	Producing	Consuming	Ports	Producing	Consuming	Ports
Rainfall	0/3	1/3	0/3	0/3	1/3	0/3

4.11 Figures

Figure 4.1 Average Wheat Prices in Selected Markets and Export Quantity

Export ban Export Quota Note: whenever the “restricted trade” regime does not prevail, the “open trade” regime applies

Figure 4.2 Average Rice Prices in Selected Markets and Export Quantity



Export ban Minimum Export Prices Note: whenever the "restricted trade" regime does not prevail, the "open trade" regime applies.

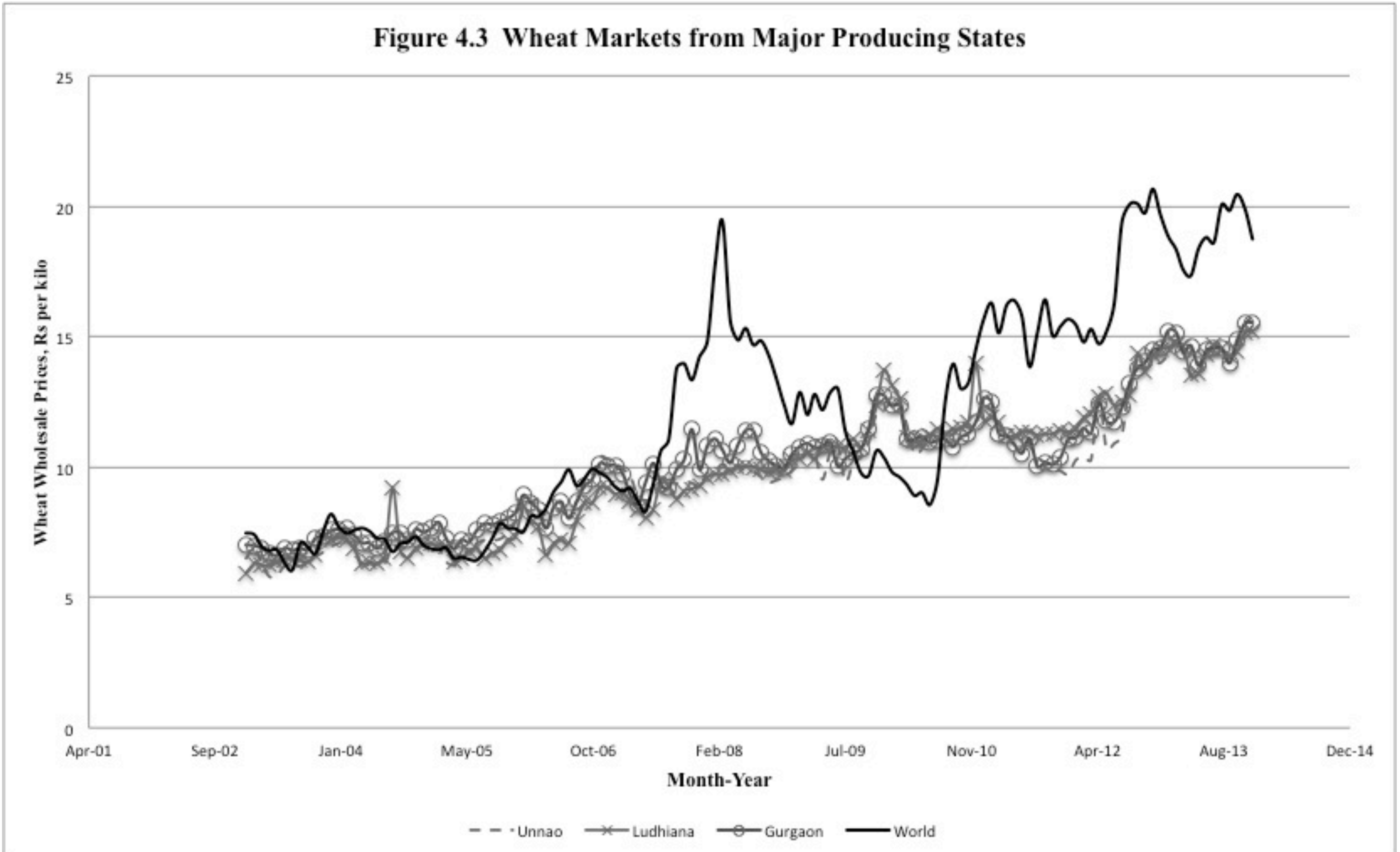


Figure 4.3 Wheat Markets from Major Producing States
25
20
15
10
5
0
Wheat Wholesale Prices, Rs per kilo
Apr-01
Sep-02
Jan-04
May-05
Oct-06
Feb-08
Jul-09
Nov-10
Apr-12
Aug-13
Dec-14
Month-Year
Unnao
Ludhiana
Gurgaon
World

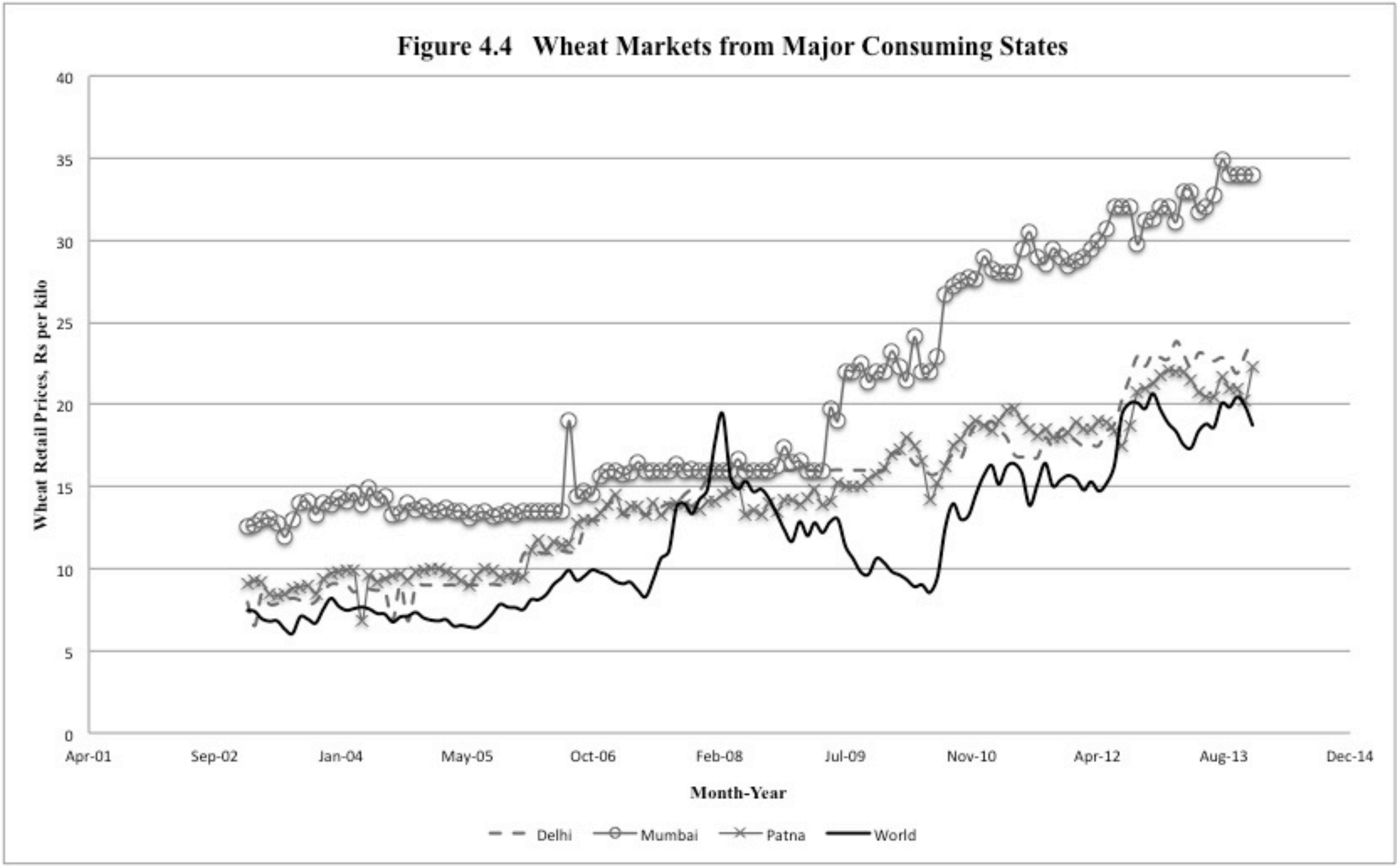


Figure 4.4 Wheat Markets from Major Consuming States
Wheat Retail Prices, Rs per kilo
40
35
30
25
20
15
10
5
0
Apr-01
Sep-02
Jan-04
May-05
Oct-06
Feb-08
Jul-09
Nov-10
Apr-12
Aug-13
Dec-14
Month-Year
Delhi
Mumbai
Patna
World

Figure 4.5 Wheat Markets from Major Ports

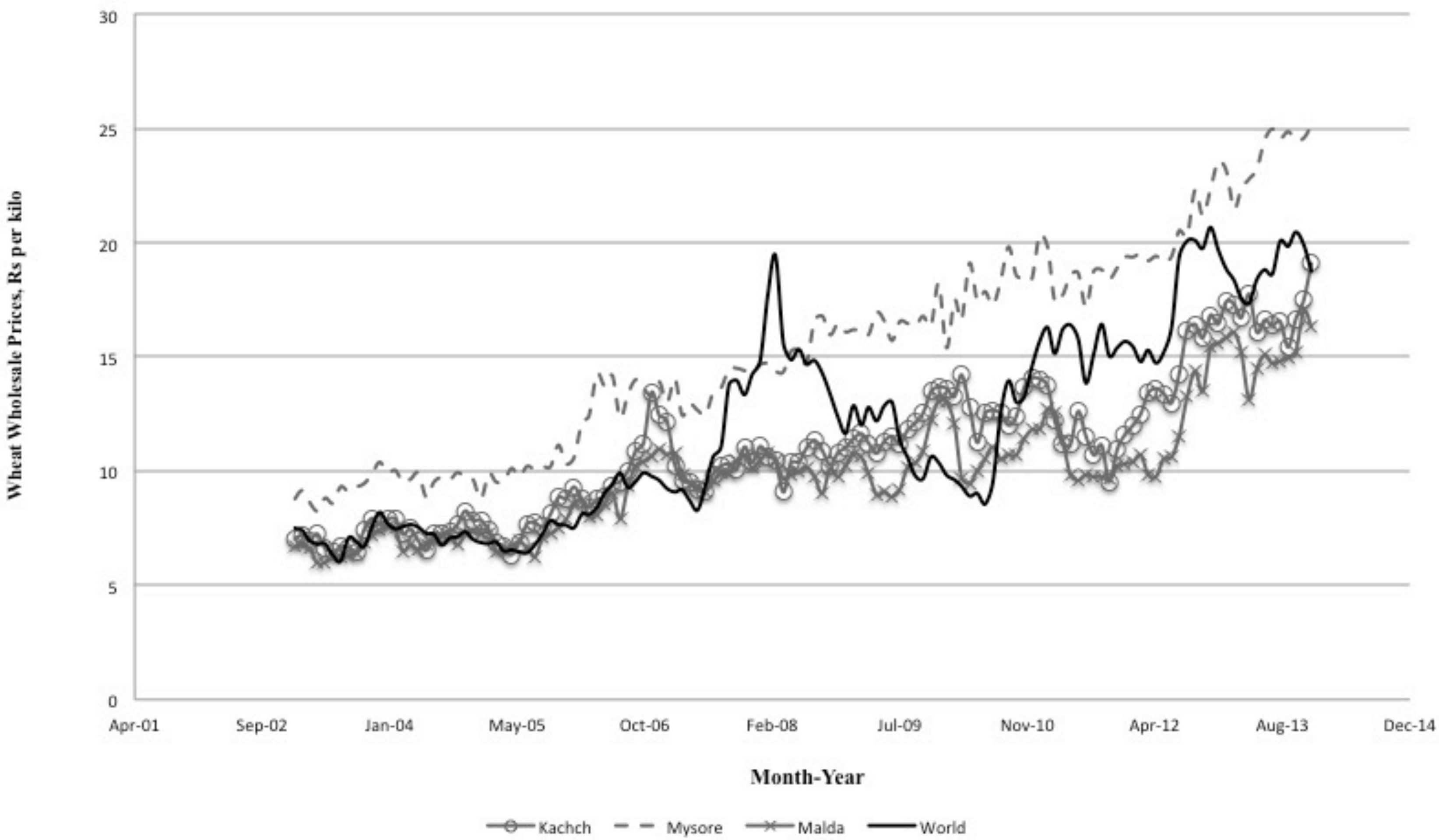


Figure 4.6 Rice Markets from Major Producing States

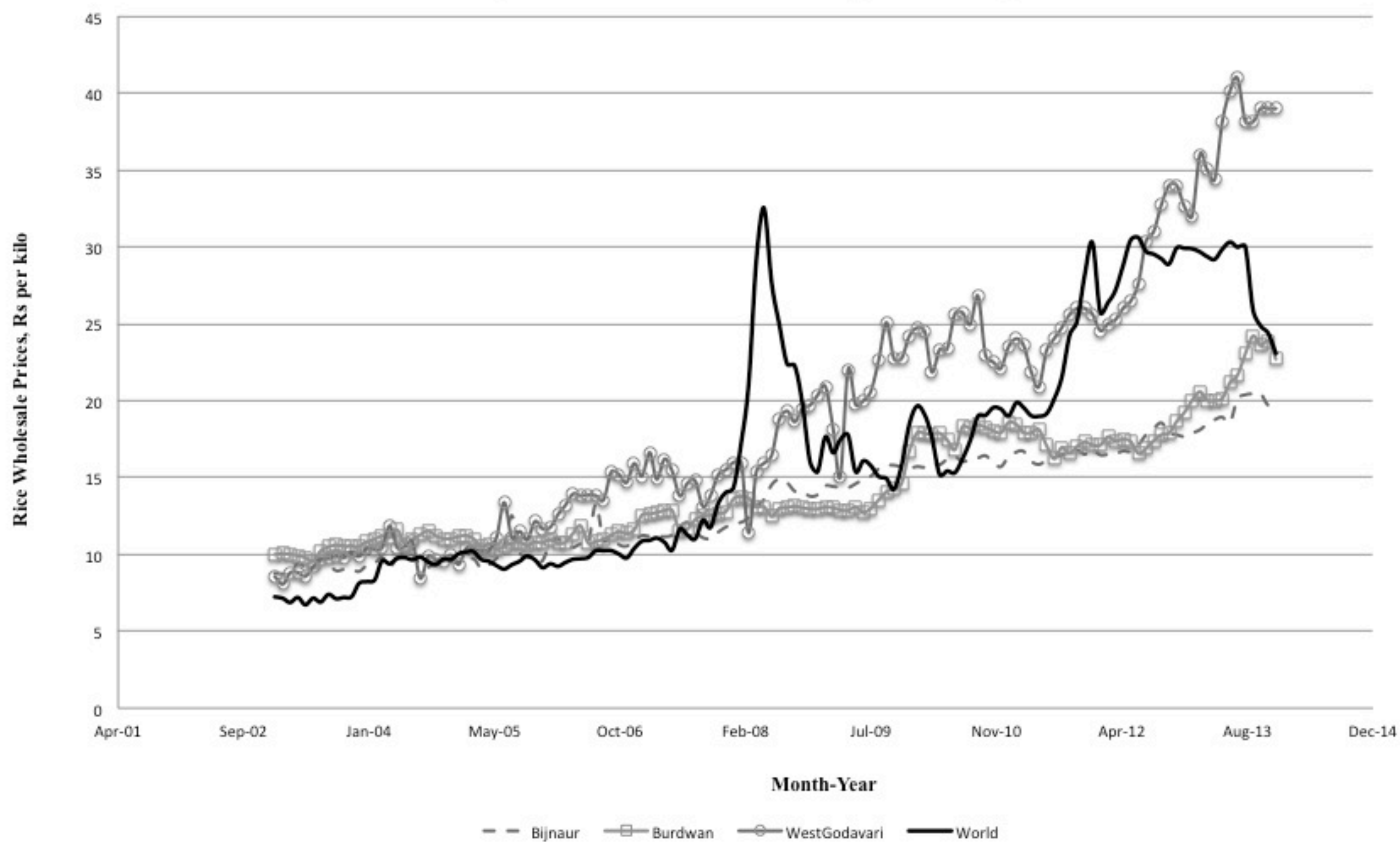
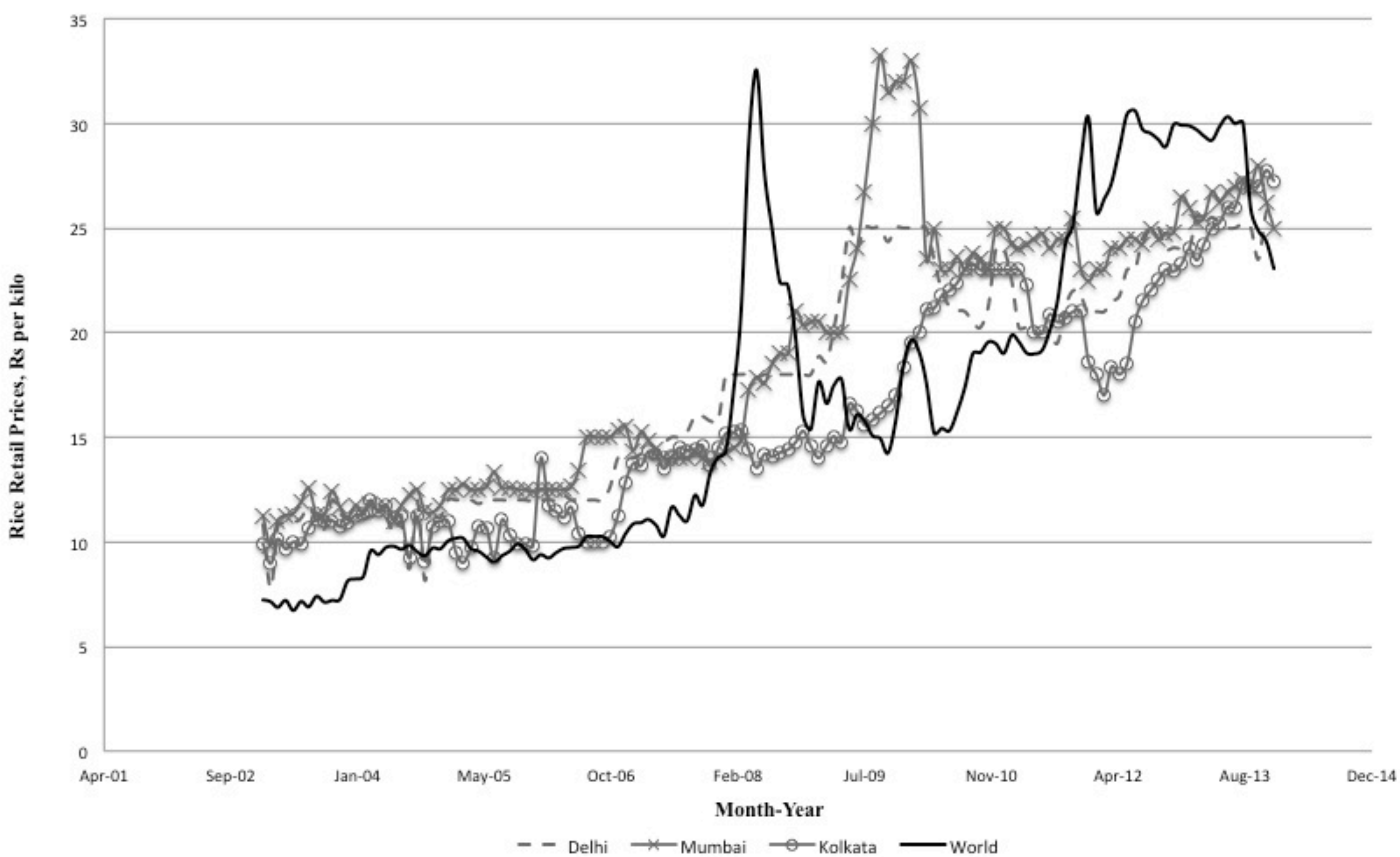


Figure 4.7 Rice Markets from Major Consuming States



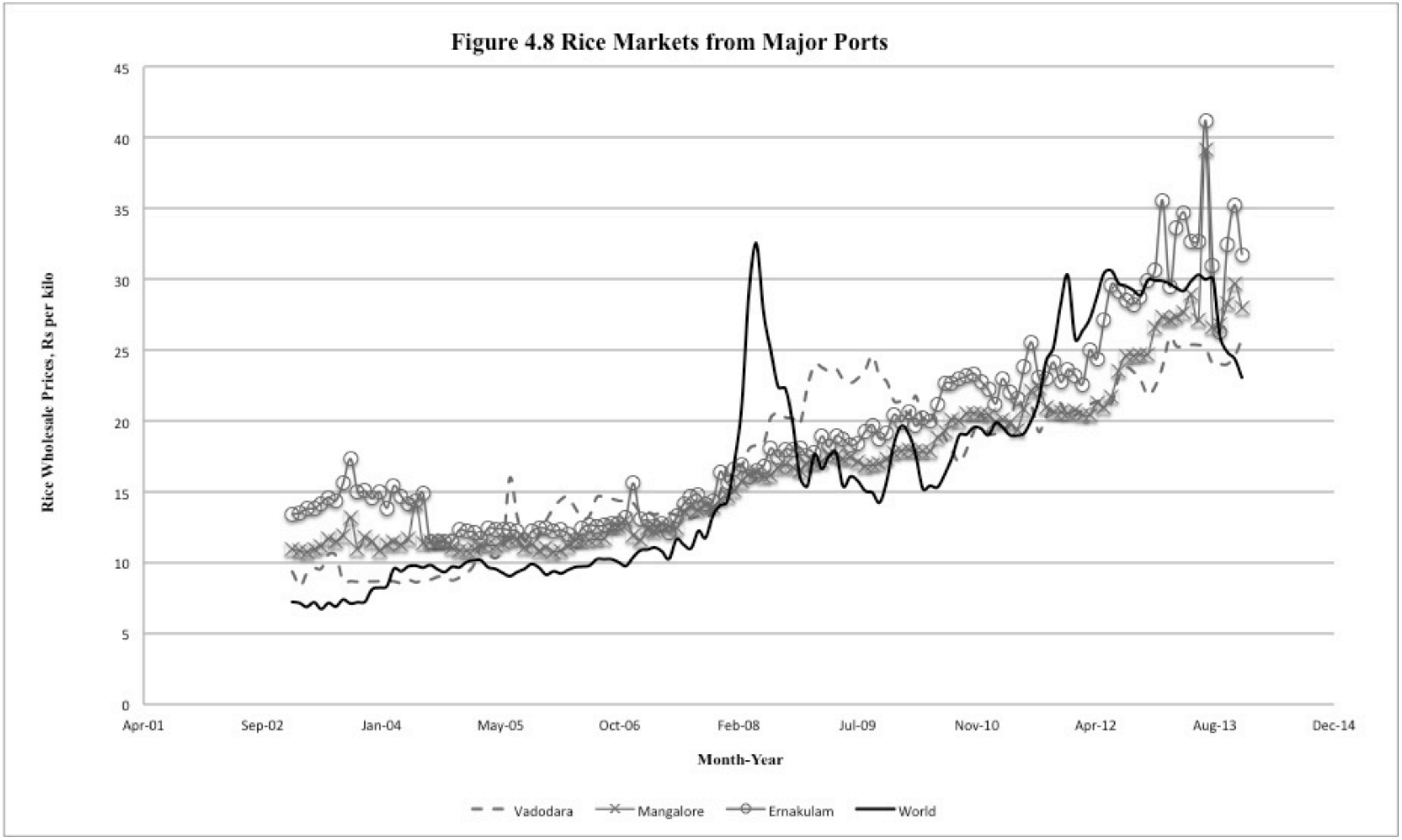


Figure 4.8 Rice Markets from Major Ports
Rice Wholesale Prices, Rs per kilo
45
40
35
30
25
20
15
10
5
0
Apr-01
Sep-02
Jan-04
May-05
Oct-06
Feb-08
Jul-09
Nov-10
Apr-12
Aug-13
Dec-14
Month-Year
Vadodara
Mangalore
Ernakulam
World

Figure 4.9 India's Market Landscape

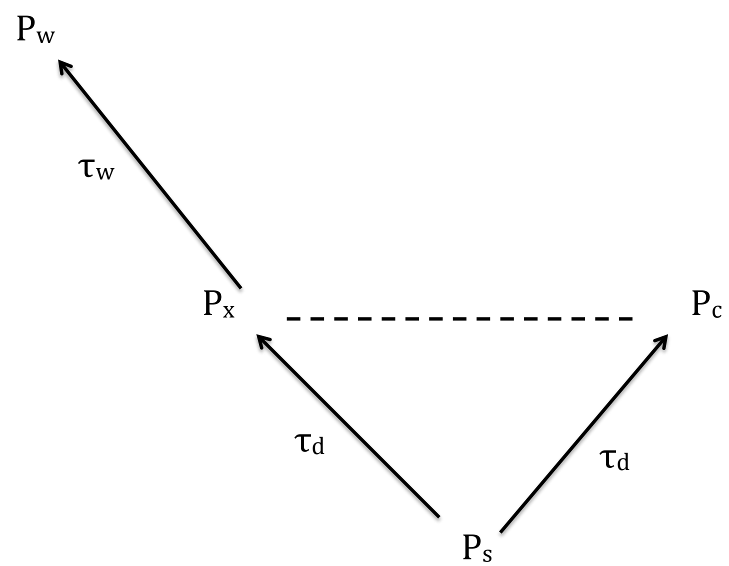
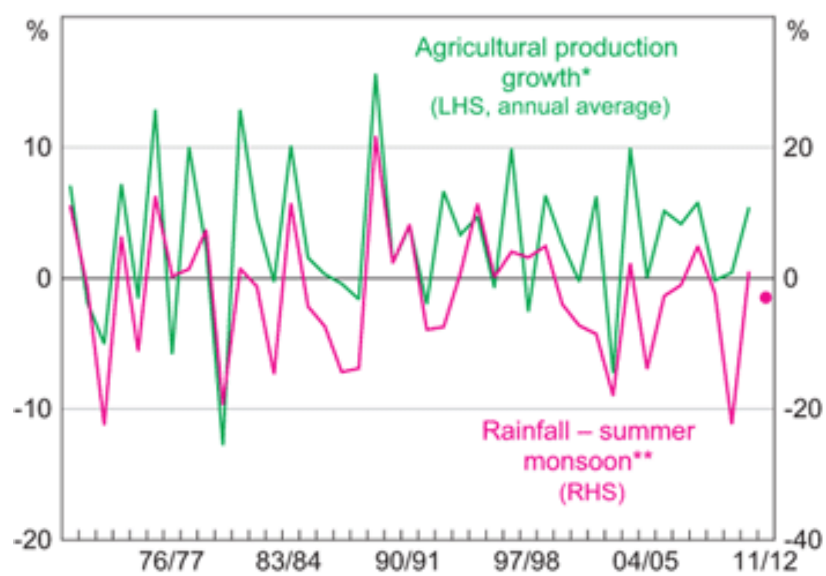


Figure 4.10 Percentage Changes in Agricultural Production and Rainfall



Source: Cagliarni and Rush (2011)

Chapter 5

CONCLUSION

With world population expected to reach 8 billion by 2030, pressure on the environment is projected to continually increase. The challenge faced by the society is to produce enough quality food to meet the needs of the growing population while preserving the natural resource base upon which the well-being of present and future generations depends (FAO, 2000).

My first essay shows how environmental stresses post a threat to food security with a reduction in the value of agricultural production. I find that existing land degradation in Ethiopia reduces value of agricultural production per hectare by 17.18 Ethiopian Birr or about 3.56% of the average value of agricultural production per hectare. Moreover, the effect of land degradation shows substantial regional heterogeneity, ranging from 2.49% to 4.37%. These results suggest the need for appropriate policy targeting by incorporating inherent characteristics of the regions in the design of policies.

In response to increasing food prices and greater food price volatility brought about by environmental constraints, national governments are pursuing a variety of policies to protect population group. Some of these policies are said to further amplify price fluctuations while others are attempting to isolate or protect price signals from reaching consumers, traders and producers (Andersen, 2012). In Philippines, I find that market prices in distribution and consuming regions take longer to respond to policy changes compared to producing and procurement regions. My comparison of historical and simulated 'no policy' prices show that the NFA activities have a very small impact on both rice price levels and variability, and the NFA's activities only impacted food prices during the small number of self-sufficient production years early in the sample.

Countries normally impose export bans to insulate the domestic market from international price volatility and ensure availability in the domestic market at a lower than world price. However, my results in Chapter 4 suggest that domestic consumer and producer markets were less integrated during export restrictions period. Plausible explanations include active role of storage in the case of rice, and the export ban not being instituted continuously and domestic production shocks. For wheat, India actually imported grain during this period, increasing the integration between ports and consumer markets, but delinking producing and consuming regions. Thus, the export ban in India, similar to what happened with Russian export ban on wheat, may have had unintended consequences of increasing domestic price differences thereby resulting in lack of domestic market integration.

In both Philippines and India studies I find that these policies may have unintended consequences in some markets and supply side policies would only work had there been enough economic activity in that sector. Since the decisions to use these distorting policy instruments are taken by domestic governments worldwide, studying the domestic effect of these policies has the potential to affect the use of these policies by other countries in the future.

References

Andersen, P.P. (2012). Contemporary food policy challenges and opportunities: a political economy perspective. AARES Conference, Fremantle, February 2012.

Food Agriculture Organization, Environment and Natural Resource Service. *Food Security and Environment*. FAO Fact Sheet, 2000.

APPENDIX A

Appendix A1. Description of Data Sources

Description of the GLADIS Data

The environmental variables used in this study come from GLADIS, which was developed in 2010 by the Food Agriculture Organization (FAO)'s Land Degradation Assessment Team. In GLADIS, the geographic areas are divided into fine resolution grids of 0.05 degrees, or 5 arc minute km^d per grid cell (9x9 km^d at the equator). The raster maps are converted to grids where each grid represents a value for the degree of land degradation. GLADIS contains multiple environmental measures of the cumulating land degradation from 1981 to 2003 and this study the first to use these data. GLADIS is comprised of a series of global maps on the status and trends of the main ecosystem services which includes soil health, water quality, biodiversity, biomass and social components overlaid on a rainfall-corrected normalized difference vegetation index map.[26] Each of these ecosystem measures comes from a huge scientific database from experts worldwide. These measures of ecosystem health are then mapped into a normalized radar trend diagram according to the parameters from the database. Appendix Figure A1 represents the database from which the GLADIS measurement is based on and Appendix Figure A2 represents a radar diagram trend map. A radar combines parameters representing differing aspects of ecosystem services, by converting these measures into indexes that run from 0 (worst) to 100 (best) and putting these indexes along each ecosystem service axis with equal weights. When the values are put in a radar diagram, they represent the strength and weakness of any ecosystem.[27]

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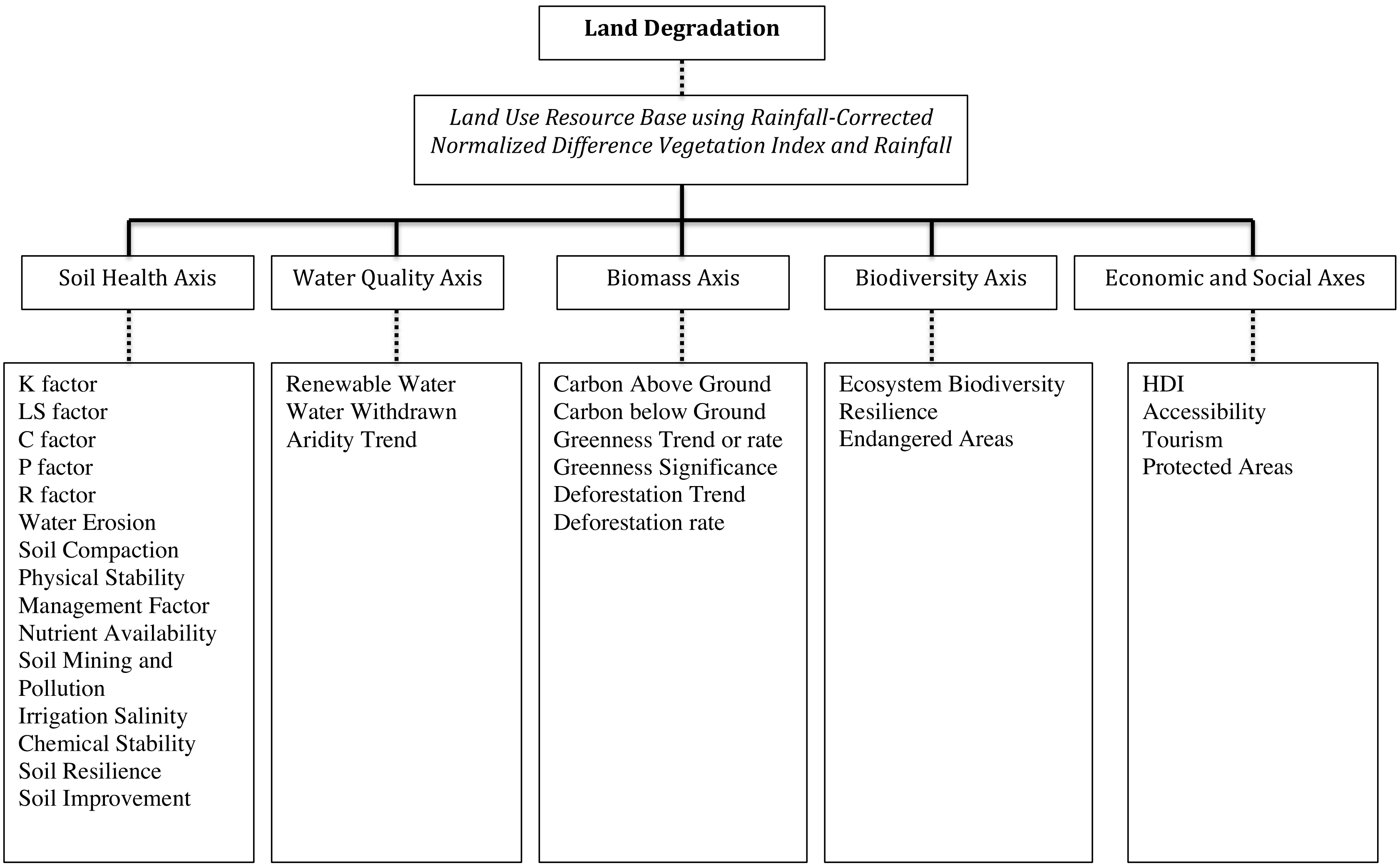
[26] Normalized Difference Vegetation Index (NDVI) is a numerical indicator to analyze remote sensing measurements to assess whether there is green vegetation present.

[27] For more details on how the radar trend diagrams are constructed, see GLADIS Technical Report (Nachtergaele, Petri, Biancalani, Lynden and Velthuizen, 2010). http://www.fao.org/nr/lada/index.php?option=com_content&view=article&id=180&Itemid=168&lang=e

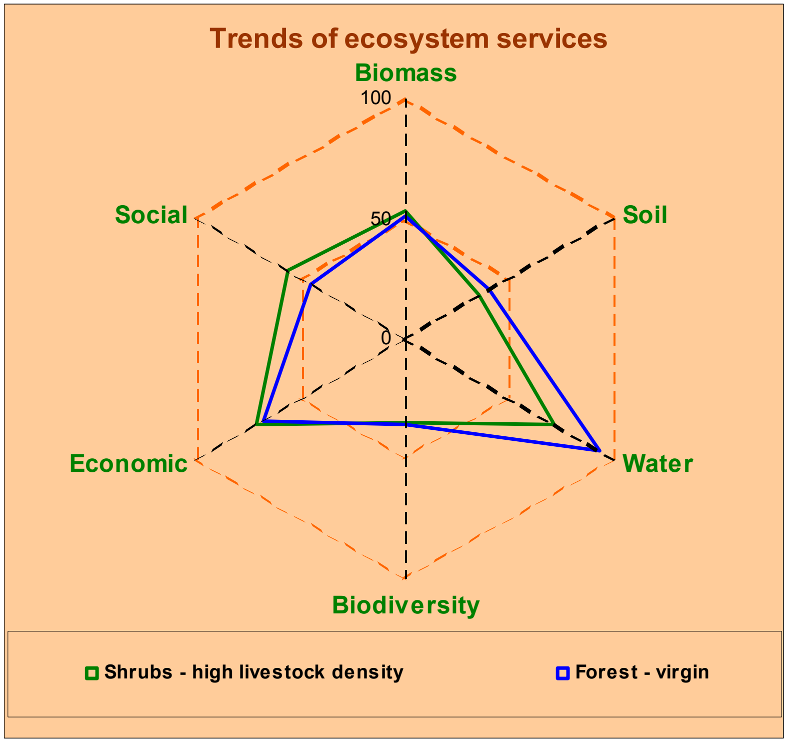
Description of the Farm Data and Climate Data

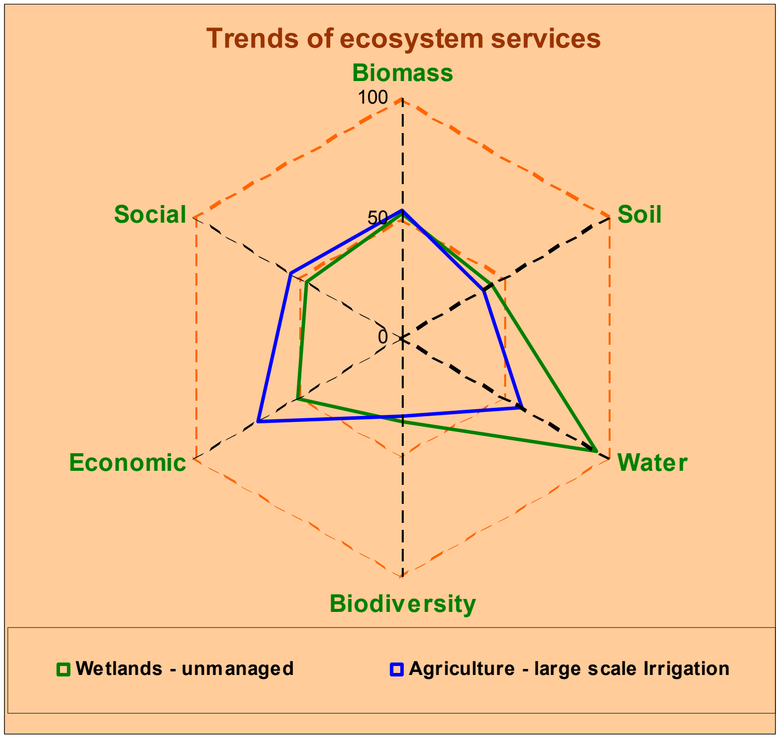
The household survey was carried out in the Nile basin within Ethiopia by the International Food Policy Research Institute (IFPRI) for the 2004-2005 crop year. It covered five major regions. Amhara is the biggest region in the Nile basin of Ethiopia, covering 38 percent of the nation's total land area, followed by Oromiya (24 percent), BG (15 percent), Tigray (11 percent), and SNNPR (5 percent) (Ethiopian Ministry of Water Resources, 1998; Kato et al, 2009). The household sampling frame was developed to ensure that the twenty woredas or districts were nationally representative of the level of rainfall patterns, classes of agro-ecological zones, vulnerability of food production systems and the presence of irrigation. One peasant association was selected from every woreda for a total 20 peasant associations. Further, random sampling was used to select 50 households from each peasant administration. The final dataset contains 1,000 households. Households may farm up to 19 plots. The household level questionnaire collected information about household endowment of assets, household composition, income and expenditures, and adoption of agricultural and land management technologies. A plot level survey collected information on all of the plots owned or operated by the household, including information about land tenure, plot quality characteristics, land management practices, use of inputs and outputs during belg (fall, February to June) and mehere (summer, June to October). Each household is geocoded, a feature of these data that has not previously been used. In addition to the farmer survey, IFPRI water research team's Climate Research Unit of East Anglia database provided average rainfall data and temperature for years 2004-2005. Appendix Figure A3 shows GLADIS and IFPRI merged data and Ethiopia State Map.

Appendix Figure A1. GLADIS Description of Axes



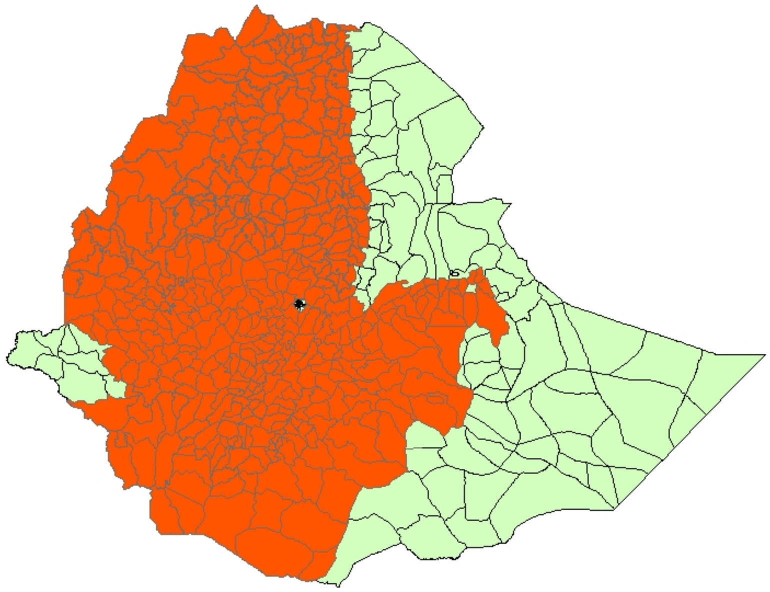
Appendix Figure A2. Land degradation Radar Trend Diagram in Different Land Use Systems

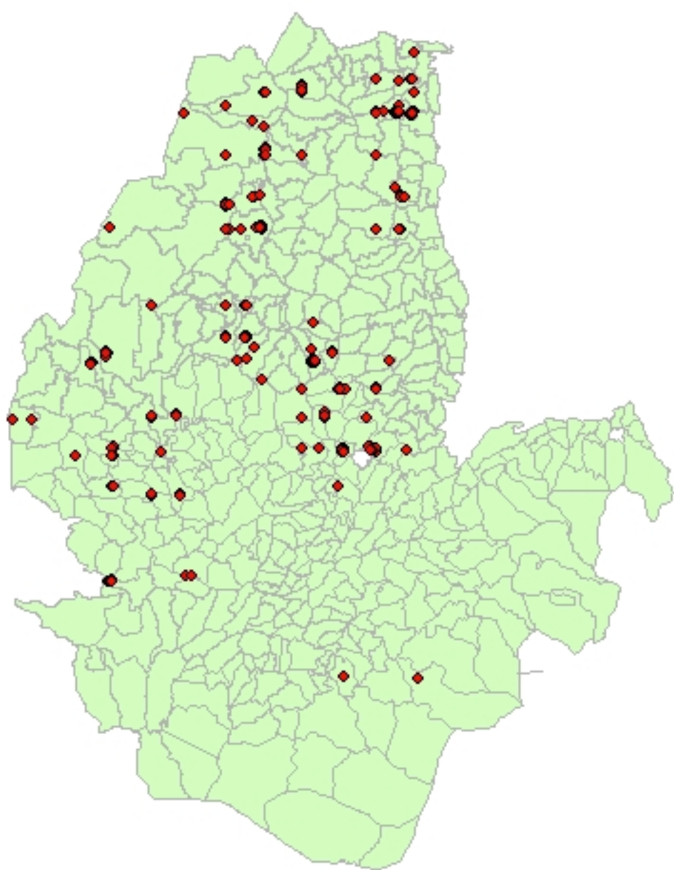




Source: GLADIS Technical Report No 17, LADA Network, FAO

Appendix Figure A3. GLADIS and IFPRI Study area and distribution of respondents





Appendix Table A1. Regression Results for Net Income as the Dependent Variable

	Spatially Weighted Regression Net Income per hectare
Land Degradation	-17.23***
	(5.63)
Environmental Characteristics	
Aridisol Soil	-299.3
	(482.00)
Entisol Soil	-463.7*
	(261.00)
Mollisol Soil	-123.51
	(264.00)
Slope	43.1
	(42.30)
Elevation	-0.004
	(0.06)
Rainfall	-0.76***
	(0.06)
Temperature	40.90***
	(15.10)
Socio-Environment Characteristics	
Population Density	-0.1
	(1.66)
Access to Basic Facilities	-0.63
	(1.26)
Access to Information	9.785*
	(7.90)
Farm Characteristics	
Irrigation Intensity	89.8*
	(72.10)
Distance of farm from home	3.9
	(7.67)
Land Tenure Characteristics	
Inheritance Dummy	1.1
	(1.48)
Land Certified from Govt Dummy	-39.7
	(15.02)
Sharecropped Dummy	12.0
	(18.60)
Rent Dummy	-13.2
	(1187.00)

Continued Appendix Table A1. Regression Results for Net Income as the Dependent Variable

	Spatially Weighted Regression
	Net Income per hectare
Farmer Demographics	
Big Ethnic Group	87.2
	(27.47)
Number of Children	2.2
	(2.33)
Male head	17.8
	(19.95)
Farming Years	-4.4
	(5.44)
Livestock ownership dummy	-417.5
	(561.00)
Asset Index	90.3
	(114.40)
Regional Fixed Effects	
Tigray Region	348.7
	(385.50)
Amhara Region	79.81**
	(33.21)
Oromiya Region	-50.4
	(29.77)
Benishangul Gumuz Region	-517.367***
	(320.00)
Neighbor's Characteristics	
N's Land Degradation	-28.6***
	(14.78)
Constant	-2,514***
	(1236.00)
Observations	828
R-squared	0.2090
Underidentification test	0.215[a]
Chi-sq(2) P-val	0.8982
Overidentification test	0.885[b]
Chi-sq(2) P-val	0.3469

[a] Anderson Canonical Correlation LM Statistic
[b] Sargan Statistic
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix Table A2. Test for Omitted Variable Bias Second Stage of Regression with Spatially Weighted Variables

	AgVal1	AgVal1b	AgVal2	AgVal3	AgVal4	AgVal5	AgVal6	AgVal7
Predicted Land Degradation	-38.6		-16.8***	-14.99***	-18.4***	-16*	-17.18***	-16.75***
	(37.7000)		(4.8000)	(6.9700)	(9.3000)	(12.0500)	(9.44)	(7.61)
Predicted Land Degradation Squared		-33.18						
		(840.8000)						
Environmental Characteristics								
Aridisol Soil			-124.1	-124.1	-124.1	-216.1	-411.1	-411.1
			(168.20)	(168.20)	(168.20)	(159.20)	(1058.00)	(1047.00)
Entisol Soil			-312.5	-387.5	-298.4**	-254.4	-293.12**	-293.12**
			(123.80)	(123.80)	(123.80)	(243.80)	(123.80)	(119.40)
Mollisol Soil			0.0	0.0	0.0	-176.0000	-194.1	-194.1
			(156.00)	(156.00)	(155.50)	(169.00)	(737.80)	(730.10)
Slope			40.7	43.5	30.4	80.5	91.5	91.5
			(35.11)	(35.11)	(35.11)	(135.11)	(229.60)	(227.20)
Elevation			0.001	0.001	0.001	0.001	0.000	0.000
			(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Rainfall			-0.28	-0.3	-0.2	-0.2	-0.338	-0.338
			(0.24)	(0.24)	(0.24)	(0.24)	(0.31)	(0.31)
Temperature			-55.89*	-65.45***	-75.95***	-35.95*	-30.63**	-30.63**
			(24.66)	(24.66)	(24.66)	(24.66)	(17.50)	(14.00)
Socio-Environment Characteristics								
Population Density				0.394	0.416	0.436	0.1	0.1
				(0.3440)	(0.3510)	(0.3360)	(0.13)	(0.13)
Access to Basic Facilities				-3.07	-1.309	1.45E+01	2.217	2.217
				(25.5100)	(25.8100)	(24.4100)	(7.94)	(7.85)
Access to Information				29.44	31.24	14.61	8.802*	8.802*
				(23.9800)	(24.3200)	(23.1500)	(6.10)	(5.98)
Farm Characteristics								
Irrigation Intensity				60.60	45.69	90.25	56.77*	56.77*
				(119.5000)	(121.9000)	(115.9000)	(47.28)	(41.28)
Distance of farm from home				16.40	18.38	26	1.5	1.5
				(143.3000)	(147.0000)	(137.8000)	(35.86)	(35.48)

Continued Appendix Table A2. Test for Omitted Variable Bias Second Stage of Regression with Spatially Weighted Variables

	AgVal1	AgVal2	AgVal3	AgVal4	AgVal5	AgVal6	AgVal7	AgVal8
Land Tenure Characteristics								
Inheritance Dummy					-1.24	3.26	-6.1	-6.1
					(220.1000)	(10.2000)	(53.67)	(53.10)
Rent Dummy					57.6	-34.41	-80.4	-80.4
					(32.4000)	(39.6000)	(186.70)	(189.50)
Sharecropped Dummy					61.02	42.78	-55.4	-55.4
					(812.2000)	(67.0000)	(56.16)	(55.57)
Land Certified from Govt					-36.0	-50.174	40.3	40.3
					(65.9000)	(161.8000)	(146.10)	(144.50)
Farmer Demographics								
Big Ethnic Group						-70.8**	-80.9	-80.9
						(28.5000)	(130.90)	(129.50)
Number of Children						-13.39	-5.7	-5.7
						(43.6200)	(11.40)	(11.28)
Male head						33.1	16.9	16.9
						(32.3900)	(103.70)	(102.60)
Farming Years						-1.98**	-3.1	-3.1
						(0.0570)	(2.69)	(2.66)
Livestock ownership dummy						35.27	478.9***	478.9***
						(40.1900)	(57.92)	(57.31)
Asset Index						-19.13*	42.72*	42.72*
						(10.6900)	(27.58)	(27.29)
Regional Fixed Effects								
Tigray Region							203.1**	223.6**
							(156.00)	(141.00)
Amhara Region							-63.3	-63.3
							(367.50)	(367.50)
Oromiya Region							-158.1	-158.1
							(138.00)	(138.00)
Benishangul Gumuz Region							-524.1***	-489.3***
							(123.80)	(117.80)

Continued Appendix Table A2. Test for Omitted Variable Bias Second Stage of Regression with Spatially Weighted Variables

	AgVal1	AgVal2	AgVal3	AgVal4	AgVal5	AgVal6	AgVal7	AgVal8
Neighbor's Characteristics								
N's Land Degradation								-27.3***
								(14.09)
Constant	1,211*	1,167*	1,935*	1,211*	1,435*	1,085*	1,375*	-1293.4*
	(671.00)	(615.00)	(564.00)	(780.00)	(435.00)	(597.00)	(576.00)	(440.10)
Observations	828	828	828	828	828	828	828	828
Adj R-squared	0	0	0.11	0.118	0.118	0.247	0.2456	0.2425
RESET Test= Ho: Model has no omitted variables								
F Statistic	1.02	1.35	1.58	1.76	1.89	1.94	2.01	2.15
Prob>F	0.38230	0.25780	0.19200	0.15800	0.40000	0.25434	0.11638	0.1524

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix Table A3. Test for Variance Inflation Factor

	AgVal1	AgVal1b	AgVal2	AgVal3	AgVal4	AgVal5	AgVal6	AgVal7	AgVal8
Predicted Land Degradation	1.00		4.34	4.96	4.51	4.34	4.87	4.15	4.12
Predicted Land Degradation Squared		1.00							
Environmental Characteristics									
Aridisol Soil			4.5	4.83	3.77	5.59	4.13	4.42	4.34
Entisol Soil			5.86	5.34	4.59	4.97	3.27	3.75	4.05
Mollisol Soil			4.74	4.47	4.38	3.59	5.51	5.02	4.09
Slope			4.92	1.01	2.12	4.43	4.01	4.54	4.45
Elevation			1.00	1.00	1.01	1.02	1.04	1.04	1.13
Rainfall			1.51	1.61	2.04	2.16	2.58	2.58	4.47
Temperature			1.25	1.30	1.56	1.75	3.09	3.24	2.57
Socio-Environment Characteristics									
Population Density				1.09	1.10	1.1	1.15	1.16	1.2
Access to Basic Facilities				1.10	1.20	1.26	1.42	1.44	2.4
Access to Information				1.08	1.11	1.13	1.18	1.24	1.94
Farm Characteristics									
Irrigation Intensity					3.60	4.73	3.82	3.12	4.64
Distance of farm from home					1.01	1.02	1.03	1.03	1.05
Land Tenure Characteristics									
Inheritance Dummy						1.49	1.62	1.67	2.87
Land Certified						1.49	1.54	1.65	3.13
Sharecrop Dummy						1.09	1.64	1.66	1.67
Rent Dummy						1	1.54	1.54	1.55

Continued Appendix Table A3. Test for Variance Inflation Factor

	AgVal1	AgVal1b	AgVal2	AgVal3	AgVal4	AgVal5	AgVal6	AgVal7	AgVal8
Farmer Demographics									
Big Ethnic Group							2.59	2.78	3.78
Children							1.17	1.17	1.19
Gender							1.12	1.12	1.18
Farming Years							1.27	1.3	1.41
Asset Index							1.18	1.18	1.25
Livestock own dummy							1.19	1.2	1.21
Neighbor's Characteristics									
N's Land Degradation								2.32	2.94
Regional Fixed Effects									
Tigray Region									1.82
Amhara Region									3.64
Oromiya Region									3.84
Benishangul Gumuz Region									4.77
Mean VIF	1.00	1.00	4.13	4.49	4.20	4.85	4.37	4.37	4.49

APPENDIX B

Appendix Table B1. Unit Root Tests for all Variables Used in the Study

	Augmented Dickey-Fuller Test			Phillips-Perron Test					
	including constant and trend	including constant but no trend	excluding both constant and trend	including constant and trend		including constant but no trend		excluding both constant and trend	
				Z(rho)	Z(t)	Z(rho)	Z(t)	Z(rho)	Z(t)
1% critical value	**-3.989**	**-3.458**	**-2.58**	**-28.452**	**-3.989**	**-20.321**	**-3.458**	**-13.61**	**-2.58**
5% critical value	**-3.429**	**-2.879**	**-1.95**	**-21.321**	**-3.429**	**-14**	**-2.879**	**-8**	**-1.95**
10% critical value	**-3.13**	**-2.57**	**-1.62**	**-18.01**	**-3.13**	**-11.2**	**-2.57**	**-5.7**	**-1.62**
Central Luzon Wholesale Price	-2.795	-0.169	1.473	-20.261*	-3.319*	-1.265	-0.575	0.750	1.024
ARMM Wholesale Price	-2.070	0.012	1.796	-10.668	-2.265	-0.806	-0.444	1.032	1.677
Mimaropa Wholesale Price	-2.360	-0.165	1.793	-15.409	-2.841	-0.932	-0.499	0.873	1.317
NCR Wholesale Price	-2.686	-0.777	1.421	-22.536**	-3.389*	-2.456	-1.090	0.741	0.954
World Price	-3.397*	-1.620	-0.159	-20.940*	-3.278*	-5.783	-1.652	-0.367	-0.218
NFA Buying Premium	-6.075***	-4.848***	-3.826***	-201.782***	-11.896***	-176.777***	-10.768***	-138.225***	-9.217***
NFA Selling Premium	-2.439	-1.811	-0.907	-13.272	-2.579	-7.406	-1.943	-2.614	-1.009
diff Central Luzon Wholesale Price	-9.325***	-9.343***	-9.047***	-224.661***	-14.564***	-224.842***	-14.753***	-225.728***	-14.523***
diff ARMM Wholesale Price	-9.057***	-9.041***	-8.597***	-217.145***	-14.278***	-217.391***	-14.298***	-218.637***	-14.155***
diff Mimaropa Wholesale Price	-8.969***	-8.949***	-8.614***	-169.093***	-11.527***	-169.110***	-11.543***	-169.175***	-11.482***
diff NCR Wholesale Price	-9.946***	-9.964***	-9.679***	-175.107***	-12.395***	-175.111***	-12.422***	-175.677***	-12.379***
diff World Price	-7.967***	-7.980***	-7.943***	-141.849***	-10.553***	-141.855***	-10.575***	-141.902***	-10.588***
diff NFA Buying Premium	-10.398***	-10.410***	-10.432***	-313.977***	-30.673***	-314.006***	-30.717***	-313.997***	-30.789***
diff NFA Selling Premium	-7.535***	-7.550***	-7.550***	-242.120***	-15.136***	-242.119***	-15.165***	-242.184***	-15.185***

Ho: unit root is present : I(1) non-stationary need to do VAR in differences; statistic is not significant
Ha: no unit root present or reject Ho: I(0) stationary implies can do VAR levels; statistic is significant
Left of critical value on the number line, significant, reject Ho.
Note: Shocks to a stationary series are temporary; thus, the series reverts to its long run means. For non stationary series, shocks resul in permanent moved away from the long run mean of series. Stationary series have a finite variance but not for non stationary. If you accept the null hypothesis, i.e. significant, you conclude that there is unit root. Thus you should first difference the series before procedding with analysis. If you reject the null hypothesis of a unit root, and conclude that the approval series is stationary or I(0); we can do VAR in levels

Continued Appendix Table B1. Unit Root Tests for all Variables Used in the Study

	Augmented Dickey-Fuller Test			Phillips-Perron Test					
	including constant and trend	including constant but no trend	excluding both constant and trend	including constant and trend		including constant but no trend		excluding both constant and trend	
				Z(rho)	Z(t)	Z(rho)	Z(t)	Z(rho)	Z(t)
1% critical value	**-3.989**	**-3.458**	**-2.58**	**-28.452**	**-3.989**	**-20.321**	**-3.458**	**-13.61**	**-2.58**
5% critical value	**-3.429**	**-2.879**	**-1.95**	**-21.321**	**-3.429**	**-14**	**-2.879**	**-8**	**-1.95**
10% critical value	**-3.13**	**-2.57**	**-1.62**	**-18.01**	**-3.13**	**-11.2**	**-2.57**	**-5.7**	**-1.62**
ln Central Luzon Wholesale Price	-3.274*	-0.500	1.384	-28.696***	-4.012***	-1.609	-0.751	0.303	1.144
ln ARMM Wholesale Price	-2.665	-0.674	1.448	-20.217*	-3.266*	-2.935	-1.352	0.417	1.498
ln Mimaropa Wholesale Price	-2.635	-0.730	1.650	-16.402	-2.890	-1.505	-0.826	0.367	1.464
ln NCR Wholesale Price	-2.802	-1.419	1.748	-20.413*	-3.269*	-3.020	-1.546	0.407	1.531
ln World Price	-3.261*	-1.318	0.814	-21.123*	-3.268*	-3.641	-1.344	0.378	0.720
ln NFA Buying Premium	-4.923***	-3.519***	-3.060***	-107.327***	-8.109***	-61.307***	-5.997***	-40.308***	-4.882***
ln NFA Selling Premium	-3.002	-2.759*	-1.535***	-18.110*	-3.011	-15.191***	-2.805*	-5.029	-1.549
diff ln Central Luzon Wholesale Price	-8.838***	-8.889***	-8.604***	-318.541***	-20.593***	-318.710***	-20.614***	-320.545***	-20.492***
diff ln ARMM Wholesale Price	-10.139***	-10.158***	-9.790***	-246.411***	-16.788***	-246.326***	-16.820***	-248.060***	-16.668***
diff ln Mimaropa Wholesale Price	-8.279***	-8.295***	-8.012***	-181.209***	-12.049***	-181.208***	-12.072***	-181.328***	-12.005***
diff ln NCR Wholesale Price	-8.887***	-8.881***	-8.560***	-184.847***	-13.183***	-184.897***	-13.201***	-185.959***	-13.113***
diff ln World Price	-7.018***	-7.032***	-6.947***	-162.702***	-11.365***	-162.703***	-11.387***	-162.764***	-11.386***
diff ln NFA Buying Premium	-10.529***	-10.542***	-10.545***	-292.639***	-24.229***	-292.688***	-24.273***	-292.786***	-24.307***
diff ln NFA Selling Premium	-7.064***	-7.078***	-7.092***	-264.404***	-16.305***	-264.410***	-16.332***	-264.409***	-16.362***

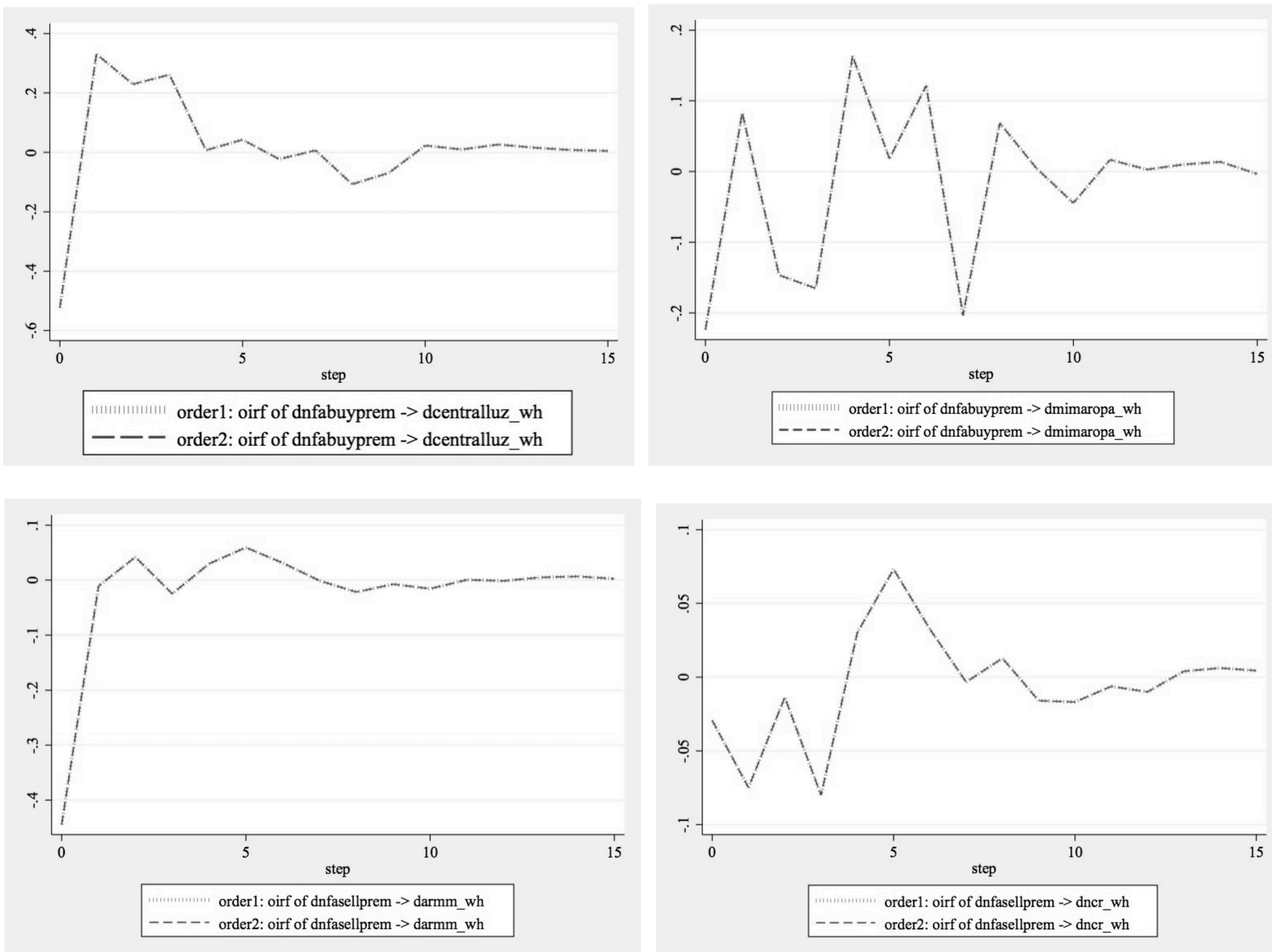
Ho: unit root is present : I(1) non-stationary need to do VAR in differences; statistic is not significant

Ha: no unit root present or reject Ho: I(0) stationary implies can do VAR levels; statistic is significant

Left of critical value on the number line, significant, reject Ho.

Note: Shocks to a stationary series are temporary; thus, the series reverts to its long run means. For non stationary series, shocks resul in permanent moved away from the long run mean of series. Stationary series have a finite variance but not for non stationary. If you accept the null hypothesis, i.e. significant, you conclude that there is unit root. Thus you should first difference the series before procedding with analysis. If you reject the null hypothesis of a unit root, and conclude that the approval series is stationary or I(0); we can do VAR in levels

Appendix Figure B1. Cholesky Decompositions of the Impulse Response Functions



Appendix Table B2. Test for Seasonality

2a. Correlogram for d.Central Luzon

Lag	AC	PAC	Q	Prob>Q
2	0.085	0.0719	5.9682	0.0506
4	-0.259	-0.2599	25.382	0.000
6	-0.1429	-0.0846	37.091	0.000
8	0.0251	-0.0197	39.143	0.000
10	0.1232	0.0506	44.108	0.000
12	0.0874	0.0567	46.57	0.000

2a. Correlogram for d.ARMM

Lag	AC	PAC	Q	Prob>Q
2	-0.042	-0.0616	5.6331	0.0598
4	-0.1505	-0.1579	12.033	0.0171
6	-0.1849	-0.1947	22.837	0.0009
8	0.0872	0.0412	25.022	0.0015
10	-0.0723	-0.0646	38.846	0.000
12	0.1086	0.0695	45.767	0.000

2a. Correlogram for d.Mimaropa

Lag	AC	PAC	Q	Prob>Q
2	0.1144	0.0102	33.074	0.000
4	-0.1908	-0.1451	45.165	0.000
6	-0.2166	-0.1106	73.923	0.000
8	0.0618	0.0949	79.439	0.000
10	0.1011	0.0548	82.413	0.000
12	0.0618	-0.0465	89.467	0.000

2a. Correlogram for d.NCR

Lag	AC	PAC	Q	Prob>Q
2	-0.0074	-0.0767	17.972	0.0001
4	-0.2609	-0.252	38.256	0
6	-0.204	-0.1714	63.74	0
8	0.0573	0.005	67.895	0
10	0.1661	0.0382	80.925	0
12	-0.0014	-0.0679	87.356	0

2a. Correlogram for d.World

Lag	AC	PAC	Q	Prob>Q
2	-0.043	-0.2217	41.125	0
4	-0.1098	-0.0068	53.258	0
6	-0.0851	-0.1716	55.354	0
8	-0.1155	0.0032	69.143	0
10	0.1014	0.021	72.144	0
12	-0.0133	-0.0118	73.101	0

2a. Correlogram for d.NFABuy Premium

Lag	AC	PAC	Q	Prob>Q
2	-0.0746	-0.2693	44.351	0
4	-0.0427	-0.1277	45.293	0
6	-0.0142	-0.1529	45.709	0
8	-0.0096	-0.2012	46.006	0
10	-0.0803	-0.1086	52.062	0
12	0.0218	-0.0891	52.248	0

Continued Appendix Table B2. Test for Seasonality

2a. Correlogram for d.NFA Sell Premium

Lag	AC	PAC	Q	Prob>Q
2	0.04	0.0334	2.3649	0.3065
4	-0.0588	-0.0465	5.3736	0.2511
6	-0.0703	-0.0718	6.9778	0.3229
8	-0.0206	-0.0263	7.3574	0.4986
10	-0.0902	-0.0872	9.9335	0.4463
12	0.0148	0.0048	10.21	0.5976

2b. Correlogram for Central Luzon Equation Residual

Lag	AC	PAC	Q	Prob>Q
2	-0.0122	-0.0132	0.36497	0.8332
4	-0.0072	-0.0064	0.40952	0.9817
6	-0.0344	-0.0357	0.75352	0.9933
8	-0.0589	-0.0649	1.8386	0.9856
10	0.0775	0.059	5.4973	0.8556
12	0.0594	0.0563	6.5438	0.8862

2b. Correlogram for ARMM Equation Residual

Lag	AC	PAC	Q	Prob>Q
2	0.0225	0.0226	0.14082	0.932
4	-0.0264	-0.0265	0.43293	0.9797
6	-0.1247	-0.1264	6.5308	0.3664
8	-0.0062	0.0017	6.655	0.5743
10	-0.0069	-0.0294	21.972	0.0152
12	0.1113	0.1008	26.791	0.0083

2b. Correlogram for Mimaropa Equation Residual

Lag	AC	PAC	Q	Prob>Q
2	-0.0336	-0.0337	0.31949	0.8524
4	-0.0073	-0.0087	0.41265	0.9814
6	-0.1584	-0.1617	7.4535	0.2809
8	0.0739	0.0671	9.1802	0.3273
10	0.0747	0.0829	20.477	0.025
12	-0.0319	-0.0797	23.267	0.0255

2b. Correlogram for NCR Equation Residual

Lag	AC	PAC	Q	Prob>Q
2	-0.0661	-0.0662	1.2306	0.5405
4	0.0088	0.0042	1.3318	0.856
6	-0.0871	-0.0875	3.4797	0.7467
8	-0.0384	-0.0548	5.73	0.6774
10	0.0435	0.0325	6.5	0.7717
12	-0.025	-0.0273	9.7246	0.6401

2b. Correlogram for World Equation Residual

Lag	AC	PAC	Q	Prob>Q
2	0.009	0.009	0.03004	0.9851
4	-0.1014	-0.1027	3.2849	0.5113
6	-0.1076	-0.114	10.694	0.0983
8	-0.0373	-0.0537	14.55	0.0685
10	0.0471	0.0184	15.459	0.1162
12	0.0494	0.0629	18.422	0.1035

Continued Appendix Table B2. Test for Seasonality

2b. Correlogram for NFA Buy Prce Premium Equation Residual

Lag	AC	PAC	Q	Prob>Q
2	-0.0492	-0.0494	0.72521	0.6959
4	-0.1251	-0.1309	6.4505	0.1679
6	-0.0867	-0.1303	17.444	0.0078
8	0.0132	-0.0733	18.155	0.0201
10	-0.0117	-0.0975	23.471	0.0091
12	0.0287	-0.0158	24.103	0.0197

2b. Correlogram for NFA Sell Prce Premium Equation Residual

Lag	AC	PAC	Q	Prob>Q
2	0.0167	0.0167	0.10713	0.9478
4	0.0049	0.0047	0.12366	0.9982
6	0.0097	0.0116	2.1674	0.9037
8	-0.0583	-0.0591	3.7251	0.881
10	-0.1496	-0.1617	11.889	0.2925
12	-0.0365	-0.0337	12.367	0.4167

2c. Likelihood Ratio Test for Seasonality

LR=2(LLU-LLR)=2[-2366.806-(-2376.07)]=18.53***

Appendix Table B3a. VAR results with Trends

VARIABLES	dcentralluz_wh	darmm_wh	dmimaropa_wh	dncr_wh	dworld	dnfabuyprem	dnfasellprem
L.dcentralluz_wh	-0.360***	-0.0958	-0.0192	0.0151	0.0828	0.711	-0.102
	(0.079)	(0.071)	(0.060)	(0.088)	(0.139)	(0.617)	(0.114)
L2.dcentralluz_wh	-0.11	-0.0726	0.00897	-0.0875	0.029	0.494	-0.0349
	(0.083)	(0.075)	(0.064)	(0.093)	(0.147)	(0.654)	(0.120)
L3.dcentralluz_wh	-0.0418	0.157**	0.0533	-0.138	0.0674	1.393**	-0.149
	(0.082)	(0.074)	(0.063)	(0.091)	(0.144)	(0.640)	(0.118)
L4.dcentralluz_wh	-0.137*	-0.0891	-0.0796	-0.0773	0.00584	0.779	-0.0342
	(0.079)	(0.071)	(0.061)	(0.088)	(0.139)	(0.620)	(0.114)
L.darmm_wh	-0.0118	-0.00943	-0.0216	-0.104	-0.196	-0.987	-0.0462
	(0.078)	(0.071)	(0.060)	(0.087)	(0.138)	(0.614)	(0.113)
L2.darmm_wh	0.014	-0.113	0.0242	0.0232	-0.183	1.289**	0.067
	(0.077)	(0.070)	(0.059)	(0.086)	(0.136)	(0.606)	(0.112)
L3.darmm_wh	-0.125	0.0796	0.0707	-0.0601	-0.00366	-0.374	-0.175
	(0.077)	(0.070)	(0.059)	(0.086)	(0.135)	(0.603)	(0.111)
L4.darmm_wh	0.128	-0.0751	-0.00684	0.0919	0.0139	0.701	-0.0511
	(0.079)	(0.071)	(0.060)	(0.087)	(0.138)	(0.616)	(0.113)
L.dmimaropa_wh	0.127	0.094	-0.0534	-0.0419	-0.261	0.365	0.0466
	(0.107)	(0.097)	(0.082)	(0.119)	(0.188)	(0.837)	(0.154)
L2.dmimaropa_wh	-0.0424	-0.0609	-0.0417	0.0456	-0.148	-0.178	-0.135
	(0.104)	(0.094)	(0.080)	(0.115)	(0.182)	(0.813)	(0.150)
L3.dmimaropa_wh	0.0242	-0.0778	-0.178**	0.0993	0.22	-0.425	0.122
	(0.100)	(0.090)	(0.076)	(0.111)	(0.175)	(0.781)	(0.144)
L4.dmimaropa_wh	-0.294***	-0.00973	-0.118	-0.181*	-0.234	0.128	0.197
	(0.094)	(0.085)	(0.072)	(0.105)	(0.165)	(0.737)	(0.136)
L.dncr_wh	0.420***	0.198***	0.335***	0.134*	0.511***	-0.827	-0.115
	(0.067)	(0.061)	(0.052)	(0.075)	(0.118)	(0.526)	(0.097)
L2.dncr_wh	-0.0735	0.00846	-0.0674	-0.191**	-0.300**	-0.990*	0.0974
	(0.073)	(0.066)	(0.056)	(0.082)	(0.129)	(0.575)	(0.106)
L3.dncr_wh	0.0724	-0.0657	-0.0448	-0.00678	0.0561	-1.028*	-0.0688
	(0.074)	(0.066)	(0.056)	(0.082)	(0.129)	(0.577)	(0.106)
L4.dncr_wh	0.0789	0.0668	0.0556	-0.116	-0.0693	-0.685	0.157
	(0.074)	(0.067)	(0.057)	(0.082)	(0.129)	(0.577)	(0.106)

Continued Appendix Table B3a. VAR results with Trends

VARIABLES	lncentralluz_wh	lnarmm_wh	lnmimaropa_wh	lnncr_wh	lnworld	lnnfabuyprem	lnnfasellprem
L.dworld	0.131***	0.0666*	0.0599**	0.111***	0.460***	-0.168	-0.114**
	(0.038)	(0.035)	(0.029)	(0.043)	(0.068)	(0.301)	(0.055)
L2.dworld	0.134***	0.140***	0.0804***	0.182***	-0.136*	0.143	-0.0743
	(0.040)	(0.036)	(0.031)	(0.045)	(0.071)	(0.314)	(0.058)
L3.dworld	0.0135	0.0438	0.0321	0.0205	-0.197***	-0.23	-0.136**
	(0.041)	(0.037)	(0.032)	(0.046)	(0.072)	(0.322)	(0.059)
L4.dworld	0.0745*	0.0471	0.0413	0.0607	0.176**	-0.146	0.0415
	(0.040)	(0.036)	(0.031)	(0.045)	(0.071)	(0.316)	(0.058)
L.dnfabuyprem	-0.0135*	-0.00311	-0.00901	-0.0162*	-0.0152	-0.595***	0.000486
	(0.008)	(0.007)	(0.006)	(0.009)	(0.014)	(0.061)	(0.011)
L2.dnfabuyprem	-0.0181**	-0.000732	0.00118	-0.00824	0.00276	-0.439***	-0.00209
	(0.009)	(0.008)	(0.007)	(0.010)	(0.016)	(0.070)	(0.013)
L3.dnfabuyprem	-0.0147*	-2.41E-03	-4.36E-03	-0.009	-0.00887	-0.242***	0.0134
	(0.009)	(0.008)	(0.007)	(0.010)	(0.016)	(0.069)	(0.013)
L4.dnfabuyprem	-0.0149*	-9.48E-04	2.28E-04	-0.0124	-0.00915	-0.140**	0.00535
	(0.008)	(0.007)	(0.006)	(0.009)	(0.014)	(0.060)	(0.011)
L.dnfasellprem	0.0468	0.0323	-0.0148	-0.0197	-0.0085	-0.394	-0.0638
	(0.047)	(0.042)	(0.036)	(0.052)	(0.082)	(0.366)	(0.068)
L2.dnfasellprem	-0.0139	0.0025	-0.0687*	0.00643	-0.0837	-0.138	0.00597
	(0.047)	(0.042)	(0.036)	(0.052)	(0.082)	(0.364)	(0.067)
L3.dnfasellprem	0.0107	0.0981**	0.054	-0.00158	0.00345	-0.401	-0.142**
	(0.046)	(0.042)	(0.035)	(0.051)	(0.081)	(0.361)	(0.067)
L4.dnfasellprem	0.0271	-0.0229	-0.0126	0.0635	0.104	0.000333	0.0138
	(0.046)	(0.042)	(0.036)	(0.052)	(0.082)	(0.364)	(0.067)
wetseason	-0.0894	-0.00917	-0.250***	-0.268**	-0.115	1.061	0.0846
	(0.096)	(0.087)	(0.074)	(0.106)	(0.168)	(0.751)	(0.138)
trend	0.000644	0.00047	0.000373	0.000155	0.000275	-0.00102	0.00019
	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.004)	(0.001)
Constant	0.0321	0.00335	0.179**	0.250**	0.119	-0.628	-0.0802
	(0.102)	(0.092)	(0.078)	(0.113)	(0.179)	(0.797)	(0.147)
Observations	272	272	272	272	272	272	272
R-squared	0.3834	0.2961	0.4201	0.2957	0.3291	0.3126	0.2264

Appendix Table B3b. Likelihood Ratio Test for Seasonality

LR=2(LLU-LLR)=2[-2365.152-(-2366.805)]=3.306; not significant

Appendix Table B4. Lag Order Selection for Model with the trend term and seasonal dummies

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-2646.33				0.793167	-0.335044	-0.335044	-.335044*
1	-2519.9	252.86	49	0	4.48E-01	-0.9065	-.644993*	-0.255194
2	-2447.57	144.66	49	0	.377428*	-1.07866*	-0.555646	0.223952
3	-2400.09	94.952	49	0	3.82E-01	-1.06741	-0.282892	0.886506
4	-2361.01	78.174*	49	0.005	4.13E-01	-0.994251	0.051774	1.61097
5	-2330.87	60.279	49	0.13	4.77E-01	-0.855059	0.452472	2.40147

Appendix Table B5. Lagrange-multiplier Test for selected VAR

Lag	chi2	df	Prob>chi2
1	80.3697	49	0.00313
2	131.0694	49	0.0000
3	76.78	49	0.00681
4*	58.9585	49	0.15595
5	65.9101	49	0.15377
6	61.3211	49	0.11134
7	54.9111	49	0.26063
8	55.52	49	0.24253
9	53.0948	49	0.31932
10	64.7946	49	0.06473
11	51.1051	49	0.39095
12	57.0314	49	0.20121

Appendix B6. Stability Conditions

Eigenvalue stability condition

Eigenvalue	Modulus
.462543 + .4763561*i*	.663974
.462543 − .4763561*i*	.663974
−.2887704 + .481023*i*	.561045
−.2887704 − .481023*i*	.561045
−.1141775 + .5396163*i*	.551563
−.1141775 − .5396163*i*	.551563
−.1170968 + .3622595*i*	.380715
−.1170968 − .3622595*i*	.380715
−.3675971	.367597
.078458 + .3121088*i*	.321819
.078458 − .3121088*i*	.321819
.2865634	.286563
−.2069883	.206988
−.1800618	.180062

All the eigenvalues lie inside the unit circle.
VAR satisfies stability condition.

APPENDIX C

Appendix Table C1. Timeline of Export Restriction Measures for Rice and Wheat in India

Non-basmati rice	• April 2007- Futures trading on rice was suspended • **October 9, 2007 – Ban exports** • October 31, 2007 – Ban lifted and replaced with MEP of ME$425/t fob • December 2007 – MEP raised to $US500/t • March 5, 2008 – MEP raised to $US650/t and import duty was reduced to zero • March 27, 2008 – MEP to ME$1000/t • **April 1, 2008 – Ban Exports** • September 2009 – Ban extended • Feb 2010 – Ban continued except for 3 premium varieties with ME$800/t MEP and quota of 150,000t for MY 2010/11 • July 2010 – Decided to continue the ban • **September 2011 – Ban lifted**
Basmati rice	• March 8, 2008 – MEP increased to $US950/t at the same time import duty was reduced to zero • March 17, 2008: basmati rice exports were restricted only to two ports, Mundra and Pipavav • March 27, 2008 – MEP raised to $US1100/t • April 1, 2008 – MEP raised to ME$1200/t • April 29, 2009 – Export tax of Rs.8000/t (approx. ME$200) • January 20, 2009- Tax removed and MEP reduced to ME$1100/t • September 2009 – MEP reduced to ME$900/t • Feb 2010 – MEP of ME$900/t
Wheat	• September 2006: Import tariff was reduced to zero and private sector allowed to import to increase supply in open market • December 2006- duty free imports • **February 2007 – export ban** on wheat and wheat products until end of December 2007. Also banned futures trading in wheat. • October 2007- ban extended indefinitely • July 3, 2009 – Export quota of 3 million tons through STEs • July 13, 2009 – July 3 quota withdrawn and full export ban re-imposed • May 2010- Export quota of 650,000 t for one year • **September 2011– Ban lifted**

Appendix Table C2. Unit root tests for all variables used in the Study (Levels, Logs, Differences in Levels, Differences in Logs)

	Augmented Dickey-Fuller Test			Phillips-Perron Test					
	including constant and trend	including constant but no trend	excluding both constant and trend	including constant and trend		including constant but no trend		excluding both constant and trend	
				Z(rho)	Z(t)	Z(rho)	Z(t)	Z(rho)	Z(t)
1% critical value	**-3.96**	**-3.43**	**-2.58**	**-29.5**	**-3.96**	**-20.7**	**-3.43**	**-13.8**	**-2.58**
5% critical value	**-3.41**	**-2.86**	**-1.95**	**-21.8**	**-3.41**	**-14.1**	**-2.86**	**-8.1**	**-1.95**
10% critical value	**-3.12**	**-2.57**	**-1.62**	**-18.3**	**-3.12**	**-11.3**	**-2.57**	**-5.7**	**-1.62**
bijnaur_rice	-4.239***	-0.433	1.639	-287.179***	-13.416***	-6.326	-1.749	0.596	0.804
burdwan_rice	-2.259	0.054	1.788	-12.339	-2.450	0.093	0.050	0.812	1.747
westgodavari_rice	-2.896	0.056	1.639	-68.333***	-6.108***	-2.364	-0.846	1.084	1.023
unnao_wheat	-3.161*	-0.296	1.358	-25.409**	-3.432**	-1.765	-0.650	0.812	1.222
ludhiana_wheat	-4.435**	-0.777	1.173	-233.244***	-11.930***	-9.021	-2.083	0.512	0.546
gurgaon_wheat	-3.158*	-0.397	1.353	-84.717***	-6.853***	-5.105	-1.426	0.654	0.899
vadodara_rice	-2.689	-0.850	1.122	-24.435**	-3.563**	-2.909	-1.171	0.664	0.875
mangalore_rice	-3.907**	-0.895	0.741	-412.083***	-16.498***	-49.927***	-5.242***	0.975	-0.484
ernakulam_rice	-3.675**	-1.127	0.421	-279.252***	-13.157***	-43.807***	-4.886***	-1.075	-0.517
kachch_wheat	-3.177*	-0.476	1.137	-148.935***	-9.277***	-12.142	-2.365	0.555	0.499
mysore_wheat	-4.772***	-0.409	1.504	-429.575***	-17.001***	-11.486	-2.392	0.528	0.509
malda_wheat	-3.274*	-0.946	0.762	-29.474**	-3.809**	-4.747	-1.301	0.641	0.711
rice world	-3.439**	-1.489	0.125	-19.423*	-3.163*	-3.395	-1.245	0.433	0.378
wheat world	-2.908	-1.153	0.460	-19.050*	-3.167*	-3.602	-1.242	0.345	0.350
delhi_rice	-2.727	-0.837	1.138	-89.615***	-7.202***	-5.398	-1.581	0.386	0.436
mumbai_rice	-2.211	-1.275	0.575	-21.292*	-3.319*	-3.823	-1.413	0.257	0.308
kolkata_rice	-2.473	-0.101	1.609	-49.719***	-5.291***	-2.189	-0.794	0.742	0.927
delhi_wheat	-3.035	-0.009	2.098	-156.335***	-9.605***	-2.670	-0.992	0.830	1.134
mumbai_wheat	-2.278	0.019	1.850	-23.734**	-3.642**	-0.821	-0.403	0.838	1.272
patna_wheat	-4.501***	-0.557	1.367	-156.547***	-9.633***	-3.380	-1.182	0.625	0.860
rainfall	-6.773***	-6.783***	-4.359***	-45.218***	-4.803***	-45.303	-4.814	-20.977***	-3.255***

Continued Appendix Table C2. Unit root tests for all variables used in the Study (Levels, Logs, Differences in Levels, Differences in Logs)

	Augmented Dickey-Fuller Test			Phillips-Perron Test					
	including constant and trend	including constant but no trend	excluding both constant and trend	including constant and trend		including constant but no trend		excluding both constant and trend	
				Z(rho)	Z(t)	Z(rho)	Z(t)	Z(rho)	Z(t)
1% critical value	**-3.96**	**-3.43**	**-2.58**	**-29.5**	**-3.96**	**-20.7**	**-3.43**	**-13.8**	**-2.58**
5% critical value	**-3.41**	**-2.86**	**-1.95**	**-21.8**	**-3.41**	**-14.1**	**-2.86**	**-8.1**	**-1.95**
10% critical value	**-3.12**	**-2.57**	**-1.62**	**-18.3**	**-3.12**	**-11.3**	**-2.57**	**-5.7**	**-1.62**
ln bijnaur_rice	-4.410***	-0.804	1.711	-272.320***	-13.030***	-6.038	-1.838	0.311	1.109
ln burdwan_rice	-2.782	-0.318	1.802	-18.930*	-3.117*	-0.597	-0.318	0.293	1.689
ln westgodavari_rice	-4.966***	-0.706	1.495	-337.464***	-14.714***	-8.251	-2.149	0.458	0.942
ln unnao_wheat	-3.494**	-0.672	1.279	-27.847**	-3.720**	-2.727	-1.045	0.371	1.258
ln ludhiana_wheat	-4.548***	-1.060	1.313	-207.880***	-11.206***	-7.456	-1.996	0.347	0.893
ln gurgaon_wheat	-3.551**	-0.724	1.332	-89.844***	-7.112***	-5.467	-1.620	0.329	1.061
ln vadodara_rice	-2.634	-1.119	1.191	-36.269***	-4.413***	-4.407	-1.604	0.330	0.981
ln mangalore_rice	-3.087	-0.233	1.849	-195.449***	-10.873***	-5.449	-1.561	0.308	0.970
ln ernakulam_rice	-5.357***	-2.174	0.297	-476.095***	-18.280***	-157.177***	-9.636***	-0.162	-0.157
ln kachch_wheat	-3.630**	-0.864	1.097	-140.609***	-9.042***	-10.916	-2.363	0.358	0.791
ln mysore_wheat	-5.107***	-0.912	1.477	-464.692***	-17.826***	-13.041*	-2.678*	0.322	0.799
ln malda_wheat	-3.477**	-1.091	0.872	-51.144***	-5.237***	-7.102	-1.805	0.329	0.790
ln rice world	-2.739	-1.320	1.026	-21.678***	-3.334***	-2.779	-1.254	0.412	1.097
ln wheat world	-2.822	-1.117	0.785	-17.729	-3.062	-2.983	-1.138	0.271	0.691
ln delhi_rice	-5.284***	-2.009	0.429	-486.061***	-18.604***	-99.190***	-7.581***	-0.142	-0.154
ln mumbai_rice	-2.130	-1.310	1.166	-33.780***	-4.242***	-3.580	-1.383	0.208	0.724
ln kolkata_rice	-3.840**	-0.978	1.066	-259.831***	-12.678***	-15.763**	-2.829**	0.213	0.422
ln delhi_wheat	-5.506***	-1.549	0.691	-531.129***	-19.818***	-68.283***	-6.257***	0.041	0.050
ln mumbai_wheat	2.717	-0.442	1.753	-39.041***	-4.675***	-1.665	-0.757	0.302	1.245
ln patna_wheat	-5.839***	-1.366	0.840	-426.356***	-17.272***	-27.773***	-3.906***	0.181	0.323
ln rainfall	-5.853***	-5.861	-1.549	-41.364***	-4.634***	-41.536***	-4.654***	-2.716	-1.142

Continued Appendix Table C2. Unit root tests for all variables used in the Study (Levels, Logs, Differences in Levels, Differences in Logs)

	Augmented Dickey-Fuller Test			Phillips-Perron Test					
	including constant and trend	including constant but no trend	excluding both constant and trend	including constant and trend		including constant but no trend		excluding both constant and trend	
				Z(rho)	Z(t)	Z(rho)	Z(t)	Z(rho)	Z(t)
1% critical value	**-3.96**	**-3.43**	**-2.58**	**-29.5**	**-3.96**	**-20.7**	**-3.43**	**-13.8**	**-2.58**
5% critical value	**-3.41**	**-2.86**	**-1.95**	**-21.8**	**-3.41**	**-14.1**	**-2.86**	**-8.1**	**-1.95**
10% critical value	**-3.12**	**-2.57**	**-1.62**	**-18.3**	**-3.12**	**-11.3**	**-2.57**	**-5.7**	**-1.62**
d bijnaur_rice	-14.581***	-14.580***	-14.403***	-614.050***	-50.467***	-614.137***	-50.489***	-615.085***	-50.119***
d burdwan_rice	-9.509***	-9.460***	-9.260***	-488.318***	-23.732***	-489.214***	-23.705***	-492.193***	-23.565***
d westgodavari_rice	-12.018***	-12.002***	-11.801***	-668.597***	-42.737***	-669.206***	-42.661***	-671.131***	-42.300***
d unnao_wheat	-10.195***	-10.160***	-10.045***	-403.865***	-18.888***	-404.173***	-18.897***	-404.450***	-18.850***
d ludhiana_wheat	-12.684***	-12.685***	-12.589***	-606.560***	-44.640***	-606.621***	-44.675***	-607.446***	-44.471***
d gurgaon_wheat	-11.469***	-11.463***	-11.342***	-574.424***	-38.021***	-574.697***	-38.016***	-575.825***	-37.827***
d vadodara_rice	-11.770***	-11.784***	-11.617***	-598.981***	-29.881***	-599.008***	-29.910***	-600.590***	-29.804***
d mangalore_rice	-16.076***	-16.070***	-16.014***	-636.474***	-61.580***	-636.553***	-61.588***	-636.757***	-61.503***
d ernakulam_rice	-14.644***	-14.632***	-14.603***	-632.855***	-55.723***	-632.994***	-55.709***	-633.158***	-55.680***
d kachch_wheat	-12.566***	-12.545***	-12.453***	-707.752***	-50.165***	-708.096***	-50.120***	-708.950***	-49.890***
d mysore_wheat	-17.436***	-17.425***	-17.233***	-682.088***	-61.689***	-682.178***	-61.705***	-682.957***	-61.245***
d malda_wheat	-10.018***	-10.021***	-9.945***	-631.336***	-28.959***	-631.884***	-28.964***	-633.133***	-28.908***
d rice world	-7.370***	-7.381***	-7.343***	-707.359***	-28.371***	-707.330***	-28.401***	-708.278***	-28.374***
d wheat world	-9.776***	-9.784***	-9.743***	-586.017***	-25.294***	-586.110***	-25.314***	-586.973***	-25.298***
d delhi_rice	-13.865***	-13.886***	-13.695***	-642.721***	-48.012***	-642.720***	-48.063***	-643.634***	-47.822***
d mumbai_rice	-10.656***	-10.656***	-10.590***	-649.738***	-35.497***	-649.812***	-35.528***	-650.742***	-35.460***
d kolkata_rice	-12.452***	-12.452***	-12.231***	-638.622***	-43.817***	-638.991***	-43.763***	-640.735***	-43.400***
d delhi_wheat	-14.508***	-14.541***	-14.133***	-657.611***	-52.911***	-657.748***	-52.913***	-659.537***	-52.199***
d mumbai_wheat	-13.364***	-13.308***	-13.087***	-600.252***	-37.296***	-600.765***	-37.240***	-603.073***	-36.914***
d patna_wheat	-12.108***	-12.109***	-11.982***	-624.829***	-41.147***	-624.934***	-41.174***	-626.329***	-40.927***
d rainfall	-7.034***	-7.037***	-7.044***	-588.028***	-23.010***	-588.048***	-23.024***	-588.048***	-23.044***

Continued Appendix Table C2. Unit root tests for all variables used in the Study (Levels, Logs, Differences in Levels, Differences in Logs)

	Augmented Dickey-Fuller Test			Phillips-Perron Test					
	including constant and trend	including constant but no trend	excluding both constant and trend	including constant and trend		including constant but no trend		excluding both constant and trend	
				Z(rho)	Z(t)	Z(rho)	Z(t)	Z(rho)	Z(t)
1% critical value	**-3.96**	**-3.43**	**-2.58**	**-29.5**	**-3.96**	**-20.7**	**-3.43**	**-13.8**	**-2.58**
5% critical value	**-3.41**	**-2.86**	**-1.95**	**-21.8**	**-3.41**	**-14.1**	**-2.86**	**-8.1**	**-1.95**
10% critical value	**-3.12**	**-2.57**	**-1.62**	**-18.3**	**-3.12**	**-11.3**	**-2.57**	**-5.7**	**-1.62**
d ln bijnaur_rice	-14.264***	-14.278***	-14.099***	-610.938***	-48.229***	-610.949***	-48.283***	-611.991***	-47.925***
d ln burdwan_rice	-10.105***	-10.092***	-9.884***	-513.471***	-24.810***	-513.780***	-24.814***	-516.858***	-24.666***
d ln westgodavari_rice	-13.957***	-13.978***	-13.772***	-666.157***	-51.208***	-666.187***	-51.259***	-667.151***	-50.929***
d ln unnao_wheat	-10.493***	-10.486***	-10.383***	-419.525***	-19.460***	-419.656***	-19.478***	-419.919***	-19.433***
d ln ludhiana_wheat	-12.281***	-12.293***	-12.192***	-613.262***	-43.004***	-613.260***	-43.053***	-614.273***	-42.829***
d ln gurgaon_wheat	-11.280***	-11.292***	-11.170***	-576.044***	-37.090***	-576.129***	-37.121***	-577.238***	-36.949***
d ln vadodara_rice	-13.737***	-13.712***	-13.478***	-657.075***	-37.809***	-657.092***	-37.846***	-658.418***	-37.684***
d ln mangalore_rice	-14.812***	-14.805***	-14.606***	-632.263***	-54.807***	-632.417***	-54.775***	-633.241***	-54.408***
d ln ernakulam_rice	-15.262***	-15.268***	-15.266***	-633.106***	-57.938***	-633.151***	-57.979***	-633.207***	-58.010***
d ln kachch_wheat	-12.173***	-12.178***	-12.095***	-679.314***	-46.435***	-679.432***	-46.461***	-680.211***	-46.285***
d ln mysore_wheat	-17.096***	-17.112***	-16.946***	-698.103***	-62.959***	-698.100**	-63.030***	-698.810***	-62.596***
d ln malda_wheat	-10.487***	-10.501***	-10.430***	-646.086***	-34.817***	-646.226***	-34.844***	-647.223***	-34.760***
d ln rice world	-8.048***	-8.050***	-7.968***	-677.183***	-32.424***	-677.359***	-32.447***	-679.174***	-32.327***
d ln wheat world	-9.468***	-9.477***	-9.430***	-579.999***	-25.191***	-580.013***	-25.214***	-581.008***	-25.192***
d ln delhi_rice	-18.509***	-18.505***	-18.432***	-642.502***	-59.873***	-642.502***	-59.943***	-642.619***	-59.938***
d ln mumbai_rice	-11.700***	-11.665***	-11.516***	-648.849***	-41.872***	-649.030***	-41.890***	-650.235***	-41.701***
d ln kolkata_rice	-14.527***	-14.548***	-14.438***	-639.912***	-52.727***	-639.928***	-52.775***	-640.414***	-52.623***
d ln delhi_wheat	-18.430***	-18.435***	-18.318***	-649.569***	-62.860***	-649.569***	-62.933***	-649.762***	-62.856***
d ln mumbai_wheat	-13.516***	-13.505***	-13.326***	-587.827***	-36.261***	-597.935***	-36.273***	-589.848***	-36.028***
d ln patna_wheat	-14.656***	-14.670***	-14.627***	-621.017***	-52.771***	-621.018***	-52.832***	-621.299***	-52.754***
d ln rainfall	-7.487***	-7.493***	-7.501***	-576.987***	-22.977***	-576.927***	-22.985***	-576.920***	-23.005***

*** 1% significance, ** 5% significance and * 10% sognificance

Note: If p-value is significant, it means it is stationary. - can do VAR in levels. If insignificant, it means unit root. - data needs to be differenced.

Appendix Table C3. Wheat Exports in India in 1,000 MT from 2000-2013

Market Year	Exports in 1000 MT	Growth Rate
2000	1569	684.50%
2001	3087	96.75%
2002	4850	57.11%
2003	5650	16.49%
2004	2120	-62.48%
2005	801	-62.22%
2006	94	-88.26%
2007	49	-47.87%
2008	23	-53.06%
2009	58	152.17%
2010	72	24.14%
2011	891	1137.50%
2012	6824	665.88%
2013	6500	-4.75%

Source: http://www.indexmundi.com/agriculture/?country=in&commodity=wheat&graph=exports

Appendix Table C4. Detailed Cointegration Results for Rice, ER Period

		Johansen Linear Cointeg Test Result	Estimated Beta Cointeg Vector in Linear VECM	Estimated Beta Cointeg Vector TVECM	Estimated Thresholds, Tau	Hansen Seo Threshold Cointeg Test Statistic Ho: LC	Hansen Seo Threshold Cointeg Test Result	Seo Threshold Cointeg Test Statistic (Ho: no Cointeg)	Seo Threshold Cointeg Test Result	Nested Conclusion from both Linear and Threshold Cointeg
Consuming-Producing	Delhi-Burdwan	no cointeg	1.27	0.72	5.11	14.28	LC	11.78	no cointeg	no cointeg
	Kolkata-Burdwan	no cointeg	0.65	0.84	1.29	41.20	LC	19.17***	cointeg	no cointeg
	Mumbai-Burdwan	no cointeg	0.85	0.64	3.47	20.16**	TC	20.17	no cointeg	no cointeg
	Delhi-Bijnaur	no cointeg	0.23	0.72	2.99	21.95	LC	13.12***	cointeg	no cointeg
	Kolkata-Bijnaur	no cointeg	0.24	0.81	2.61	25.67	LC	15.6***	cointeg	no cointeg
	Mumbai-Bijnaur	no cointeg	0.15	0.64	5.40	11.13	LC	18.72***	cointeg	no cointeg
	Delhi-West Godavari	no cointeg	0.79	0.99	-6.07	19.58	LC	12.38	no cointeg	no cointeg
	Kolkata-West Godavari	no cointeg	0.82	1.14	-4.46	33.12	LC	15.82***	cointeg	no cointeg
	Mumbai-West Godavari	no cointeg	0.56	0.89	3.06	30.34	LC	12.96	no cointeg	no cointeg
Port-Producing	Mangalore-Burdwan	no cointeg	1.35	0.84	1.48	25.01	LC	16.74***	cointeg	no cointeg
	Ernakulam-Burdwan	no cointeg	1.06	0.78	1.84	34.15	LC	17.63***	cointeg	no cointeg
	Vadodara-Burdwan	no cointeg	-2.06	0.75	2.22	15.43	LC	12.64	no cointeg	no cointeg
	Mangalore-Bijnaur	no cointeg	0.41	0.82	1.15	26.19***	TC	9.29***	cointeg	cointeg
	Ernakulam-Bijnaur	no cointeg	0.54	0.76	2.07	29.09	LC	14.29	no cointeg	no cointeg
	Vadodara-Bijnaur	no cointeg	-0.54	0.73	3.25	23.57***	TC	11.53***	cointeg	cointeg
	Mangalore-West Godavari	no cointeg	1.43	1.19	5.06	25.67	LC	27.66	no cointeg	no cointeg
	Ernakulam-West Godavari	cointeg	1.31	1.06	-2.73	30.52	LC	14.81***	cointeg	cointeg
	Vadodara-West Godavari	no cointeg	-0.68	1.04	-0.37	12.56	LC	10.92	no cointeg	no cointeg
Consuming-Port	Delhi-Managalore	no cointeg	-4.17	0.84	-3.70	29.78	LC	8.92***	cointeg	no cointeg
	Kolkata-Mangalore	no cointeg	0.45	0.97	2.58	15.14	LC	10.25***	cointeg	no cointeg
	Mumbai-Mangalore	no cointeg	3.90	0.76	6.79	18.35	LC	17.45	no cointeg	no cointeg
	Delhi-Ernakulam	no cointeg	0.01	0.93	-5.40	23.40	LC	9.82	no cointeg	no cointeg
	Kolkata-Ernakulam	no cointeg	0.59	1.07	-2.18	31.75	LC	18.32***	cointeg	no cointeg
	Mumbai-Ernakulam	no cointeg	0.09	0.84	2.06	20.68	LC	18.02	no cointeg	no cointeg
	Delhi-Vadodara	no cointeg	-0.11	0.95	-3.12	21.59	LC	12.92***	cointeg	no cointeg
	Kolkata-Vadodara	no cointeg	-0.63	1.07	0.06	37.25	LC	8.83**	cointeg	no cointeg
	Mumbai-Vadodara	no cointeg	0.34	0.85	-1.15	10.02	LC	15.91	no cointeg	no cointeg
World-Port	World-Mangalore	no cointeg	4.52	0.92	4.14	27.09	LC	15.19	no cointeg	no cointeg
	World-Ernakulam	no cointeg	5.89	0.99	5.29	39.86	LC	13.66	no cointeg	no cointeg
	World-Vadodara	cointeg	-0.23	1.04	-2.48	13.18	LC	8.01***	cointeg	cointeg

Continued Appendix Table C4. Detailed Cointegration Results for Wheat, ER Period

		Johansen Linear Cointeg Test Result	Estimated Beta Cointeg Vector in Linear VECM	Estimated Beta Cointeg Vector TVECM	Estimated Thresholds, Tau	Hansen Seo Threshold Cointeg Test Statistic Ho: LC	Hansen Seo Threshold Cointeg Test Result	Seo Threshold Cointeg Test Statistic (Ho: no Cointeg)	Seo Threshold Cointeg Test Result	Nested Conclusion from both Linear and Threshold Cointeg
Consuming-Producing	Delhi-Unnao	no cointeg	0.45	0.66	-0.30	17.29*	TC	13.88	no cointeg	no cointeg
	Patna-Unnao	no cointeg	0.45	0.67	1.67	14.12	LC	14.05***	cointeg	no cointeg
	Mumbai-Unnao	no cointeg	0.17	0.49	1.77	9.94	LC	6.61	no cointeg	no cointeg
	Delhi-Ludhiana	cointeg	0.66	0.66	-1.64	43.05**	TC	15.82	no cointeg	no cointeg
	Patna-Ludhiana	cointeg	0.62	0.68	-1.60	42.25**	TC	14.23***	cointeg	cointeg
	Mumbai-Ludhiana	no cointeg	0.22	0.49	-1.60	45.22**	TC	12.38***	cointeg	cointeg
	Delhi-Gurgaon	no cointeg	0.43	0.69	-0.07	29.63	LC	17.10	no cointeg	no cointeg
	Patna-Gurgaon	no cointeg	0.36	0.69	0.91	27.01	LC	17.19	no cointeg	no cointeg
	Mumbai-Gurgaon	no cointeg	0.12	0.52	3.76	27.00	LC	8.10***	cointeg	no cointeg
Port-Producing	Kachch-Unnao	no cointeg	0.82	0.89	-1.84	32.74	LC	34.46	no cointeg	no cointeg
	Mysore-Unnao	no cointeg	0.43	0.64	0.03	42.92	LC	15.52***	cointeg	no cointeg
	Malda-Unnao	no cointeg	1.13	0.99	0.96	20.58***	TC	39.92***	cointeg	cointeg
	Kachch-Ludhiana	no cointeg	1.31	0.90	-1.76	32.96	LC	22.38***	cointeg	no cointeg
	Mysore-Ludhiana	cointeg	0.68	0.64	-0.21	36.71	LC	15.16	no cointeg	cointeg
	Malda-Ludhiana	cointeg	2.47	0.98	-0.90	43.46*	LC	12.15	no cointeg	cointeg
	Kachch-Gurgaon	no cointeg	0.82	0.91	-1.17	39.46***	TC	23.38***	cointeg	cointeg
	Mysore-Gurgaon	no cointeg	0.47	0.67	1.13	30.45	LC	13.43***	cointeg	no cointeg
	Malda-Gurgaon	no cointeg	1.12	1.03	-1.60	28.60	LC	31.77	cointeg	no cointeg
Consuming-Port	Delhi-Kachch	no cointeg	0.48	0.75	2.00	23.96	LC	16.7***	cointeg	no cointeg
	Patna-Kachch	cointeg	0.45	0.75	3.79	24.12	LC	16.36***	cointeg	cointeg
	Mumbai-Kachch	no cointeg	0.16	0.54	4.25	32.14	LC	7.51***	cointeg	no cointeg
	Delhi-Mysore	cointeg	0.93	1.04	-2.40	40.97***	TC	38.91***	cointeg	cointeg
	Patna-Mysore	cointeg	0.88	1.04	-2.49	29.79*	TC	37.68***	cointeg	cointeg
	Mumbai-Mysore	cointeg	0.38	0.76	-2.58	29.02	LC	7.88	no cointeg	cointeg
	Delhi-Malda	no cointeg	0.31	0.67	1.03	10.30	LC	17.90	no cointeg	no cointeg
	Patna-Malda	no cointeg	0.32	0.66	0.97	15.15	LC	21.71***	cointeg	no cointeg
	Mumbai-Malda	cointeg	0.12	0.74	0.32	11.36	LC	20.52	no cointeg	cointeg
World-Port	World-Kachch	no cointeg	0.08	0.90	4.98	26.92*	TC	21.05***	cointeg	cointeg
	World-Mysore	no cointeg	1.12	1.24	-7.43	31.76	LC	12.66***	cointeg	no cointeg
	World-Malda	no cointeg	0.10	0.83	0.24	14.17	LC	22.48***	cointeg	no cointeg

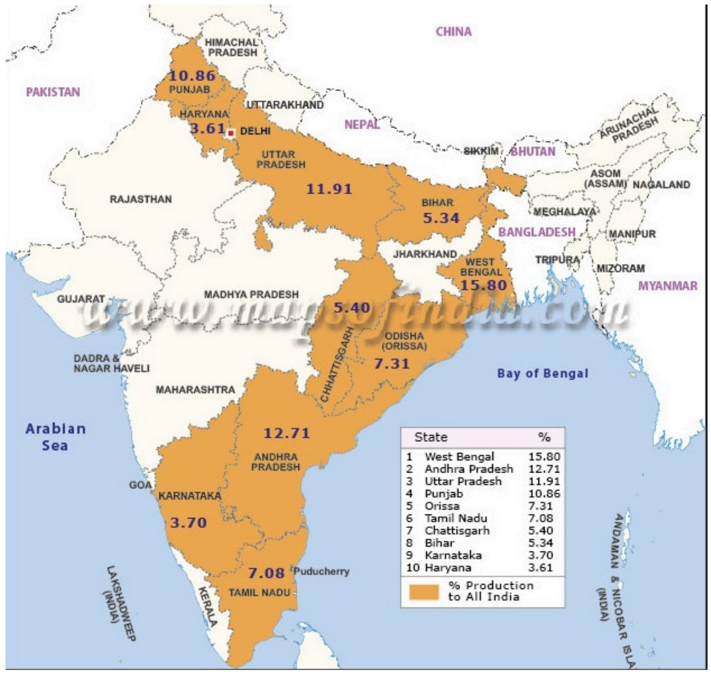
Continued Appendix Table C4. Detailed Cointegration Results for Rice, OT Period

		Johansen Linear Cointeg Test Result	Estimated Beta Cointeg Vector in Linear VECM	Estimated Beta Cointeg Vector TVECM	Estimated Thresholds, Tau	Hansen Seo Threshold Cointeg Test Statistic Ho: LC	Hansen Seo Threshold Cointeg Test Result	Seo Threshold Cointeg Test Statistic (Ho: no Cointeg)	Seo Threshold Cointeg Test Result	Nested Conclusion from both Linear and Threshold Cointeg
Consuming-Producing	Delhi-Burdwan	cointeg	0.48	0.89	-1.70	46.61***	TC	49.29***	cointeg	cointeg
	Kolkata-Burdwan	cointeg	0.52	0.84	1.29	25.98	LC	27.7	no cointeg	cointeg
	Mumbai-Burdwan	no cointeg	0.51	0.87	-0.37	36.73	LC	26.7	no cointeg	no cointeg
	Delhi-Bijnaur	cointeg	0.60	0.82	-1.31	61.18***	TC	46.1	no cointeg	no cointeg
	Kolkata-Bijnaur	no cointeg	0.47	0.89	-1.94	44.62**	TC	25.2	no cointeg	no cointeg
	Mumbai-Bijnaur	cointeg	0.61	0.79	0.73	53.70***	TC	30.13***	cointeg	cointeg
	Delhi-West Godavari	no cointeg	2.03	0.98	-0.03	59.46***	TC	18.08***	cointeg	cointeg
	Kolkata-West Godavari	no cointeg	2.30	1.04	1.05	32.92	LC	14.15***	cointeg	no cointeg
	Mumbai-West Godavari	cointeg	1.79	0.94	-2.45	36.24	LC	13.5	no cointeg	cointeg
Port-Producing	Mangalore-Burdwan	cointeg	1.24	0.93	0.13	32.66*	TC	38.5	no cointeg	no cointeg
	Ernakulam-Burdwan	no cointeg	2.95	0.82	2.00	43.11	LC	22.8	no cointeg	no cointeg
	Vadodara-Burdwan	no cointeg	0.31	0.93	-2.68	27.38	LC	18.0	no cointeg	no cointeg
	Mangalore-Bijnaur	no cointeg	1.21	0.85	-0.93	47.02**	TC	87.02***	cointeg	cointeg
	Ernakulam-Bijnaur	no cointeg	-0.43	0.76	-1.76	38.05***	TC	57.03***	cointeg	cointeg
	Vadodara-Bijnaur	cointeg	0.34	0.86	1.75	43.26***	TC	22.8	no cointeg	no cointeg
	Mangalore-West Godavari	no cointeg	4.82	0.99	1.95	36.42	LC	18.22***	cointeg	no cointeg
	Ernakulam-West Godavari	no cointeg	-2.78	0.87	3.54	33.48	LC	10.1	no cointeg	no cointeg
	Vadodara-West Godavari	no cointeg	0.95	1.02	1.38	46.77***	TC	20.4	no cointeg	no cointeg
Consuming-Port	Delhi-Managalore	cointeg	0.49	0.95	-1.88	63.7**	TC	47.38***	cointeg	cointeg
	Kolkata-Mangalore	cointeg	0.45	1.04	-1.95	45.17***	TC	31.7	no cointeg	no cointeg
	Mumbai-Mangalore	cointeg	0.53	0.92	-1.13	35.05	LC	30.14***	cointeg	cointeg
	Delhi-Ernakulam	no cointeg	0.17	1.06	-3.52	34.30	LC	16.67***	cointeg	no cointeg
	Kolkata-Ernakulam	no cointeg	0.32	1.16	-3.00	35.68	LC	18.67***	cointeg	no cointeg
	Mumbai-Ernakulam	no cointeg	-0.09	1.02	-3.50	28.39	LC	17.34***	cointeg	no cointeg
	Delhi-Vadodara	no cointeg	1.62	0.93	0.24	48.07***	TC	17.4	no cointeg	no cointeg
	Kolkata-Vadodara	no cointeg	1.74	1.01	-0.81	24.91	LC	15.8	no cointeg	no cointeg
	Mumbai-Vadodara	no cointeg	1.82	0.89	1.05	41.74**	TC	11.1	no cointeg	no cointeg
World-Port	World-Mangalore	no cointeg	0.36	1.24	-2.93	36.08***	TC	15.06***	cointeg	cointeg
	World-Ernakulam	no cointeg	-0.41	1.36	-5.43	39.92***	TC	14.27***	cointeg	cointeg
	World-Vadodara	no cointeg	0.96	1.19	1.71	39.23***	TC	23.08***	cointeg	cointeg

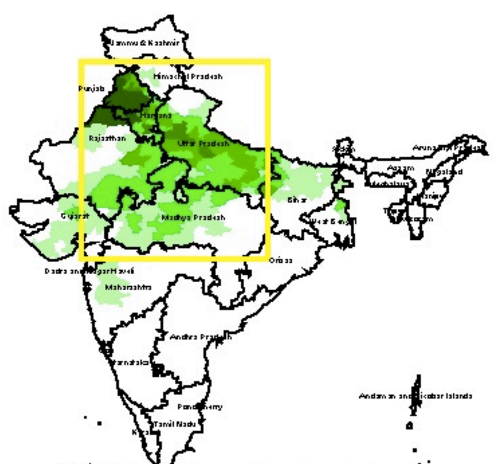
Continued Appendix Table C4. Detailed Cointegration Results for Wheat, OT Period

		Johansen Linear Cointeg Test Result	Estimated Beta Cointeg Vector in Linear VECM	Estimated Beta Cointeg Vector TVECM	Estimated Thresholds, Tau	Hansen Seo Threshold Cointeg Test Statistic Ho: LC	Hansen Seo Threshold Cointeg Test Result	Seo Threshold Cointeg Test Statistic (Ho: no Cointeg)	Seo Threshold Cointeg Test Result	Nested Conclusion from both Linear and Threshold Cointeg
Consuming-Producing	Delhi-Unnao	no cointeg	0.98	0.78	-0.23	26.78	LC	37.96	no cointeg	no cointeg
	Patna-Unnao	no cointeg	0.86	0.69	0.22	28.67	LC	13.94***	cointeg	no cointeg
	Mumbai-Unnao	no cointeg	0.72	0.50	-0.19	26.69	LC	33.14***	cointeg	no cointeg
	Delhi-Ludhiana	no cointeg	0.77	0.76	0.21	50.75***	TC	24.94***	cointeg	cointeg
	Patna-Ludhiana	no cointeg	0.74	0.74	0.03	52.38***	TC	25.87	no cointeg	no cointeg
	Mumbai-Ludhiana	no cointeg	0.16	0.51	0.16	43.32***	TC	23.54***	cointeg	cointeg
	Delhi-Gurgaon	cointeg	0.91	0.86	0.33	28.99	LC	28.16***	cointeg	cointeg
	Patna-Gurgaon	no cointeg	0.71	0.75	0.05	25.48	LC	15.30***	cointeg	no cointeg
	Mumbai-Gurgaon	no cointeg	0.85	0.53	0.65	31.44	LC	21.15	no cointeg	no cointeg
Port-Producing	Kachch-Unnao	no cointeg	0.70	0.90	0.21	20.92	LC	34.82***	cointeg	no cointeg
	Mysore-Unnao	no cointeg	0.72	0.70	-0.59	27.21	LC	31.84	no cointeg	no cointeg
	Malda-Unnao	no cointeg	0.62	0.98	0.44	29.48	LC	33.65	no cointeg	no cointeg
	Kachch-Ludhiana	no cointeg	0.32	0.92	-0.08	47.66***	TC	38.42	no cointeg	no cointeg
	Mysore-Ludhiana	no cointeg	0.65	0.73	-0.47	50.29***	TC	19.18	no cointeg	no cointeg
	Malda-Ludhiana	no cointeg	0.82	0.96	0.35	55.8**	TC	42.29	no cointeg	no cointeg
	Kachch-Gurgaon	cointeg	0.80	0.99	0.10	34.45	LC	42.36***	cointeg	cointeg
	Mysore-Gurgaon	no cointeg	0.81	0.77	0.63	29.33	LC	25.13	no cointeg	no cointeg
	Malda-Gurgaon	no cointeg	0.74	1.05	0.31	34.67*	TC	19.63	no cointeg	no cointeg
Consuming-Port	Delhi-Kachch	no cointeg	6.34	0.85	0.64	57.5***	TC	18.1***	cointeg	cointeg
	Patna-Kachch	no cointeg	1.02	0.79	0.19	30.21	LC	24.45***	cointeg	no cointeg
	Mumbai-Kachch	no cointeg	0.87	0.52	0.58	19.05	LC	20.93	no cointeg	no cointeg
	Delhi-Mysore	cointeg	1.49	1.11	-0.69	36.75	LC	34.16***	cointeg	cointeg
	Patna-Mysore	no cointeg	1.17	0.99	-0.97	29.60	LC	21.15***	cointeg	no cointeg
	Mumbai-Mysore	no cointeg	1.24	0.69	-0.92	30.00	LC	17.56***	cointeg	no cointeg
	Delhi-Malda	no cointeg	2.13	0.81	-0.31	37.55***	TC	24.36***	cointeg	cointeg
	Patna-Malda	no cointeg	0.94	0.74	0.32	30.27*	TC	20.30	no cointeg	no cointeg
	Mumbai-Malda	no cointeg	0.99	0.51	0.89	24.73	LC	17.01***	cointeg	no cointeg
World-Port	World-Kachch	no cointeg	1.00	1.04	1.05	24.5*	TC	36.64***	cointeg	cointeg
	World-Mysore	no cointeg	-2.88	1.35	0.82	31.29	LC	10.74***	cointeg	no cointeg
	World-Malda	cointeg	0.87	0.97	0.29	34.71***	TC	34.35***	cointeg	cointeg

Appendix Figure C1. Major Rice and Wheat Producing States



Source: http://www.mapsofindia.com/top-ten/india-crops/top-10-rice-producing-states-of-india.jpg



India Wheat Production - top five states	
State	5yr* Avg. Prod %
Uttar Pradesh	**34.6%**
Punjab	**20.7%**
Haryana	**11.5%**
Madhya Pradesh	**10.6%**
Rajasthan	**8.7%**
	*Years 1994 - 1998
1998/1999 season India produced 70,780,000 tons	
1997/1998 season India produced 66,350,000 tons	

Source: Joshi, A.K., B. Mishra, R. Chatrath, G. Ortiz Ferrara and R.P. Singh. 2007. "Wheat Improvement in India: present status, emerging challenges and future prospects". *Euphytica* 157(3):431-446.

Appendix Figure C2. Major Ports of India

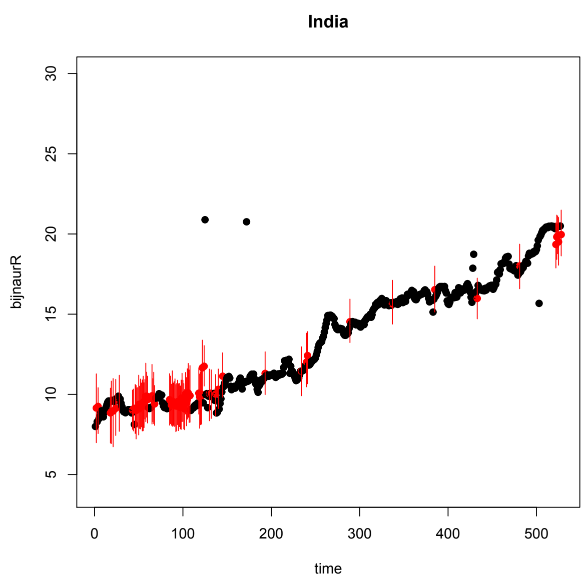
Source: http://ntseverma.blogspot.com/2013/10/lifelines-of-national-economy-meansof.html

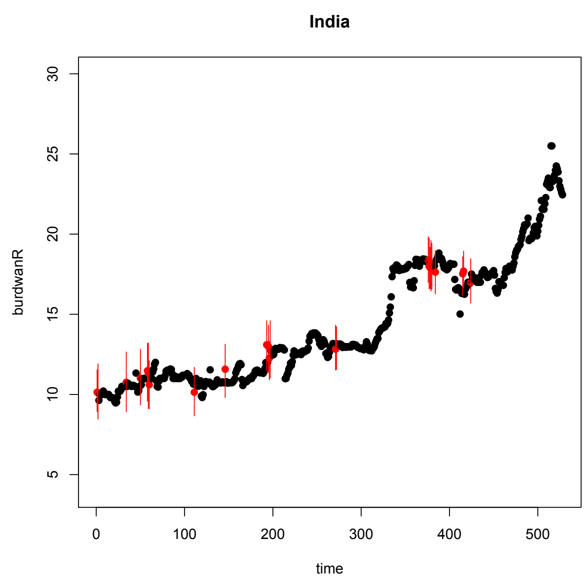
Appendix Figure C3. Imputed Data Plots

1) Aggregated the daily data to weekly by taking the median of price data in each week.
2) Used the multiple imputation method in the Amelia r package to reduce missing observations further.
3) Generated the plots below to see what the imputed data looks like.

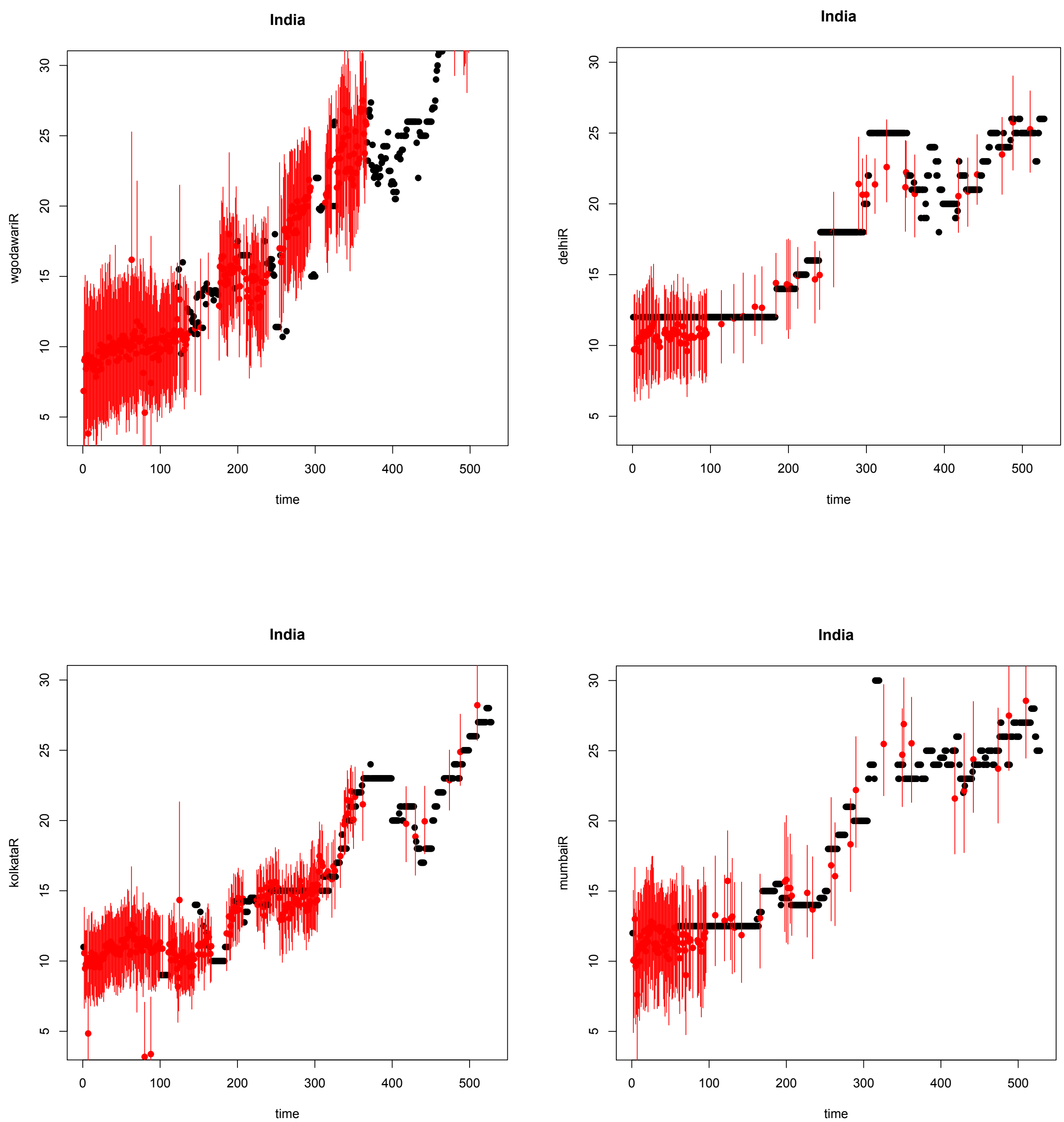
Notes:

- Black dots are actual monthly observations.
- Red dots are imputed.
- The red vertical lines are error bars that show the degree of uncertainty regarding imputed data point.
- The program generates many imputed datasets, then measures uncertainty by bootstrapping the imputed points. That is where the error bars come from.

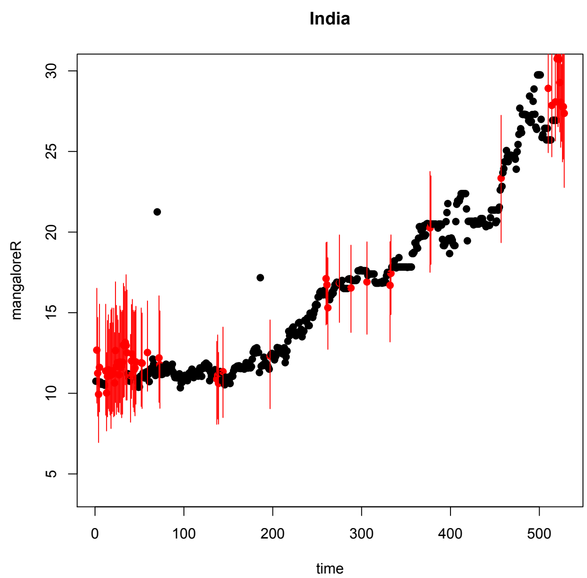


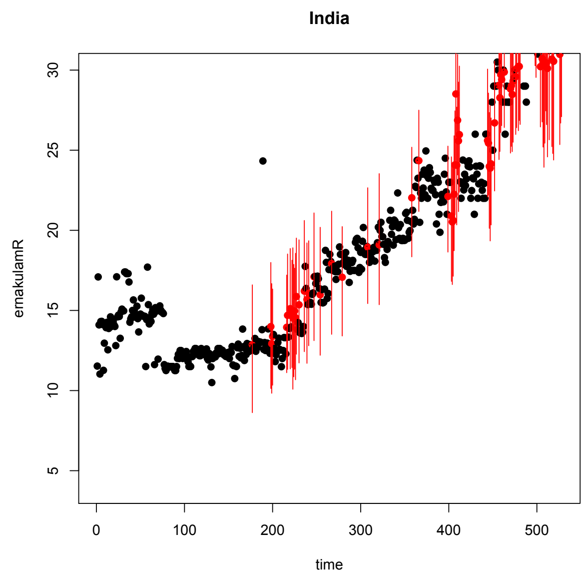


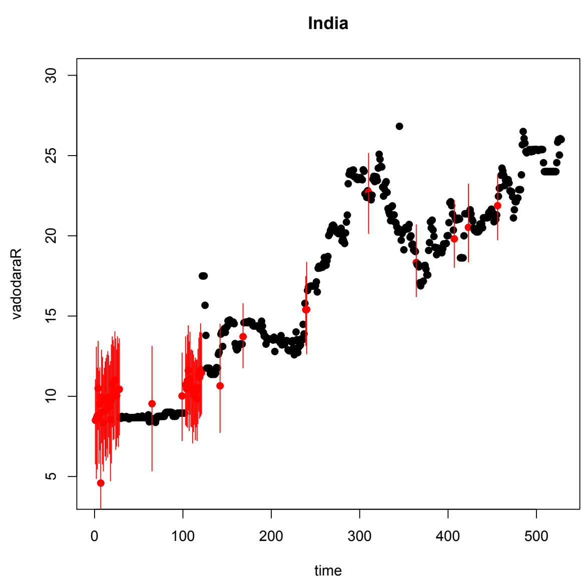
Continued Appendix Figure C3. Imputed Data Plots

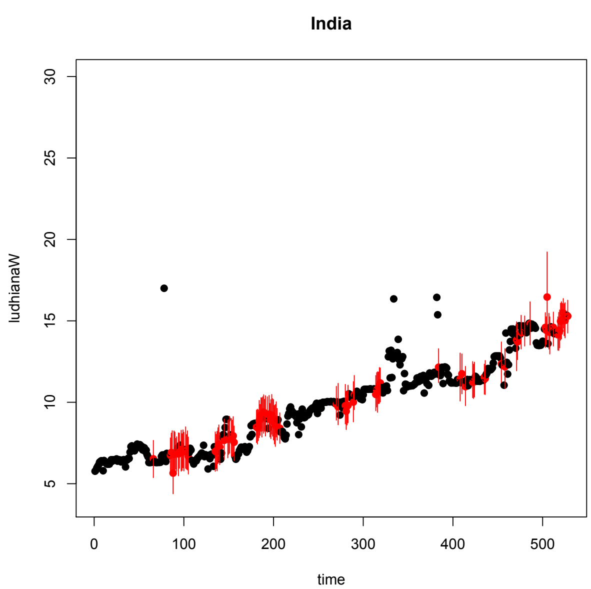


Continued Appendix Figure C3. Imputed Data Plots

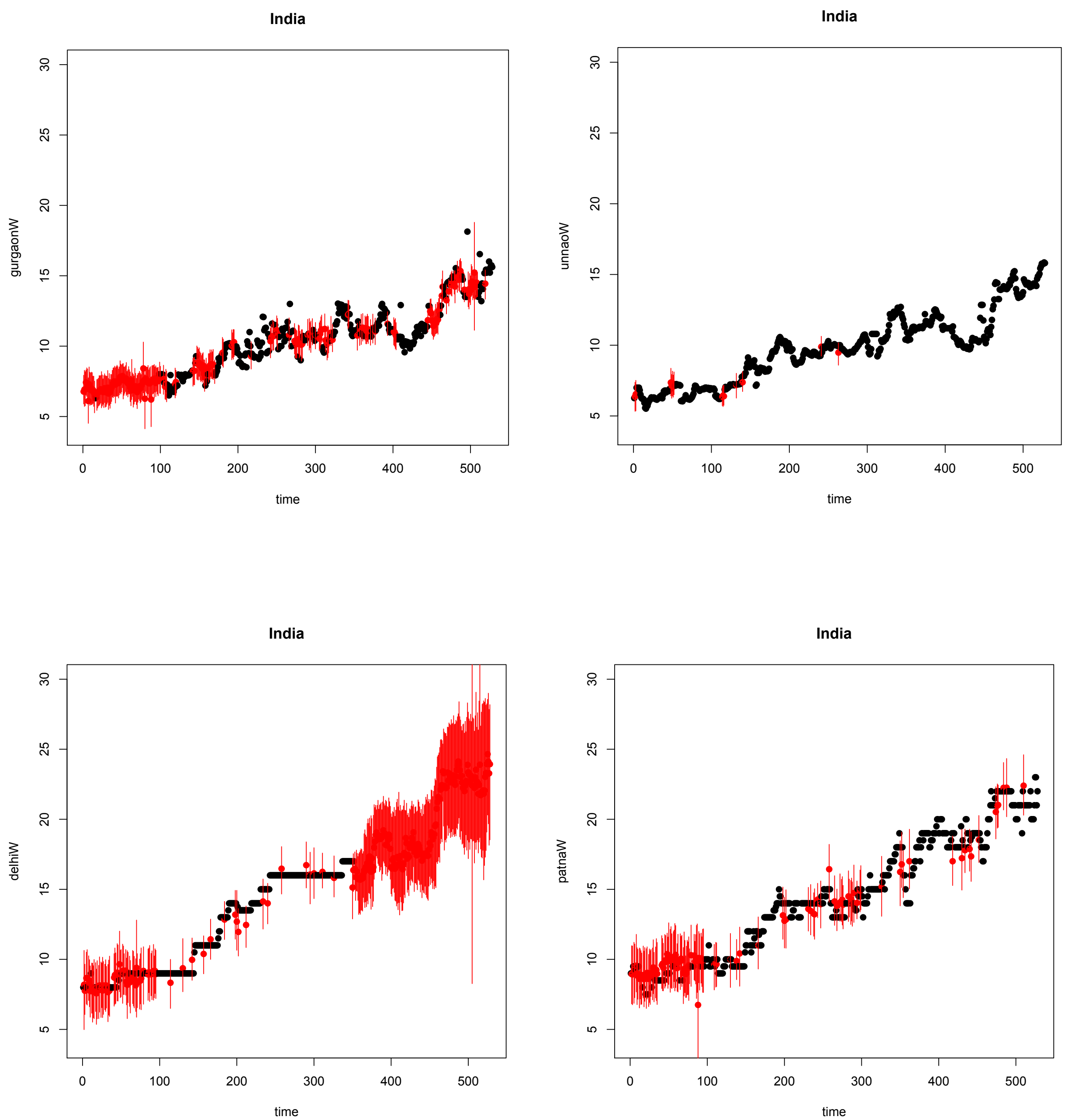




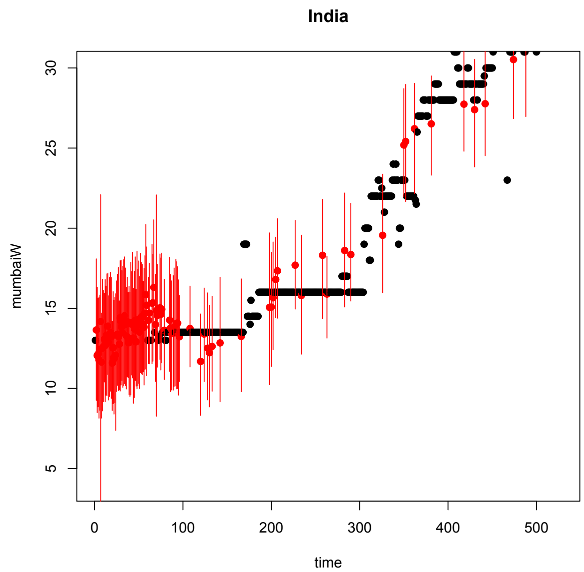


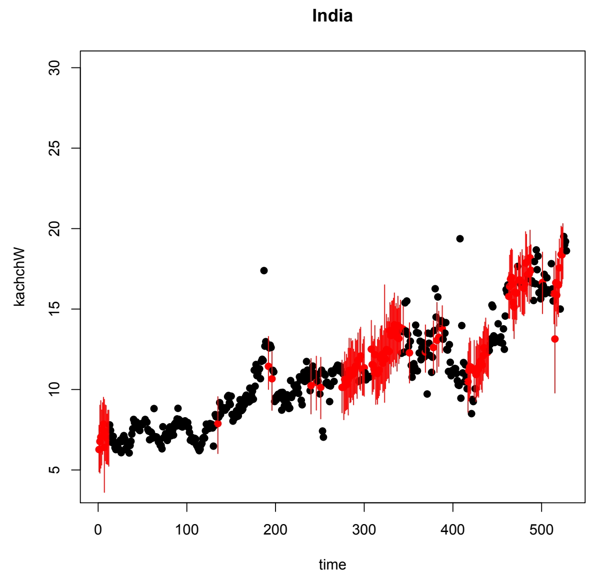


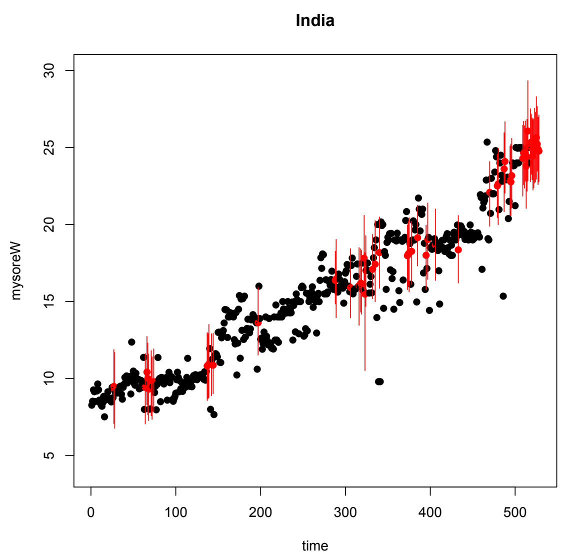
Continued Appendix Figure C3. Imputed Data Plots

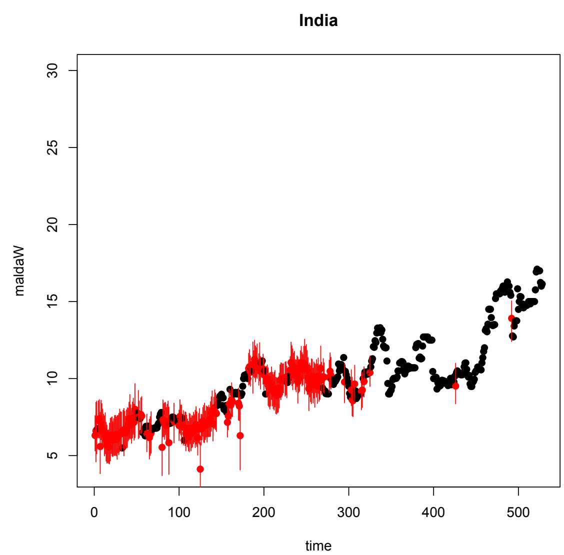


Continued Appendix Figure C3. Imputed Data Plots

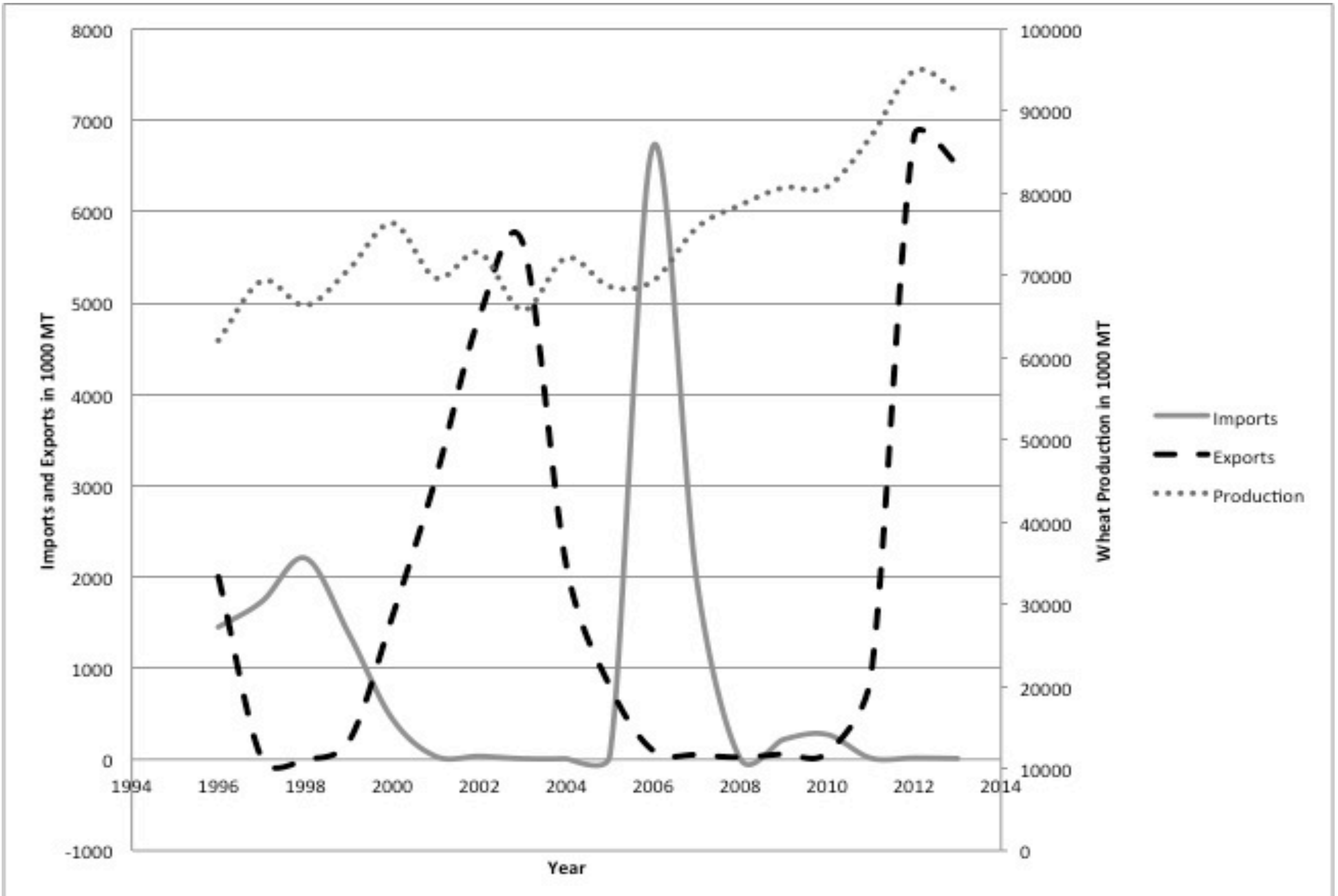








Appendix Figure C4. India's Wheat Exports, Imports and Production, 1996-2013



Source: http://www.indexmundi.com