# MODELLING WEATHER INDEX BASED DROUGHT INSURANCE FOR PROVINCES IN THE CENTRAL ANATOLIA REGION

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**MODELLING WEATHER INDEX BASED DROUGHT INSURANCE FOR PROVINCES IN THE CENTRAL ANATOLIA REGION**

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# ABSTRACT

MODELLING WEATHER INDEX BASED DROUGHT INSURANCE FOR PROVINCES IN THE CENTRAL ANATOLIA REGION

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Drought, which is an important result of the climate change, is one of the most serious natural hazards globally. It has been agreed all over the world that it has adverse impacts on the production of agriculture, which plays a major role in the economy of a country. Studies showed that the results of the drought directly affected the crop yields, and it seems that this negative impact will continue drastically soon. Moreover, many researches revealed that, Turkey will be affected from the results of climate change in many aspects, especially the agricultural production will encounter dry seasons after the rapid changes in the precipitation amount. Insurance is a well-established method, which is used to share the risk based on natural disasters by people and organizations. Furthermore, a new way of insuring against the weather shocks is designing index-based insurance, and it has gained special attention in many developing countries. In this study, our aim is to model weather index based drought insurance product to help the small holder farmers in the Cental Anatolia Region under different models. At first, time series techniques were applied to forecast the wheat yield relying on the past data. Then, the AMS (AgroMetShell) software outputs, NDVI (Normalized Difference Vegetation Index) values were used, and SPI values for distinct time steps were chosen to develop a basic threshold based drought insurance for each province. Linear regression equations were used to calculate the trigger points for weather index, afterwards based on these trigger levels; pure premium and indemnity calculations were made for each province separately. In addition to this, Panel Data Analysis were used to construct an alternative linear model for drought insurance. It can be helpful to understand the direct and actual effects of selected weather index measures on wheat yield and also reduce the basis risks for constructed contracts. A simple ratio was generated to compare the basis risk of the different index-based insurance contracts.

Keywords: Drought, index-based insurance, time series analysis, panel data analysis, premium, indemnity

# ÖZ

İÇ ANADOLU BÖLGESİ İLLERİ İÇİN ENDEKS BAZLI KURAKLIK SİGORTASI MODELLEMESİ

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İklim değişikliğinin bir sonucu olan kuraklık, en büyük küresel doğal afetlerden biri olmuştur. Ülke ekonomisine büyük katkısı olan tarım üretimi üzerine olumsuz etkileri olduğu tüm dünyada kabul edilmiştir. Yapılan çalışmalara göre, kuraklığın sonuçları ürün verimini doğrudan etkilemiş ve bu olumsuz etkilerin yakın gelecekte de büyük ölçüde devam edeceği tahmin edilmektedir. Birçok araştırmacı, Türkiye'nin bu iklim değişikliğinden farklı açılardan etkileneceğini ve özellikle de tarımsal üretimde yağışlarda oluşan ani değişiklikler sonucu ciddi verim kayıpları yaşayacağını düşünmektedir. Sigorta, doğal afetlere dayalı risklerin de paylaşılması adına kullanılan etkin bir risk yönetim tekniğidir. Ayrıca, hava olaylarına karşı endeks bazlı sigorta ürünleri iyi bir alternatif olarak görülmektedir ve gelişmekte olan ülkelerde özel önem kazanmıştır. Bu çalışmada amaç, farklı modeller kullanarak, İç Anadolu Bölgesi'nde yer alan çiftçilere yardımcı olabilecek endeks bazlı kuraklık sigortası ürünü modellemektir. Her il için zaman serisi analizi ile öncelikle poliçe yılına ait buğday verimi tahmin edilmiştir. Daha sonra, Agrometshell (AMS) çıktıları, Normalized Difference Vegetation Index (NVDI) değerleri ve farklı zaman süreleri için hesaplanan Standard Precipitation Index (SPI) değerleri kuraklık sigortası için endeks değerler olarak seçilmiştir. Doğrusal regresyon denklemleri yardımıyla önce tetik nokta ve arkasından buna göre prim ve tazminat hesaplamaları yapılmıştır. Ayrıca, Panel veri analizi alternatif modeller oluşturmak adına tercih edilmiştir. Bu uygulamanın seçilen endeks değerlerin gerçek etkilerini anlamak ve oluşan baz riski azaltmak adına faydalı olacağı düşünülmüştür. Farklı endeks bazlı sigorta ürünlerine ait baz riskini karşılaştırmak için basit bir katsayı üretilmiştir.

Anahtar Kelimeler: Kuraklık, endeks bazlı sigorta, zaman serisi analizi, panel veri analizi, prim, tazminat

*To my family*

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# CHAPTER 1

# INTRODUCTION

## 1.1 Contributions of thesis

In many developing countries, the protection of agricultural areas is a vital issue in the national security plans with the awareness of adverse impacts of climate change. Kemal Öztürk points out that Turkey could be seen as one of the most affected countries due to the structure of complex climate, especially changes in climate as a result of global warming [3]. The main goal of this thesis to emphasize potential usage of index based insurance, which started to be used as an alternative way of traditional agricultural insurance products. In this sense, general purpose of this pilot study is to give preliminary ideas about threshold based drought insurance under different approaches. Central Anatolia Region was chosen as the exemplary location and wheat as the exemplary crop type in this pilot study. For this reason, a suitable weather index-based drought insurance policy was set for provinces of Central Anatolia. Additionally, the basis risks of insurance products under different models were compared, and then general opinions were obtained about how an index based insurance can be beneficial for Turkey.

It will be a first pilot study of weather index based drought insurance for Turkey. Firstly, instead of generally preferred weather index variables such as rainfall, wind speed, temperature, satellite and weather data etc., AgroMetSheel(AMS) outputs and Normalized Difference Vegetation Index(NVDI) values were used to address the limitations of weather data and provide more reliable index variables for wheat yield. Furthermore, the ratios of AMS outputs and NVDI values were considered to obtain alternative and efficient index variables. Besides these values, Standard Precipitation Index (SPI) values, widely known drought indicators in many countries, for some months were utilized in this study, since it allows the analyst easy calculations. Secondly, two different linear models were considered to design alternative index-based insurance contracts. According to results of different policies, basis risk of each insurance product was compared by using a simple ratio.

The results of this pilot study may be used for further studies to derive more extensive weather index-based insurance models for Central Anatolia region, even for other regions of Turkey in the future.

## 1.2 The importance of drought insurance in Turkey

The livelihood of local farmers depends on agriculture mostly (IFAD,2006) [2]. Agriculture has always been dependent on the weather variabilities for the growing season [1]. For this reason, any changes in climate have many direct and indirect effects on the rural society and the whole economy of the country. Governments and development agencies have looked to crop insurance models in developed countries to cover the production loss of farmers due to weather shocks [2]. One of the most important results of climate change is the increase trend in the frequency and severity of drought, which is a combination of low soil moisture, precipitation amount falling under the average and arid-warm air over a long time period in general.

The most probably, agricultural production will be narrowed because of the seasonal sharp declines in the rainfall in many countries. As a result, there might be adverse changes in farmland areas and quality of the crop. Moreover, the crop type, sowing and harvesting time can change because of the new climate patterns after global warming all over the world. Indeed, the loss of wheat, corn, soybean and other crop productions may arise after the climate change in irrigated and non-irrigated areas for Turkey like other countries [3].

In recent years, Turkey experienced its driest seasons, and many institutions predict that this movement will continue drastically [3]. The results of global warming have different effects on the different zones of Turkey as might be expected. Especially, agricultural production will suffer from climate change by means of available soil water in the semi-arid and semi-humid zones like Southeast Anatolia Region, Mediterrarean Region, Aegean Region and Central Anatolia Region. For instance, some observations at the beginning of May in 2001 showed that crop yields of Konya, Karaman and Yozgat provinces suffered from drought by 80-90 %, as a result of the deficient precipitation amount in the sowing period (TAGEM,2001) [3]. It was an impressive example of how our agricultural production affected negatively from the new climatic conditions most recently.

Although there seems to be severe reductions on agricultural production in Turkey because of its climate patterns, agricultural insurance system in Turkey has been recently evolving. Farmers are trying to be informed by the government using different channels about the concept of insurance. Although they are protected by ex-post risk management techniques against the loss resulted in most natural disasters like hail, flood, etc., there is not a specific insurance product covering also drought yet. On the other hand, drought coverage is a still controversial issue all over the world and in Turkey. Currently, farmers Union demand also protection against drought in the existing agricultural insurance system whereas the TARSIM administrators claim that such a coverage can become a burden in the insurance market[7]. However, the law 5363, legislated in 2005, Turkey's agricultural insurance system needs to implement an index based crop insurance product with the government subsidy up to 50 % of the premium.

## 1.3 Why Central Anatolia Region ?

Central Anatolia Region is located at the centre of the Anatolia peninsula with a surface area of 151.000 kilometer square, that is nearly 20 % of the Turkey's land. Geographically, this region is covered by folded and high mountains. This geographical properties bring us hot, dry summers and cold, snowy winters which are called semi-arid continental climate for Central Anatolia. The Figure 1.1 represent the provinces for that region.

In general, the basis of economy in this region based on agriculture. The most part of the working region laboured in farming. The climatic features of Anatolian Plateau with landforms determine the agricultural production. Generally, cereal farming is playing major role in the economy of this region, which has a great contribution to the Turkey's national income as 20 %. In this region, wheat, sugar beets and apples are mostly produced, and large areas are divided into agriculture production even if the region is dominated by semi-arid climate.

The most important problem of farmers for wheat production is high deficiencies in annual precipitation amount. For example, the center of the region only receives average rainfall


Figure 1.1: Provinces for Central Anatolia Region

of 300 millimeters yearly. Especially, in spring, when there is a failure or delay in rainfall, this deficiency may cause large fluctuations in wheat production. In the farmers' level, these severe reductions in wheat yield have been devastating effects on farmers' income, which is one of the rolling stones of the national economy. Thus, there is a great potential for an insurance against drought for this region that allows farmers protection from income loss after any weather shocks.

Table 1.1: Drought support for 40 provinces in Turkey

| | | | |
|---|---|---|---|
| Adana | Ankara | Karaman | Muğla |
| Afyonkarahisar | Çorum | Kastamonu | Nevşehir |
| Aksaray | Denizli | Kayseri | Niğde |
| Amasya | Eskişehir | Kırıkkale | Ordu |
| Çankırı | Gaziantep | Kırşehir | Samsun |
| Antalya | Gümüşhane | Konya | Sinop |
| Aydın | Hatay | Kütahya | Sivas |
| Balıkesir | Isparta | Malatya | Tokat |
| Bolu | İzmir | Manisa | Uşak |
| Burdur | Kahramanmaraş | Mersin | Yozgat |

**Source** : Council of Ministers, 04.07.2007 Official Gazette dated 26572

In recent years, Turkey faced with a series drought in 2007 and the financial results of it are so expressive to illustrate the importance of insurance. The decision of the Council of Ministers of Turkey confirmed that there were 25 % or more of decrease on crop production for 40 provinces because of the dry spring season for that year. The ex-post drought support costing 264.499.098,58 TL covered to only yield failure in wheat, barley and vetch in Turkey. The table 1.1 represents the provinces of Turkey supported by government after that drastic dry year.

Furthermore, Table 1.2 shows how important the well-organized drought insurance for Central Anatolia by means of support payments.

As table shows, almost 46 % of farmers belonged to Central Anatolia Region and 63 % of total drought coverage were done for this region. The economic results of drought in this region seems to be devastating. Hence, it is essential to manage the results of dry seasons by well developed insurance systems.

Table 1.2: Drought support payments for Central Anatolia Region,

| Province name | Number of farmers | Total Payment (TL) |
|---|---|---|
| Ankara | 42.450 | 38.106.675,78 |
| Çankırı | 10.152 | 6.196.305,41 |
| Eskişehir | 22.826 | 10.242.685,33 |
| Kayseri | 10.945 | 5.995990,25 |
| Kırşehir | 20.410 | 11.212.651,20 |
| Konya | 62.446 | 51.398.408,00 |
| Nevşehir | 18.505 | 13.754.482,17 |
| Niğde | 3.212 | 1.237.104,28 |
| Sivas | 19.191 | 8.077.903,44 |
| Yozgat | 40.897 | 20.867.994,42 |
| Central Anatolia Total | 251.034 | **167.090.200,28** |
| Turkey Total | 544.579 | **264.499.098,58** |

**Source** : Council of Ministers, 04.07.2007 Official Gazette dated 26572

## 1.4 Thesis structure

This master thesis is comprised of four chapters, mainly as Introduction, Methodology, Data Analysis and Results & Discussions.

In Chapter 2, some brief explanations of index based insurance are given with its advantages and disadvantages against the traditional agricultural insurance. Then, some applications of index-based insurance from all over the world are mentioned. Afterwards, definitions of chosen weather index variables and their relationship between wheat yield are also included.

In Chapter 3, for each province, wheat yield in 2007 is forecasted by using time series analysis. Then, these results are used to design a simple insurance product after selection of weather index measure. First of all, simple linear regression estimation method is considered for designing an insurance contract. Alternatively, linear panel models are used as well because of the limited data set. Afterwards, pure premium and indemnity payment calculations are made under different models in 2007. Basis risk comparisons are made under different insurance contracts.

In Chapter 4, main results of this pilot study are summarized. Moreover, important problems of study and possible future works are presented here.

# CHAPTER 2

# METHODOLOGY

## 2.1 Weather Index based Drought insurance

### 2.1.1 A Brief Introduction

Some important abbreviations that will be frequently used in the following sections are defined basically here.

AgroMetShell (AMS) is a model that was built on the plant, air, soil and climate data used to calculate the soil water budget of any crop product. Also, it generates some significant parameters related to agricultural production (FAO, 2004) [8]. This model is designed for the effects of climate conditions on the crop development, and it is a very useful tool to produce exact values of parameters that are closely related to crop yield.

Actual Evapotranspiration (ETA) is the process of evaporation and transpiration together. Evapotranspiration (ET) comprises the simultaneous movement of water from the soil and vegetation surfaces into atmosphere through evaporation (E) and transpiration (T) [18]. It represents the whole water vaporization amount which is used by the plant while growing.

Normalized Difference Vegetation Index (NVDI) is a measure of the greenness in a specified area. It is calculated from space platform and graphical indicator for estimating the amount of green vegetation using satellite and radar technology.

Standard Precipitation Index (SPI) is a very well known drought monitoring tool in many countries, developed by McKee in 1993 [26]. The nature of the SPI allows an analyst to determine the rarity of a drought or a wet season at a particular time scale for any location that has a precipitation record.

### 2.1.2 Fundamentals of Index Insurance

Although the index based insurance products have some problems about scalability and sustainability relative to past experiences, it has gained expressive attention recently. The focus will be on basic properties of index insurance with its advantages and disadvantages. Index insurance differs from the traditional approaches in several ways. The most important difference between them is that the loss estimates are based on any index variable rather than on the loss of each policyholder [2]. The important theoretical beginning to design a more effective index based insurance product is determining how the index variable is correlated with the actual value of loss. A commonly used one is the rainfall amount from local weather stations, but other alternatives should be sought to be used [4].

The biggest advantage of index based insurance is that it is very useful to cope with the problem of moral hazard and adverse selection of traditional insurance products. Firstly, moral hazard is a type of asymmetric information in the market. In some cases, the policyholder develops an attitude that directly affects the crop production after purchasing the insurance product. For instance, they do not use necessary fertilizers and pesticides since they know that the crop loss will be compensated. This behavioral response leaves the insurer exposed to higher levels of risk than anticipated when premium rates were calculated (Barnett, 1995) [9]. On the other hand, the weather index variable is not affected by the behavior of the insurer, so the index-based insurance overcomes the moral hazard problem. Secondly, adverse selection is the other type of asymmetric information problem. In the insurance market, it occurs when potential policyholders have private information about their risk exposure that is not available to the insurer (Rothschild and Stiglitz, 1976) [9]. However, there is no asymmetric information between the insurer and the insured about the weather events that determine the loss amount. It helps to avoid the adverse selection problem of the traditional insurance policies.

Other useful characteristics of modelling threshold based insurance can be listed as follows [11],

1. Transparency: Under this type of insurance contracts, farmers can easily reach the in-

formation about the pay outs and this property strengthens the trust of the policyholder in the insurer companies.

2. No on-farm loss adjustment: Another important advantage is using indices to make calculations for indemnities and premiums rather than the actual loss of a farm, because on-farm loss adjustment procedure is complex and costly in many developing countries.

3. Addressed correlated risks: Index based risk transfer mechanism work well when there is a correlated risk such as drought.

4. Low operational and transactional costs: They require a lower expense for underwriting the insurance product, distributing to farmers and settling the claims as a result of the crop loss.

5. Rapid pay out: Since insurance companies do not determine the crop loss for each farmland separately, it allows the rapid payment of indemnity in a very short time when the claim is reported.

Figure 2.1 illustrates the cost differences between traditional and index based insurance contracts. The cost of an insurance contract can be basically divided into three parts as actuarial, administrative and financial. The index based insurance has priority in the sense of reducing the actuarial and administrative costs of a policy according to its advantages that are mentioned above.

Despite its many advantages, it still has some problems in the insurance market. Even if the index variable is highly correlated to the actual loss, there will be some incompatibility between the loss determined by the index value and the real loss of the policyholder who will eventually lead to the most important disadvantage, the basis risk. This mismatch between the determined loss and the actual loss can occur in two ways: either there is no indemnity payment according to the insurance design when the insured faces a loss, or even if there is no indicated loss by the proxy chosen, the policyholder receives loss payment as a result of the triggered index measurement in the threshold based model.

The basis risk can be classified basically as [11];

Spatial: It is the most widely known basis risk type coming from local variations in the selected index measure. In other words, it results from the difference in the selected index where

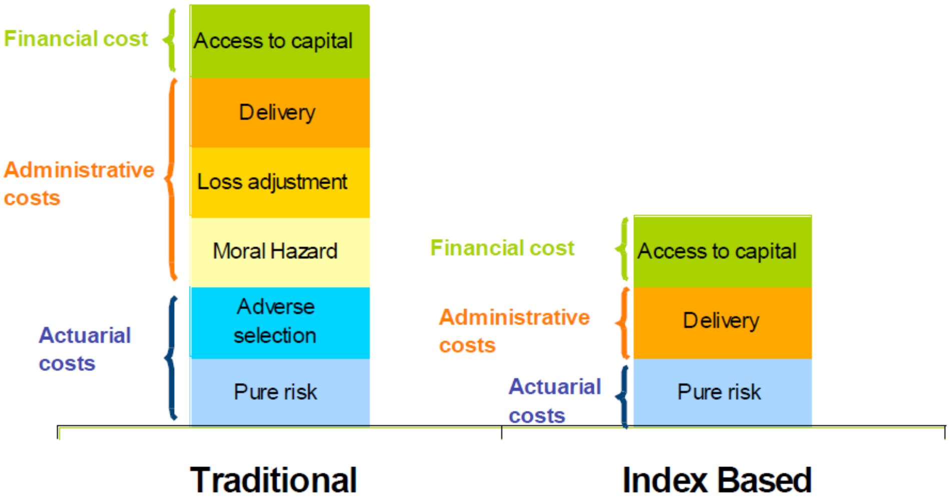



Figure 2.1: Cost differences : Traditional versus index based insurance

the crop loss occurs and the location of the station where the weather index is calculated.

Temporal: This type of basis risk emerges from the importance of loss occurrence time throughout the growing plant. For example; lack of rainfall can harm for the growth of the crop differently based on its developmental stage.

Product: It occurs when there is no direct relationship between the yield loss and the selected index, while there are many other factors that can reduce the crop production.

Other important disadvantages of the index based insurance are namely the followings;

1. Limited perils : In general, this type of contracts covers one or two perils. Although, there is a reduction in the cost, it may not be an efficient risk management.

2. Replication : Weather index based policies require more examining to set the correct trigger and limit values for the sustainability of each crop product.

3. Technical capacity and expertise : There is a special need for experts to design index-based insurance products efficiently.

4. Lack of weather data : The most important limitation about index based insurance products, particularly in developing countries, is the absence of quality in historical and real time weather data.

### 2.1.3 How index-based insurance works

This type of policies is modeled by the defined threshold and limit values that varies between some certain values. These certain values are crucial for calculating indemnity payments. Consider an index insurance policy which is framed according to the rainfall level at a specific weather station. When the precipitation amount falls below the defined trigger level over a certain period of time (monthly or seasonally), the indemnity payments start to manage the drought risk of specified crop. If the measurements of the rainfall index show that it is less than or equal to the limit value for a policy, the maximum payment is made. Figure 2.2 represents basic payment schedule for an index based insurance contract [2].

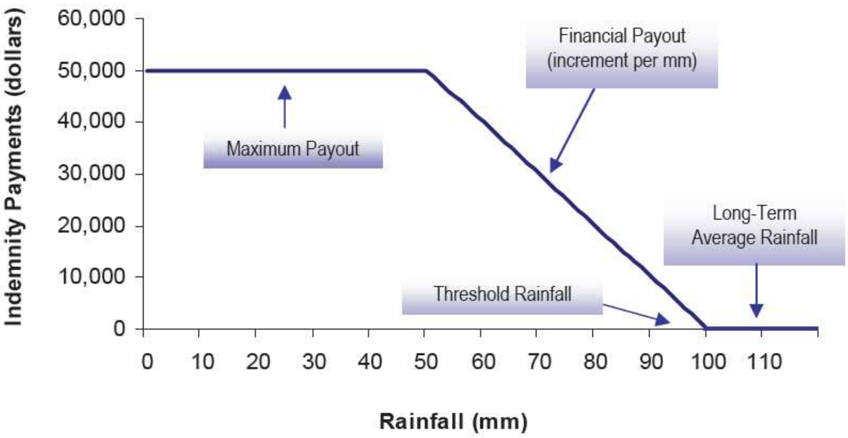



Figure 2.2: Basic Payment Schedule

In the index based insurance, indemnity payments are equivalent for each policyholder who has the same insurance policy regardless of the actual loss that insurer is faced with. Skees et al. explains that indemnity payment is calculated by multiplying the calculated payment rate by the amount of liability the policyholder has [2]. In addition, the insurance product is based on an independently verifiable index variable, so it can also be reinsured. Thus, this allows insurance companies to transfer part of their risk to international markets efficiently [5].

As a starting point, it is so important to minimize the basis risk while structuring any type of index based policies. For this reason, the first step is analyzing the correct and significant correlation between the loss amount and the index variable carefully. This part needs accurate data changes for each variable over a long period of time to build up an efficient and high performance contract.

In some studies, complex crop growth models have been created to determine the most critical periods and rainfall requirements of certain crops to minimize basis risk [2]. Besides the rainfall amount, the temperature, wind speed, etc. are good candidates to be an index variable for a policy. There can be complex estimation models for yield by using all important weather demands for a crop. Moreover, new weather index variables, that include all important needs for a whole growing period, can be created.

In summary, weather-related risks have been devastating effects on the welfare of the small holders in the long run even if informal risk management strategies look worthwile by the farmers at first sight. In situations where such a risk is particularly covariate, it causes relatively infrequent but severe loss for small holders, so where it is well captured by an easily measurable index, index insurance would appear to be a very useful tool for assisting farmers in managing weather-related risk [10].

### 2.1.4 Background and Brief History

Barrett et al. claim that catastrophic events are important obstacles to sustained household wealth accumulation and to the development and availability of financial services worldwide [2]. Especially, weather shocks are a major reason for income fluctuation usually translating into consumption interruptions and destroying accumulated assets through years of limited consumption [6]. For example, a seasonal drought can have catastrophic effects on the farms' productivity.

In general, many developing countries can respond to natural hazards after they happen instead of paying attention to ex-ante risk management strategies. This focus on so-called -recovery- is a consequence of governments' limited awareness of risk exposure, their generally weak institutional capacity in disaster risk management, and the often ample availability of free or inexpensive post-disaster third party financing (Cummins and Mahul, 2009) [10].

This type of solutions to the loss related to weather-events, after the adverse event occurred, are not useful and they are costly for low and middle income countries. In this respect, efforts to develop the insurance system for a country are so crucial to change the idea of recovery with the prevention or mitigation techniques against disasters. Furthermore, these weather-related hazards are insurable principally due to the fact that they are idiosyncratic reasonably i.e.

they do not occur every year. A strong insurance market for country-level weather risk would allow state and national governments to spread their risk. Thus, this implements more rapid and capable response strategies in affected regions while smoothing public budget outlays over time [10].

With the financial support of international organizations such as World Bank, there are 25 index-based risk coping mechanisms in developing countries [2]. Most of them are insurance products provide contingent financing for natural disasters. The figure 2.3 illustrates the increase of interest on this issue by giving the number of pilot index-based insurance contracts for each year.

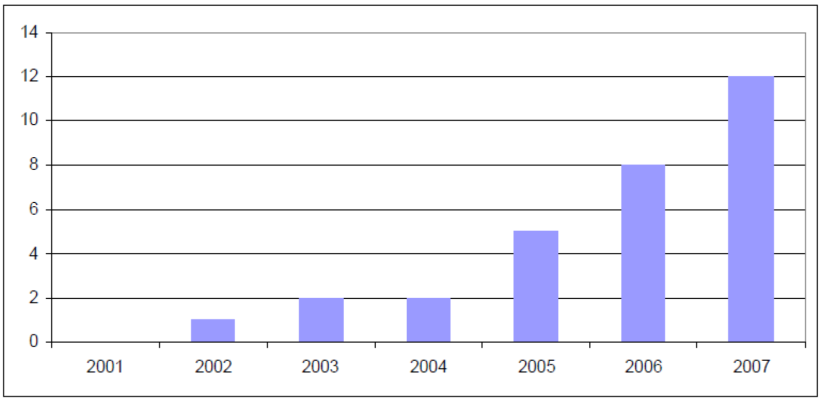



Figure 2.3: The number of pilot insurance schemes

Moreover, the figures 2.4 and 2.5 summarize the different index based insurance policies in lower income countries all over the world up to year 2007 by giving general opinion about the type of risk event, measure of index, target profile and their status [2].

In many countries, this type of insurance policy structure was considered against the drought risk and most of them were based on the rainfall amount as an index variable. Actually, it is an easy way to select precipitation amount for the proxy of contract however considering impacts of rainfall deficiency on crop yield annually leads to inaccurate results. For this reason, it should be analyzed in depth instead of using the annual amount to design insurance policy. Monthly or decadal based rainfall data might give a better correlation result and this offers a more efficient insurance policy.

| Country | Risk Event | Contract Structure | Index Measure | Target User | Status |
|---|---|---|---|---|---|
| Bangladesh | Drought | Index insurance linked to lending | Rainfall | Smallholder rice farmers | In development. Pilot launch planned for 2008. |
| Caribbean Catastrophe Risk Insurance Facility | Hurricanes and earthquakes | Index insurance contracts with risk pooling | Indexed data from NOAA and USGS | Caribbean country governments | Implemented in 2007 |
| China | Low, intermittent rainfall | Index insurance | Rainfall and storm day count | Smallholder watermelon farmers | Implemented in Shanghai only in June 2007. Includes a 40% premium subsidy |
| Ethiopia | Drought | Index insurance | Rainfall | WFP operations in Ethiopia | USD 7 million insured for 2006. Policy not renewed for 2007 due to lack of donor support. |
| Ethiopia | Drought | Index Insurance | Rainfall | Smallholder farmers | 2006 pilot, currently closed due to limited sales. |
| Ethiopia | Drought | Weather Derivative | Satellite and weather data | NGO | Implemented 2007 |
| Honduras | Drought | | Rainfall | | In development |
| India | Drought and flood | Index insurance linked to lending and offered directly to farmers. | Rainfall | Smallholder farmers | Began with pilot in 2003. Now index insurance products are being offered by the private sector and the government |
| Kazakhstan | Drought | Index insurance linked to MPCI program | Rainfall | Medium and large farms | In development |
| Kenya | Drought | Weather Derivative | Satellite and weather data | NGO | Implemented 2007 |
| Mali | Drought | Weather Derivative | Satellite and weather data | NGO | Implemented 2007 |
| Malawi | Drought | Index insurance linked to lending | Rainfall | Groundnut farmers who are members of NASFAM. | Pilot began in 2005. 2500 policies sold in 2006 pilot season. $7000 in premium volume. |
| Mexico | Natural disasters impacting smallholder farmers, primarily drought | Index insurance | Rainfall, wind speed, and temperature | State governments for disaster relief. Supports the FONDEN program. | Pilot began in 2002. Available in 26 of 32 states. Currently 28% (2.3 million ha) of dry land cropland is covered |
| Mexico | Major earthquakes | Index-linked CAT bond and index insurance contracts | Richter scale readings | Mexican government to support FONDEN. | Introduced in 2006. CAT bond provides up to USD 160 million. Index insurance coverage up to USD 290 million. |

Figure 2.4: Index based insurance examples (1)

| Country | Risk Event | Contract Structure | Index Measure | Target User | Status |
|---|---|---|---|---|---|
| Mexico | Drought affecting livestock | Index Insurance | Normalized Difference Vegetation Index | Livestock breeders | Launched in 2007. Sum insured USD 22.5 million across 7 states. Insured 913,000 cattle. |
| Mexico | Insufficient irrigation supply | Index insurance | Reservoir levels | Water users groups in the Rio Mayo area | Proposed |
| Mongolia | Large livestock losses due to severe weather | Index insurance with direct sales to herders | Area livestock mortality rate | Nomadic herders | Second pilot sales season of pilot completed in 2007; 14% participation |
| Morocco | Drought | Index Insurance | Rainfall | Smallholder farmers | No interest from market due to declining trend in rainfall |
| Nicaragua | Drought and excess rain during | Index insurance | Rainfall | Groundnut farmers | Launched in 2006. |
| Peru | Flooding, torrential rainfall from El Niño | Index insurance | ENSO anomalies in Pacific Ocean | Rural financial institutions | Proposed |
| Peru | Drought | Index insurance linked to lending | Area-yield production index | Cotton farmers | Proposed |
| Senegal | Drought | Index insurance linked to area-yield insurance | Rainfall and crop yield | Smallholder farmers | Proposed |
| Tanzania | Drought | Index insurance linked to lending | Rainfall | Smallholder maize farmers | Pilot implementation in 2007. |
| Thailand | Drought | Index insurance linked to lending | Rainfall | Smallholder farmers | Pilot implementation in 2007. |
| Ukraine | Drought | Index Insurance | Rainfall | Smallholders | Implemented in 2005, currently closed due to limited sales |
| Vietnam | Flooding during rice harvest | Index insurance linked to lending | River level | The state agricultural bank and, ultimately, smallholder rice farmers | In development, a draft business interruption insurance contract is being considered by the state agricultural bank |

Source: Authors (a version of this table also appears in Barrett et al., 2007)

Figure 2.5: Index based insurance examples (2)

Especially, Mexico case has impressive results. This country covered 28 % of its farmland area in 5 years successfully [2]. The Mexican government were succeeded at the sustainability of index-based insurance products by transferring their risks to international reinsurance market. Furthermore, they used a set of index variables to describe the crop yield for insurance designing. Such a wide range of predictor set indicates the importance of the most correlated index variable usage in contract designing.

Even if these different index-based insurance contracts were operated in many developing countries, all of these insurance schemes are ongoing products. For this reason, there is no definite conclusion about the existing insurance products so far. Moreover, some of them were already closed in the market due to the lack of sales. The implementation decision for the index-based insurance policies deserves more detailed examination.

After 2007, the number of index-based insurance contracts was increased and Kenya, Mongolia, Benin, Senegal, Burkina Faso, Niger and Togo have added to list of pilot insurance projects. Insurance coverage exists for fertilizer and seeds also in some countries. Especially, the marketing and distribution is considered in detail in pilot studies. The recent index insurance projects can be followed in the database of FARM [28].

## 2.2 Methodology of Modelling

### 2.2.1 Crop Selection

The world and our country's population's nutrition is mostly based on grains. Among the grains, the wheat is the premier one with 215 million hectare plantation and 628 million tonnes per annum production [15]. Mızrak points out that only wheat provides nearly 20 % of world food sources and 30 % of all cereal productions [16].

In this thesis, wheat was chosen as a crop type to design weather index based drought insurance for Central Anatolia Region, the second place that has a wide cultivated area after Marmara region in Turkey. The economy of the region mostly based on agriculture production. Also, wheat is the premier crop that most of the farmer's income volatility is directly related to its fertility. The equally weighted average of durum and other wheat types was used to get a unique wheat yield value for each province. This mean value was used to design insurance in this semiarid region.

### 2.2.2 The concept of Basis Risk

As it was mentioned above, the most important part of the index based insurance contracts is using an independent variable that is well correlated to the crop yield. It is important to attract farmers' attention while minimizing the basis risk arose from the contract structure. As an example, when the majority of agriculture is rainfed i.e. no irrigation, especially in African countries, insurance contracts are designed according to the rainfall index in general. Unfortunately, rainfall (or any single index variable) is never perfectly correlated with farmer yields and measurements which are frequently taken at points quite distant from the farmer's yield. This results in the problem of basis risk -the imperfect match between the index and individual farmer outcomes- and that will discourage some farmers from purchasing the product [10]. In this thesis, to understand the basis risk concept for provinces of Central Anatolia Region, alternative index variables were used like AMS outputs, NVDI values and their combinations to estimate the wheat yield rather than just using the precipitation amount. Moreover, since the data range is small for AMS outputs and NVDI values, Panel Data Analysis were preferred to establish true casual effects of each predictor on wheat yield. This approach can be also helpful for reducing some basis risk since it allows regression analysis with a both spatial and temporal dimension. The basis risk reduction efficiency of different index based insurance schemes were tested by pure premium and indemnity calculation results. A simple indicator was generated to make basis risk comparison between different insurance contracts. The other non-weather related basis risk generators like educational levels of farmers, usage of agricultural production tools etc. were not considered in this study.

### 2.2.3 Weather Index Selection

Designing an optimal threshold based insurance policy is directly related to the most suitable variable to predict the wheat yield. Under this section, AMS outputs, NVDI values, AMS-NVDI combinations and SPI values were explained in detail.

In the past decades, Food and Agricultural Organization (FAO) have contributed to the methodologies on crop water management. The most important tool developed by FAO is AgroMet-

Shell (AMS) software providing crop yield monitoring and forecasting. This tool allows to generate estimations for actual evapotranspiration, water excess or deficiency and water satisfaction index based at different time periods by some calculations on the soil water budget for a specific crop.

The outputs of AMS software are so noteworthy for early information about the crop yield. The most useful output of it is actual evapotranspiration (ETA) for the given crop over different stages of the growth period. Penman-Monteith equation is used for the calculation of ETA, which includes all important weather data i.e. temperature, humidity, wind speed and sunshine, with the following input variables

1. Water-holding capacity of soil (WHC)
2. Effective rain amount, a percentage value of actual rain for water supply (Efrain, i.e. usually 100 % is used)
3. The international identification number of the specific crop (for Wheat)
4. The length of a cycle in dekads i.e. 10 day time period (Cycle)
5. The planting dekad, a value between 1 and 36 (Pldek)
6. Type of irrigation, (Rainfed crop production was considered, so put the value 0 which means no irrigation)
7. The height of the bund for irrigated crop (In our study, it is assumed that there is no irrigation for wheat production)
8. Crop specific coefficients for the different growth cycle (KCP)

The water balance equation is based on the observations on dekads from sowing to harvesting period under the assumption that the soil has a capacity of holding certain amount of water (WHC). It is a simple but useful modelling for the effects of changes in weather-related variables on crop yield. The equation (2.1) calculates soil water budget for each dekad for the selected crop:

$$Wa = Wp + Ra - ETA - (losses) \tag{2.1}$$

where, Wa is the water amount held by the soil, Wp is the water amount holded by the soil at the end of last dekad, Ra is the precipitation amount in terms of millimeter, ETA is the actual amount of water consumed by the crop (actual evatranspiration) and losses are resulted in runoff and deep water infiltration by the crop.

The AMS software runs the Penman-Monteith method by using lots of climatic data like daily precipitation, humidity, wind speed, sunshine, the minimum, maximum and average temperature values and calculate the reference evapotranspiration [18]. Afterwards, the crop parameters given for wheat in Table 2.1 are also used with the results of water budget calculations to obtain the actual evapotranspiration (ETA) values.

Table 2.1: Kc values for Wheat

| Crop | | Initial | Development | Mid-Season | Late Season |
|---|---|---|---|---|---|
| Wheat | Kc values | 0.35 | 1.1 | 1.1 | 0.25 |
| | Stage length(day) | 20 | 25 | 60 | 30(135) |

AMS algorithm produces many explanatory variables to reveal the effects of climatological conditions for the crop yield. In this study, water deficiency and actual evapotranspiration values in four different growth stages and cumulative values of them were focused on. Moreover, water satisfaction index in harvesting period was also considered.

1. $WDEF_x$ where x = i, v, f, r, t represents the water deficiency for initial, vegetative, flowering, ripening stages of and the whole growth period respectively.
2. $ETA_x$ where x = i, v, f, r, t represents actual evapotranspiration for initial, vegetative, flowering, ripening stages of and the whole growth period respectively.
3. $WSI_h$ represents the water satisfaction index for the given crop in harvesting time.

Furthermore, some of NVDI values and their effects on the wheat yield were studied. These values were derived from FAO, and some of them were listed here to be used for an alternative index variable for the wheat yield estimation. The following parameters were generated by using Vegetation Analysis in Space and Time (VAST) model.

1. vert is the difference of NVDI values between the dates when the vegetation start, and the NVDI reached to its maximum.

2. eval is the NVDI value after four days then it reached to its maximum.

3. pval is the NVDI value when it reached to its maximum.

4. cum is the sum of NVDI values between the beginning of vegetation and when it reached to its maximum.

5. drop is the difference of pval and eval.

The following alternative index variables were constructed, ratios of AMS outputs and NVDI values. Some of them will be good candidates to describe the wheat yield in Central Anatolia Region and listed here as,

1. $WDEF_{f,r,t}/vert$ is the water deficiency per NVDI measured as the difference between the peak and the start of the vegetation in flowering, ripening and whole stage of growth.

2. $WDEF_t/eval$ is the total water deficiency per NVDI measured four days after it is reached to its maximum.

3. $WDEF_{f,t}/pval$ is the water deficiency per peak NVDI in flowering and whole stage of growth.

4. $ETA_r/eval$ is the actual evapotranspiration per NVDI measured four days after it is reached to its maximum in ripening stage of growth.

The other alternative for index variable is SPI values for different time periods. It is a simple index that is mostly used for drought monitoring. It gives a practical way of detecting drought seasons by using total cumulative precipitation data for a specified region. Precipitation amount is normalized using a probability distribution with a mean of zero and variance of one. These normalized values allow to predict the wet and dry seasons over a specific time period. When the results of SPI values are lower than zero, it represents the dry seasons whereas the values above the zero level indicate the humid air. Calculation methods for SPI values for different time steps (the last 1, 3, 6, 9, 12, 24 months) were explained in detail by McKee and Edwards in 1997 [26]. Intervals for SPI values which define the drought event for any time scale were summarized in Table 2.2 [26].

Table 2.2: SPI Threshold values

| Class | Threshold |
|---|---|
| Extremely Wet | SPI >= 2.0 |
| Very Wet | 1.5 <= SPI <= 1.99 |
| Moderately Wet | 1.0 <= SPI <= 1.49 |
| Near Normal | -0.99 <= SPI <= 0.99 |
| Moderately Dry | -1.0 <= SPI <= -1.49 |
| Severely Dry | -1.50 <= SPI <= -1.99 |
| Extremely Dry | SPI <= -2 |

The main purpose is finding the mean value for the selected index variable for each province. In the literature, there are different interpolation techniques, which can be classified as deterministic, probabilistic and other methods. Mainly, all interpolation techniques predict the value at an unmeasured location by using the known data belonging to its neighborhoods. According to the McDonnell and Burrough [27], kriging is the best interpolation method when the data is sparse in geostatistical analysis. It is a kind of probabilistic interpolation method and based on the employing distinct semivariogram models. Moreover, it allows a linear estimate based on the expectation. Also, it considers the variance of the spatial data while interpolating. Collectively, it can be defined as the best linear unbiased surface interpolation method with identical means and minimal variance.

ARCGIS 10 software was used to interpolate the $SPI'3$ values and rainfall for each province by using the station based data. The $SPI'3$ values were calculated based on the last 3 months total precipitation amount. In this study, Ordinary and Simple Kriging techniques with Spherical, Exponential and Gaussian semivariogram models were considered since they are widely-known modellings in the climate data interpolation. ARCGIS 10 permits the optimization for the distinct models and it generates the necessary parameters automatically. The best method was selected according to the nearest Root Mean Square Standardized value to the value 1. Afterwards, the mean of the index variable for each province was calculated based on the spatially interpolated surface by using the Zonal Statistics Tool in ARCGIS 10. Afterwards, spatially interpolated average values were used to find how it is related to the wheat yield.

### 2.2.4 Relation between Wheat Yield and Weather Index

Firstly, the annual precipitation amount, commonly used weather index variable in the world, does not represent the behavior of wheat yield accurately. Instead of the total rainfall amount, the distribution of rainfall should be observed and effects of this distribution on the growth of wheat after sowing up to harvesting time should be studied in depth. Assuming that rainfall amount mostly belongs to the winter, whereas the water need of the grain crop is highest in spring season in Konya, the best representative of Central Anatolia Region. In such cases, the drought impacts on yield can be observed due to inadequate precipitation throughout this period.

In Central Anatolia Region, where the winter grain production is being widespread, agricultural droughts can occur in two seasons [17].

1. Fall Season Drought is vital since after sowing, the wheat needs water to germinate vigorously. If drought occurs at the sowing season or consequent time period after sowing like November and December, this leads to no or late germination of the seeds [17]. After planting in dry soil or when there is a rainfall just to moisturize the seed bed before sowing and insufficient precipitation falls for a long period, the wheat faces with a harmful situation called ”alatav” in colloquial speech. This type of damage causes the death of wheat.

2. Spring Season Drought occurs between months March and July; this period of time covers end of tillering, pseudo stem elongation, flowering and grain formation phases of wheat. In this period, wheat needs water in the highest level, and it is so sensitive.

In general, Central Anatolia is most sensitive to the risk of drought for the spring months especially between April and June, i.e. time period when the vegetative growth is fastest [17]. For this reason, $SPI'3$ values and precipitation amount for months April, May and June were considered to detect the relationship between the wheat yield in this study. Furthermore, some of AMS outputs i.e. $WDEF_r$, $WDEF_f$, $ETA_r$, $ETA_f$ and $WSI_h$ are directly correlated to yield since they are related weather variables with the most important growth stages for wheat production. Moreover, the NVDI values, the ratios of AMS outputs with the NVDI values might indicate strong correlation with the wheat yield.

### 2.2.5 Insurance Product Design

Insurance is the most powerful risk management technique against the results of uncertain events. In this study, impacts of drought occurrence on farm's income volatility were considered. Brown and Gottlieb clarify that an individual (the insured) can transfer this risk, or variability of possible outcomes, to an insurance company (the insurer) in exchange for a set payment (the premium) by purchasing an insurance policy. Because of the law of large numbers, the insurer will end up with an average risk that is relatively smaller compared to the original risk to individual policyholders through careful underwriting and selection [15]. Designing a valuable index based insurance based primarily on careful selection of proxies. Then, the next step is the financial calculations of insurance contract under the relationship between the log yield and index variable.

In this study, Central Anatolia Region's provinces were chosen to design index-based insurance policies. The basis risk properties of weather based insurance contracts in 2007 was compared under different models and distinct selections of index variable. Moreover, the feasibility and efficiency of these products were discussed by means of net premium and indemnity payments.

In actuarial science, without considering any acquisition and administration costs, we can define the net premium by (2.2)

$$\text{Net Premium} = E[X] + \lambda.\sigma[X] \tag{2.2}$$

where, E[X] is the mean or expected value of claim amounts i.e. pure premium, $\lambda.\sigma[X]$ represents the risk loading factor of the insurer, in other words it defines the risk premium.

Pure premium calculations are relied on the multiplication of the indemnification of under the given model in our past data and the probability of its occurrence in the sample without considering the risk premium in equation (2.3)

$$\begin{aligned} \text{Pure Premium} = E[X] &= E[Losses] \\ &= (1/n)\sum_{i=1}^{n}\widehat{I_i} \end{aligned} \tag{2.3}$$

where n is the number of years i.e. wheat yield data range, 1/n represents the occurrence of indemnification in the past data and $\widehat{I_i}$ represents the claim payment of the index based insurance starts from year 1 to n according to the predicted wheat yield.

In the index based insurance policies, indemnity payment occurrence depends on the trigger or strike level of the weather index variable. For example, if the correlation between the yield and the weather data is positive, whenever the index variable falls below the trigger point, the corresponding policy is resulted in indemnification. In general, the function (2.4) indicates the claim amount paid to the policyholder:

$$I(X) = \gamma . \max(S - X, 0) \tag{2.4}$$

where, $I(X)$ denotes the claim amount that will be paid to the insured in the policy year, S represents the trigger level or point of the selected index variable, X represents the observed weather index data in the policy year and $\gamma$ is the size of the index level that quantifies the indemnity payment.

# CHAPTER 3

# DATA ANALYSIS

## 3.1 Data sources

The wheat yield data for each province in Central Anatolia was derived from the database of Prime Ministry State Institute of Statistics for years between 1964-2010 [30]-[56]. Firstly, there are doubts about the quality of this data even if it was collected from the governmental administration. Furthermore, for provinces Aksaray, Karaman and Kırıkkale, wheat yield data is missing for time periods 1964-1978 and 1985-1988. For this reason, there will be no index-based insurance design for this provinces as it is discussed earlier that the long term wheat yield data is so crucial for efficient insurance contracts.

In this study, the alternative index variables for designing a drought insurance product were generated by AMS software. Because of the limited input data for results of AMS algorithms, it was just calculated for years between 1991 and 2007 correctly (the range of data is 17). Moreover, NDVI values belonging to the provinces of Central Anatolia Region for the same time period were obtained from the National Oceanic and Atmospheric Administration (NOAA).

The rainfall amount was derived from the Turkish State Meterological Service which is the only legal organization for providing all kinds of meteorological informations in Turkey. Monthly precipitation data for all provinces for years between 1951-2010 was acquired. Furthermore, $SPI'3$ values of weather stations of each province were obtained by handling these precipitation data for different time steps. According to this station based values, the mean value of $SPI'3$ values and precipitation data for provinces were calculated by using the most appropriate spatial interpolation (Kriging models) method.

## 3.2 Weather Index Design

### 3.2.1 Wheat Yield Forecasting

Initially, it is needed a prediction about the wheat yield in 2007 for each province, before designing any insurance contract. All pure premium and indemnity amount calculations will be based on this wheat yield estimation. One of the most simplest and easy computable ways of setting an estimation for the next year's wheat yield is that calculating long-term average or mean value of the recorded yield data for each province. However, this basic approach is not reliable for the prediction of the wheat yield for 2007. For this reason, Box-Jenkins models were used to forecast the wheat yield value in 2007 in this study.

Basically, any time-series process can be described by the following single equation (3.1) or (3.2)

$$Y(t) = \lambda.Y(t-1) + \mu + \beta.t + \epsilon(t) \tag{3.1}$$

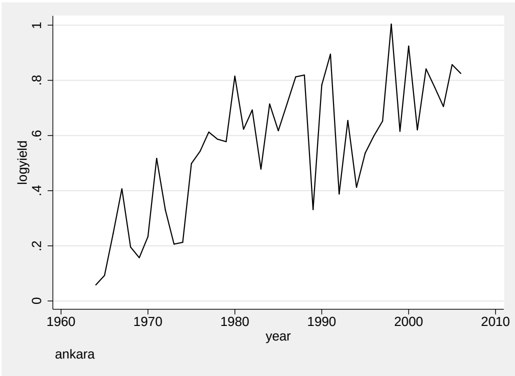
or,

$$Y(t) - Y(t-1) = \mu + (\lambda - 1).Y(t-1) + \beta.t + \epsilon(t) \tag{3.2}$$

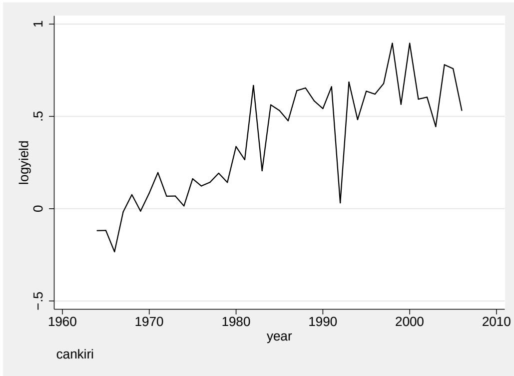
where $\epsilon$(t) is the error term, which may have zero mean and variance of $\sigma^2$, $\mu$, $\lambda$ and $\beta$ are some appropriate constants, Y(t) represents time series value at year t. The processes is given in the equation (3.1) get different names according to the different values of given values. For instance, if Y(t) is a function of Y(t-1) and $\epsilon$(t), then it is called as a random walk.

The most important starting point of analyzing any time-series process is that determine whether the given series has stationary or non-stationary structure. Based on this distinction, there are different estimation techniques and the most proper one was tried to be selected in this study. For instance, in the equation (3.1); if ($\lambda$-1)=0 then given time-series is non-stationary, i. e. the series contains a unit root. When $\beta > 0$ then the series contains trend, and it should be removed by detrending method before analyzing. But, if the $\beta$ value is zero and ($\lambda$-1) is different from zero then our series is stationary.

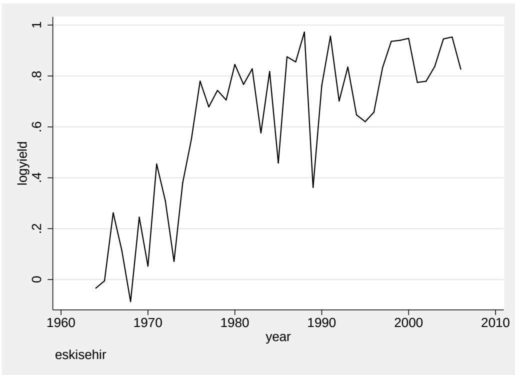
Firstly, the plots of logyield time-series were considered to determine the properties of wheat yield data. The following Figures 3.1(a)-3.1(j) represent these plots for each province and they are generated by STATA 9.1 statistical software.



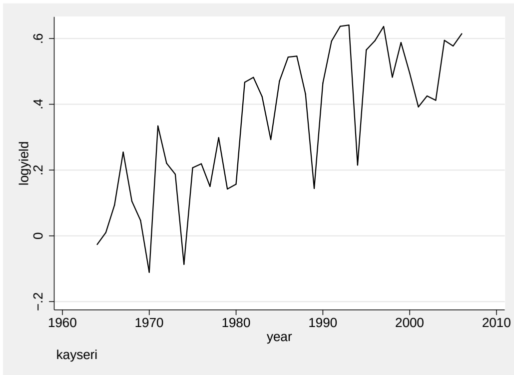

(a) Ankara



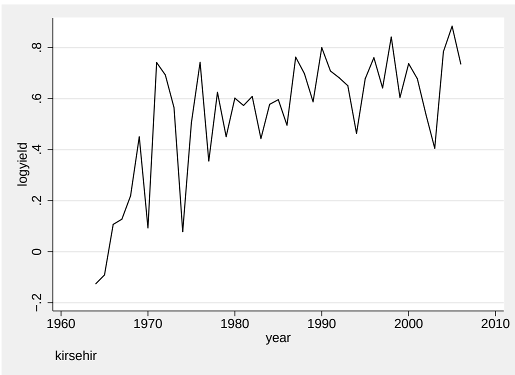

(b) Çankırı



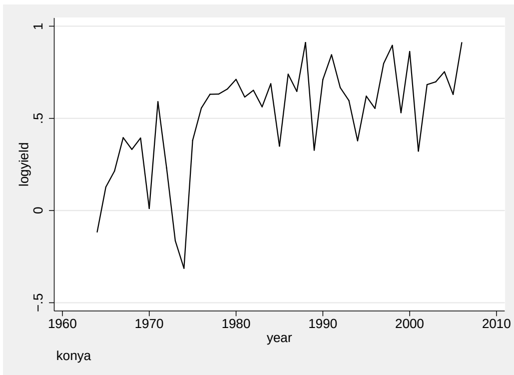

(c) Eskişehir




(d) Kayseri



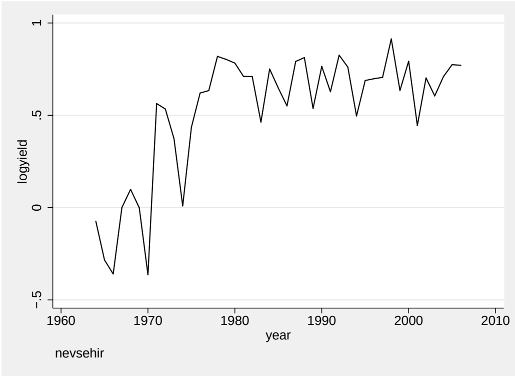

(e) Kırşehir



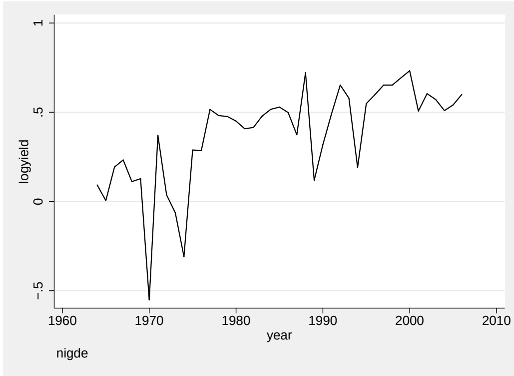

(f) Konya

While analyzing the given logyield time series data, the Box-Jenkins procedure is followed step by step. Firstly, increasing trend was removed by detrending method for each province. Afterwards, The Augmented Dickey Fuller (ADF) and the Philips-Perron (PP) test results were used to describe the stationarity of given logyield series. The following Table 3.1 represents unit root test results for given time series after detrending.

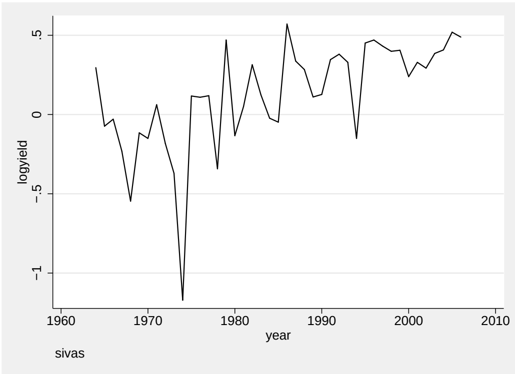
According to the results of table 3.1, differencing one time is enough to reject the null hy-



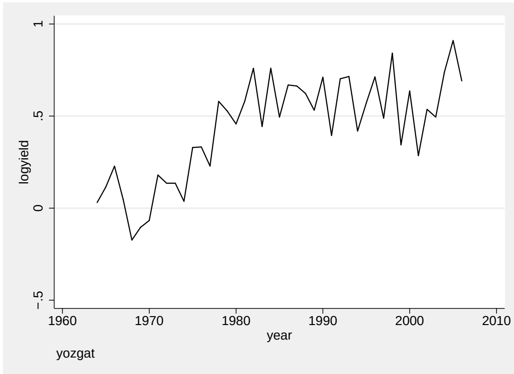

(g) Nevşehir




(h) Niğde




(i) Sivas




(j) Yozgat

Figure 3.1: Time series plots for original logyield data

pothesis after detrending. In other words, the logyield time-series data for provinces were transformed to stationary after one level of differencing. Theoretically, ADF and PP test results were used to interpret these findings. The following graphs 3.2(a)-3.2(j) represent these transformed series:

After discovering the stationarity and non-stationarity properties of the given logyield time-series for each province, the wheat yield value in 2007 was estimated. Simply, the Box-Jenkins ARIMA processes were used for the wheat yield prediction.

As it explained above, when the given original series was not stationary, the first-order difference process was calculated by the equation (3.3).

$$X(t) = \nabla Y(t) = Y(t) - Y(t-1) \tag{3.3}$$

This differencing process continues up to make the original series stationary. In this study, first-order difference was enough for all provinces to make the given logyield series station-

Table 3.1: Unit root test results for stationarity

| Time series | Level of differencing | ADF tests [a] t-value | ADF tests [a] McKinnon p-value | PP tests [b] Z(rho) | PP tests [b] Z(t) |
|---|---|---|---|---|---|
| detrankara | 0 | -3.043 | 0.1204 | -13.950 | -2.893 |
| detrankara | 1 | -6.453 | 0.0000 | -32.515 | -6.875 |
| detrçankırı | 0 | -2.696 | 0.2376 | -14.766 | -2.729 |
| detrçankırı | 1 | -6.793 | 0.0000 | -39.945 | -6.955 |
| detreskişehir | 0 | -2.446 | 0.3554 | -9.574 | -2.264 |
| detreskişehir | 1 | -6.450 | 0.0000 | -32.694 | -6.847 |
| detrkayseri | 0 | -3.538 | 0.0355 | -16.761 | -3.299 |
| detrkayseri | 1 | -5.291 | 0.0001 | -21.959 | -5.451 |
| detrkırşehir | 0 | -3.175 | 0.0895 | -13.026 | -2.941 |
| detrkırşehir | 1 | -6.667 | 0.0000 | -33.276 | -7.238 |
| detrkonya | 0 | -3.010 | 0.1294 | -15.147 | -2.993 |
| detrkonya | 1 | -5.228 | 0.0001 | -26.470 | -5.111 |
| detrnevşehir | 0 | -2.366 | 0.3979 | -8.273 | -2.105 |
| detrnevşehir | 1 | -6.593 | 0.0000 | -30.216 | -7.650 |
| detrniğde | 0 | -3.012 | 0.1289 | -15.189 | -2.929 |
| detrniğde | 1 | -5.743 | 0.0000 | -27.678 | -5.880 |
| detrsivas | 0 | -3.906 | 0.0119 | -17.871 | -3.664 |
| detrsivas | 1 | -5.648 | 0.0000 | -26.105 | -5.821 |
| detryozgat | 0 | -2.191 | 0.4947 | -9.283 | -2.201 |
| detryozgat | 1 | -6.804 | 0.0000 | -42.049 | -6.864 |

[a] Interpolated DF values for 1% 5% and 10%, when d=0 is -4.224 -3.532 and -3.199 respectively and when d=1 is -4.233 -3.536 and -3.202 respectively in ADF test

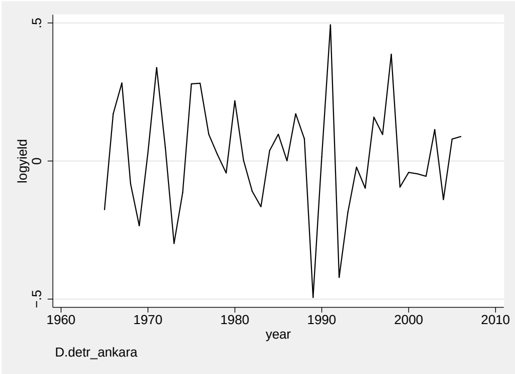
[b] Interpolated DF values for 1% 5% and 10%, when d=0 is -24.676 -19.192 and -16.416 respectively and when d=1 is -24.548 -19.116 and -16.368 respectively in PP test

arity. After finding the differenced process is stationary, the autoregressive moving average (ARMA) models were used for estimation. Since the transformed series were used, the process X(t) defined in (3.4) is called an autoregressive integrated moving average process, ARIMA(p,d,q) where p and q are the degrees of the autoregressive and the moving average processes respectively. The value of d represents the level of differencing in this definiton.

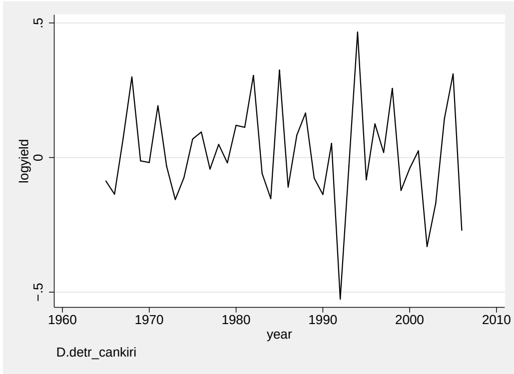
In general, ARMA(p,q) process can be described by the equation (3.4)

$$X(t) = \sum_{r=1}^{p} \phi(r)X(t-r) + \sum_{s=0}^{q} \theta(s)\epsilon(t-s) \tag{3.4}$$

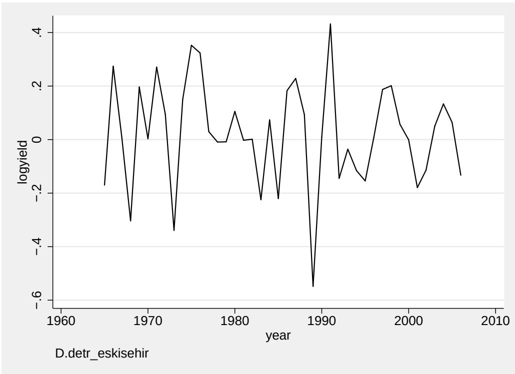
where $\phi$ and $\theta$ are appropriate constants and also $\epsilon(t)$ represents white noise for the stationarity process i.e. $\epsilon(t)$ is a sequence of independent random variables with mean 0 and variance ($\sigma^2$).



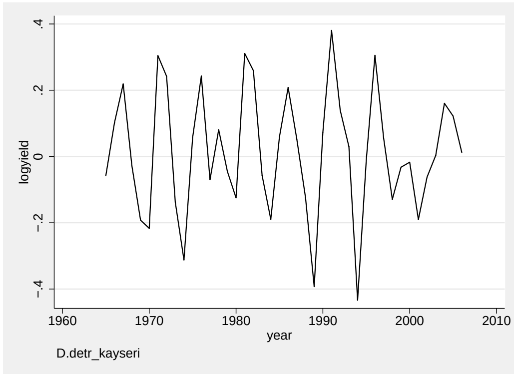

(a) D.detrankara



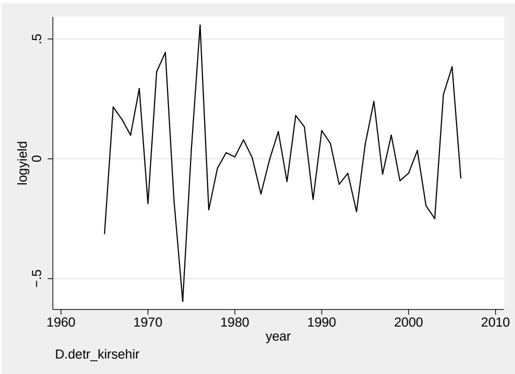

(b) D.detrçankırı



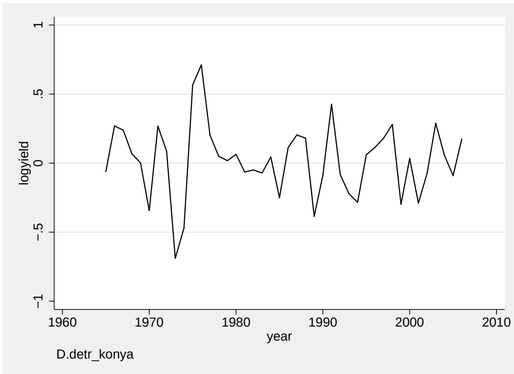

(c) D.detreskişehir




(d) D.detrkayseri

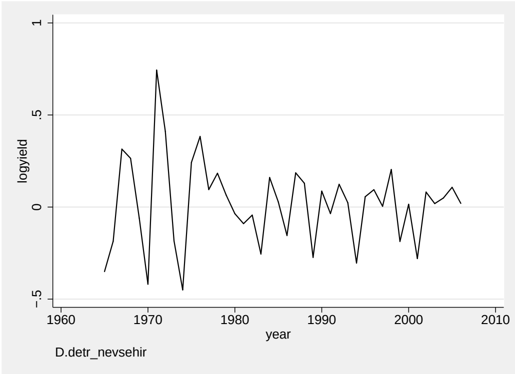



(e) D.detrkırşehir

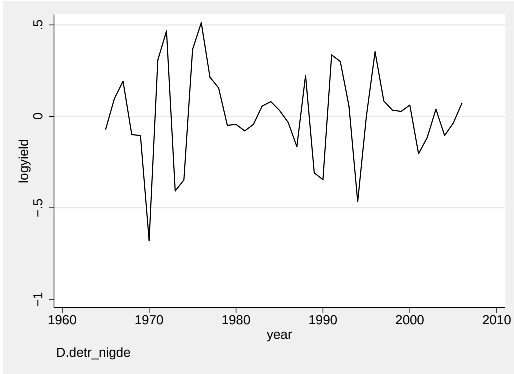



(f) D.detrkonya

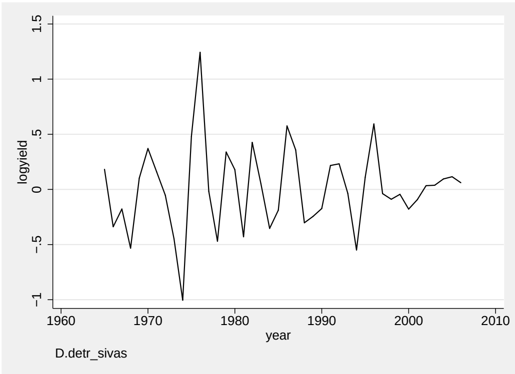
The logyield time series became stationary after one level of differencing for each province. For this reason, ARIMA (p,1,q) processes were used to understand the behavior of the logyield data in 2007. Primarily, the optimum value of order ( i.e. the p and q) were identified by looking at the Autocorrelation function (ACF) and Partial Autocorrelation function (PACF) plots. After this selection, the best model for wheat yield estimation was made upon Akaike's Information Criterion (AIC) and Schwarz's Bayesian Criterion (SBC) values. These information-based criteria techniques can automate the model identification process. Further-



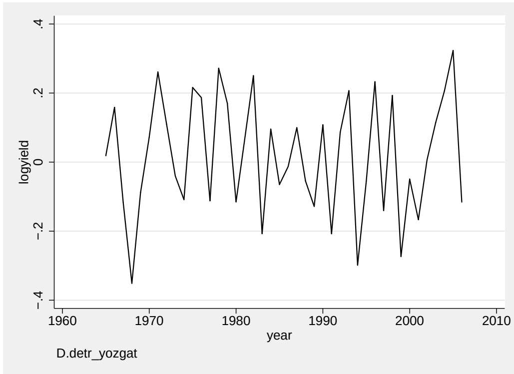

(g) D.detrnevşehir




(h) D.detrniğde




(i) D.detrsivas




(j) D.detryozgat

Figure 3.2: Time series plots for detrended logyield data after one level of differencing

more, the Adjusted Rsquare and Mean Absolute Error (MAE) parameters were used for model validation. Collectively, the minimum the AIC, SBC and MAE values and the maximum the Adjusted Rsquare, the best prediction equation was derived. Besides these values, also parameter estimates for ARIMA processes were reported for the significance of parameters. JMP 7 software used for the ARIMA modelling of the logyield data. Moreover, the residual plots resulted in the white noise process for each province under the best selected process. For instance, the table 3.2 below summarized the best process for Ankara. The ARIMA modelling summary for the remaining provinces were tabulated in Appendix A.

According to the different ARIMA(p,1,q) process selection for each province, the wheat yield value was estimated in 2007. Then, these predictions were compared with the actual wheat yield for that year. The Table 3.3 reveals the observed wheat yield versus the predicted wheat yield for each province under ARIMA models.

According to predicted wheat yield value of provinces in 2007, apart from Kayseri, all provinces

Table 3.2: ARIMA process for Ankara

| | | Model Fit Summary | | | |
|---|---|---|---|---|---|
| | | AIC | SBC | Adj Rsquare | MAE |
| ARIMA(1,1,1) | | -16.610017 | -11.397008 | 0.57058565 | 0.14297685 |
| Coeff. | Lag # | Estimates | Std Error | t ratio | Prob> $\|t\|$ |
| AR1 | 1 | -0.5913458 | 0.1561576 | -3.79 | 0.0005* |
| MA1 | 1 | -0.9294278 | 0.0796528 | -11.67 | $< 0.0001*$ |
| Intercept | 0 | 0.0173589 | 0.0341333 | 0.51 | 0.6139 |

* : Correlation is significant at the 0.05 level
Constant estimation is 0.02762398

Table 3.3: Observed versus Predicted Wheat Yield in 2007

| Province | TS process | Observed yield (t/ha) | Forecasted yield (t/ha) |
|---|---|---|---|
| Ankara | ARIMA (1,1,1) | 1.211 | 2.333 |
| Çankırı | ARIMA (1,1,1) | 1.202 | 1.806 |
| Eskişehir | ARIMA (2,1,2) | 1.860 | 2.053 |
| Kayseri | ARIMA (2,1,1) | 1.614 | 1.599 |
| Kırşehir | ARIMA (1,1,1) | 1.503 | 2.268 |
| Konya | ARIMA (1,1,2) | 1.646 | 2.436 |
| Nevşehir | ARIMA (2,1,0) | 1.445 | 2.000 |
| Niğde | ARIMA (1,1,1) | 1.415 | 1.645 |
| Sivas | ARIMA (2,1,1) | 1.282 | 1.506 |
| Yozgat | ARIMA (1,1,1) | 1.739 | 2.219 |

faced with a drastic yield decline in this year if the observed and forecasted yield was compared relying on the past data. In this respect, index based drought insurance contracts can respond to that yield reduction according to the selected of index variable. The following two sections will be related to the selection of the index variable and the usage of a simple regression modelling for the given index variable to design alternative insurance policies.

### 3.2.2 Index Selection

In this section, the correlation between the logyield and weather index variables was considered for each province. The correlation power of the each alternative index variable for distinct provinces was tested by SPSS software. Firstly, the results of Spearman's rank correlation (i. e. Spearman's rho) for the AMS software predictors and NDVI values were shown in following Tables 3.4-3.6.

Table 3.4: Correlation between logyield and WDEF values

| Province | $WDEF_i$ | $WDEF_v$ | $WDEF_f$ | $WDEF_r$ | $WDEF_t$ |
|---|---|---|---|---|---|
| Ankara | -0.075 | -0.310 | -0.706** | -0.635** | -0.659** |
| Çankırı | 0.078 | -0.102 | -0.635** | -0.575* | -0.605* |
| Eskişehir | -0.120 | - | -0.153 | -0.227 | -0.224 |
| Kayseri | -0.188 | -0.357 | -0.084 | -0.445 | -0.408 |
| Kırşehir | -0.230 | -0.026 | 0.035 | -0.266 | -0.246 |
| Konya | -0.350 | -0.224 | -0.482 | -0.600* | -0.650** |
| Nevşehir | -0.129 | - | -0.451 | -0.536* | -0.536* |
| Niğde | -0.167 | -0.256 | -0.527* | -0.553* | -0.586* |
| Sivas | -0.032 | - | -0.506* | -0.276 | -0.291 |
| Yozgat | -0.017 | -0.408 | -0.477 | -0.401 | -0.418 |

* : Correlation is significant at the 0.05 level
** : Correlation is significant at the 0.01 level

Table 3.5: Correlation between logyield and ETA & WSI values

| Province | $ETA_i$ | $ETA_v$ | $ETA_f$ | $ETA_r$ | $ETA_t$ | $WSI_h$ |
|---|---|---|---|---|---|---|
| Ankara | 0.172 | 0.179 | -0.092 | 0.583* | 0.603* | 0.691** |
| Çankırı | 0.374 | -0.060 | -0.206 | 0.617** | 0.602 | 0.621** |
| Eskişehir | 0.378 | 0.139 | -0.031 | 0.094 | 0.255 | 0.230 |
| Kayseri | -0.098 | -0.280 | -0.203 | 0.412 | 0.318 | 0.409 |
| Kırşehir | 0.250 | 0.352 | -0.345 | 0.237 | 0.363 | 0.246 |
| Konya | 0.066 | 0.172 | 0.049 | 0.591* | 0.554* | 0.662** |
| Nevşehir | -0.064 | 0.246 | -0.248 | 0.490* | 0.475 | 0.535* |
| Niğde | -0.362 | 0.118 | 0.458 | 0.552* | 0.597* | 0.584* |
| Sivas | -0.187 | -0.135 | 0.455 | 0.342 | 0.438 | 0.314 |
| Yozgat | -0.123 | 0.141 | -0.292 | 0.504* | 0.407 | 0.417 |

* : Correlation is significant at the 0.05 level
** : Correlation is significant at the 0.01 level

It was also considered the correlation power of the new index variables generated by the combination of AMS outputs and NDVI values. Especially, the new drought indicators were defined in section 2, which are the ratios of AMS outputs and NVDI values. The Tables 3.7-3.8 shows the correlation power results of these alternative index variables for each province.

Furthermore, the relationship between $SPI'3$ values and rainfall amount in April, May, June and the wheat yield were also figured on in this study. The selections of the above months were based on the drought sensitivity of the wheat in Central Anatolia. As it was said earlier in section 2, these months are the most important time periods for the wheat production in this semiarid area. $SPI'3$ values for the selected months might help to reveal the short term

Table 3.6: Correlation between logyield and NVDI values

| Province | vert | eval | pval | cum | drop |
|---|---|---|---|---|---|
| Ankara | 0.514* | 0.503* | 0.689** | 0.260 | 0.115 |
| Çankırı | 0.319 | 0.354 | 0.378 | 0.401 | 0.217 |
| Eskişehir | 0.400 | 0.629** | 0.609** | 0.006 | 0.262 |
| Kayseri | -0.232 | -0.145 | -0.225 | 0.069 | -0.336 |
| Kırşehir | 0.013 | 0.194 | 0.189 | 0.253 | -0.168 |
| Konya | 0.312 | 0.172 | 0.383 | 0.163 | -0.086 |
| Nevşehir | 0.166 | 0.123 | 0.194 | 0.211 | -0.101 |
| Niğde | 0.241 | 0.173 | 0.266 | -0.067 | 0.241 |
| Sivas | 0.075 | -0.295 | 0.028 | 0.309 | -0.071 |
| Yozgat | 0.198 | -0.052 | 0.012 | 0.118 | -0.044 |

* : Correlation is significant at the 0.05 level
** : Correlation is significant at the 0.01 level

Table 3.7: Correlation between logyield and the ratios of WDEF and NVDI values

| Province | $WDEF_f/vert$ | $WDEF_f/eval$ | $WDEF_f/pval$ | $WDEF_r/vert$ | $WDEF_r/eval$ |
|---|---|---|---|---|---|
| Ankara | -0.711** | -0.625** | -0.685** | -0.887** | -0.684** |
| Çankırı | -0.687** | -0.636** | -0.636** | -0.735** | -0.477 |
| Eskişehir | -0.153 | -0.153 | -0.153 | -0.430 | -0.291 |
| Kayseri | -0.076 | -0.108 | -0.075 | -0.386 | -0.464 |
| Kırşehir | 0.035 | 0.035 | 0.035 | -0.323 | -0.282 |
| Konya | -0.549* | 0.417 | -0.456 | -0.652** | -0.667** |
| Nevşehir | -0.451 | -0.291 | -0.451 | -0.673** | -0.646** |
| Niğde | -0.594* | -0.586* | -0.594* | -0.669** | -0.693** |
| Sivas | -0.509* | -0.319 | -0.509* | -0.319 | -0.304 |
| Yozgat | -0.477 | -0.370 | -0.477 | -0.500* | -0.404 |
| Province | $WDEF_r/pval$ | $WDEF_t/vert$ | $WDEF_t/eval$ | $WDEF_t/pval$ | |
| Ankara | -0.721** | -0.885** | -0.689** | -0.738** | |
| Çankırı | -0.641** | -0.739** | -0.636** | -0.641** | |
| Eskişehir | -0.419 | -0.430 | -0.221 | -0.357 | |
| Kayseri | -0.432 | -0.379 | -0.525* | -0.422 | |
| Kırşehir | -0.283 | -0.280 | -0.270 | -0.235 | |
| Konya | -0.691** | -0.804** | -0.647** | -0.723** | |
| Nevşehir | -0.646** | -0.661** | -0.639** | -0.639** | |
| Niğde | -0.692** | -0.709** | -0.717** | -0.751** | |
| Sivas | -0.346 | -0.313 | -0.343 | -0.296 | |
| Yozgat | -0.434 | -0.495* | -0.424 | -0.434 | |

* : Correlation is significant at the 0.05 level
** : Correlation is significant at the 0.01 level

drought impact on the wheat yield. Also, monthly precipitation was considered instead of the annual rainfall amount. The following Table 3.9 summarizes results of the correlation power

Table 3.8: Correlation between logyield and the ratios of ETA and NVDI values

| Province | $ETA_r/vert$ | $ETA_r/eval$ | $ETA_r/pval$ | $ETA_t/vert$ | $ETA_t/eval$ | $ETA_t/pval$ |
|---|---|---|---|---|---|---|
| Ankara | 0.154 | 0.485* | 0.424 | -0.216 | -0.098 | -0.076 |
| Çankırı | 0.222 | 0.526* | 0.427 | -0.021 | 0.309 | 0.125 |
| Eskişehir | -0.096 | -0.058 | -0.093 | -0.228 | -0.120 | -0.189 |
| Kayseri | 0.303 | 0.331 | 0.299 | 0.335 | 0.221 | 0.338 |
| Kırşehir | 0.177 | 0.148 | 0.243 | 0.107 | 0.029 | 0.181 |
| Konya | 0.206 | 0.502* | 0.419 | -0.176 | 0.292 | 0.005 |
| Nevşehir | 0.218 | 0.272 | 0.279 | 0.071 | 0.115 | 0.137 |
| Niğde | 0.359 | 0.404 | 0.381 | 0.200 | 0.295 | 0.309 |
| Sivas | 0.058 | 0.103 | 0.037 | 0.167 | 0.389 | 0.177 |
| Yozgat | 0.309 | 0.549* | 0.385 | 0.186 | 0.387 | 0.301 |

* : Correlation is significant at the 0.05 level

of these index variables. The $SPI'3_4$, $SPI'3_5$, $SPI'3_6$ and $P_4$, $P_5$, $P_6$ in Table 3.9 represents the $SPI'3$ values and rainfall amounts for months April, May and June respectively.

Table 3.9: Correlation between logyield and SPI'3 values & Precipitation amount

| Province | $SPI'3_4$ | $SPI'3_5$ | $SPI'3_6$ | $P_4$ | $P_5$ | $P_6$ |
|---|---|---|---|---|---|---|
| Ankara | 0.149 | 0.165 | 0.214 | 0.426** | -0.037 | -0.042 |
| Çankırı | 0.163 | 0.283 | 0.210 | 0.426** | 0.445** | 0.250 |
| Eskişehir | 0.024 | 0.014 | 0.132 | 0.302 | 0.047 | 0.005 |
| Kayseri | -0.060 | 0.092 | 0.111 | 0.055 | 0.160 | 0.191 |
| Kırşehir | 0.020 | 0.237 | 0.352* | 0.351* | 0.222 | 0.183 |
| Konya | 0.156 | 0.213 | 0.335* | 0.470** | 0.101 | 0.170 |
| Nevşehir | 0.032 | 0.127 | 0.252 | 0.222 | 0.215 | 0.300 |
| Niğde | 0.231 | 0.168 | 0.189 | 0.228 | 0.003 | 0.124 |
| Sivas | -0.036 | 0.058 | 0.162 | -0.032 | 0.138 | 0.318* |
| Yozgat | -0.057 | 0.115 | 0.174 | 0.403** | 0.287 | 0.289 |

* : Correlation is significant at the 0.05 level
** : Correlation is significant at the 0.01 level

From each table, the most significant index variables were selected. The table 3.10 represented here denotes the most significant index variable for each province. This selection will be used in the following section to identify the relationship between logyield and the selected index variable.

As in the Table 3.10, it is observed that the most correlated index variables are $WDEF_f$, $WDEF_t$, $ETA_r$, $ETA_t$ and $WSI_h$ and its ratios with NVDI values for many provinces. Moreover, the precipitation in April, May and June can be used alternatively for some provinces.

Table 3.10: Index summary for provinces

| Province | Table3.4 | Table3.5 | Table3.6 | Table3.7 | Table3.8 | Table3.9 |
|---|---|---|---|---|---|---|
| Ankara | $WDEF_f$ | $ETA_t$ | $WSI_h$, pval | $WDEF_r/vert$ | $ETA_r/eval$ | $P_4$ |
| Çankırı | $WDEF_f$ | $ETA_r$ , $WSI_h$ | NI | $WDEF_t/vert$ | $ETA_r/eval$ | $P_5$ |
| Eskişehir | NI | NI | eval | NI | NI | NI |
| Kayseri | NI | NI | NI | $WDEF_t/eval$ | NI | NI |
| Kırşehir | NI | NI | NI | NI | NI | $P_4$ |
| Konya | $WDEF_t$ | $ETA_r$ , $WSI_h$ | NI | $WDEF_t/vert$ | $ETA_r/eval$ | $P_4$ |
| Nevşehir | $WDEF_r$ , $WDEF_t$ | $ETA_r$ , $WSI_h$ | NI | $WDEF_r/vert$ | NI | NI |
| Niğde | $WDEF_t$ | $ETA_t$ , $WSI_h$ | NI | $WDEF_t/pval$ | NI | NI |
| Sivas | $WDEF_f$ | NI | NI | $WDEF_f/vert$ , $Wdeff_f/pval$ | NI | $P_6$ |
| Yozgat | NI | $ETA_r$ | NI | $WDEF_r/vert$ | NI | $P_4$ |

NI : There is no correlated index variable significantly under the selected table

However, there was only one significant index variable for the provinces Eskişehir, Kayseri and Kırşehir which were eval, $WDEF_t/eval$ and $P_4$ respectively.

### 3.2.3 Regression between wheat yield and selected index

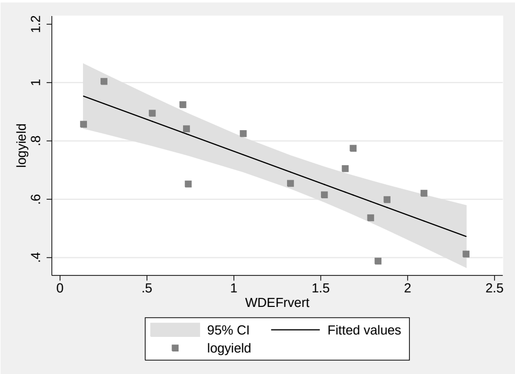
In the previous step, how these index variables describe the wheat yield for each province was revealed based on Spearman's correlation. The relationship between the weather index variable and wheat yield presented above will be used for designing an insurance contract. For simplicity, linear regression equations were choosen to calculate the trigger levels for index variables. The selection of the most appropriate prediction equation basically based on the minimum Root Mean Square Error (RMSE) and the maximum Adjusted R-square. Moreover, the significancy of the coefficient parameters for the selected predictors were stated. Stata 9.1 Statistical software was used to summarize the results of regression fit for each province.

For Ankara, $WDEF_f$, $ETA_t$, $WSI_h$, pval, $WDEF_r/vert$, $ETA_r/eval$ and $P_4$ were the most correlated index variables with the wheat yield. The linear regression fit results were given in Table 3.11

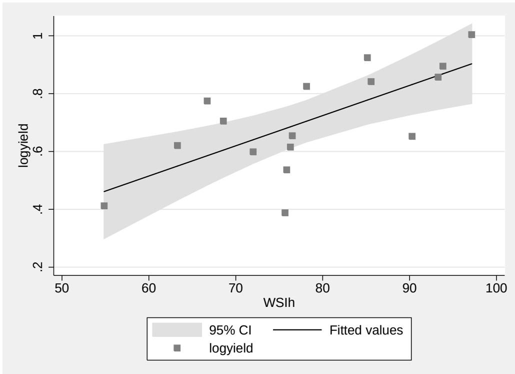
Table 3.11: Linear regression fit results for Ankara

| Index | Adj. R-square | RMS value | P> \|t\| |
|---|---|---|---|
| $WDEF_f$ | 0.4300 | 0.1352 | 0.003 |
| $ETA_t$ | 0.3779 | 0.14125 | 0.007 |
| pval | 0.3759 | 0.14147 | 0.007 |
| $WSI_h$ | 0.4452 | 0.13339 | 0.003 |
| $WDEF_r/vert$ | 0.6682 | 0.10315 | 0.000 |
| $ETA_r/eval$ | 0.2233 | 0.15782 | 0.037 |
| $P_4$ | 0.1663 | 0.22296 | 0.004 |

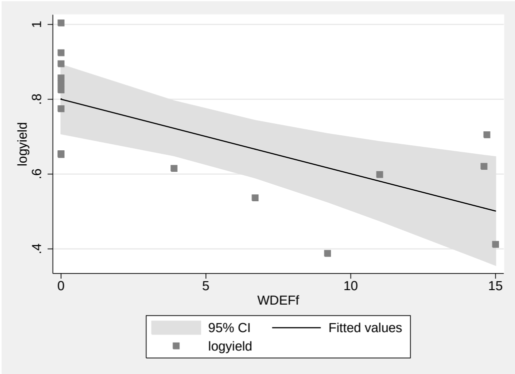
The numerical results of regression fit in the Table 3.11 denote that regression fit results for all index variables were significant, but some of them were better. For example, $WDEF_r/vert$ was the best index variable according to the given parameters. All these index variables will be used to design alternative insurance contracts except $ETA_r/eval$ and $P_4$ since their linear fit results were poorer than the others. The Figures 3.3(a)-3.3(e) summarize linear fit plots for these regressions.



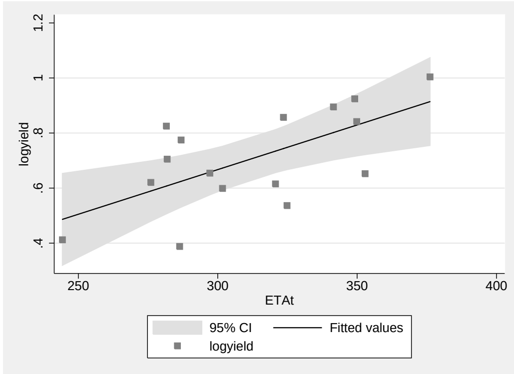

(a) $WDEF_r/vert$



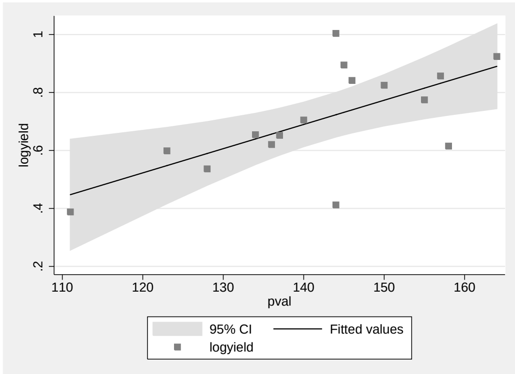

(b) $WSI_h$




(c) Linear fit plot for $WDEF_f$




(d) Linear fit plot for $ETA_t$




(e) Linear fit plot for pval

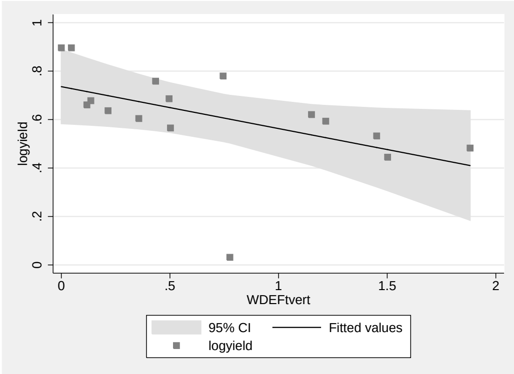
Figure 3.3: Linear fit plots for Ankara

For Çankırı, $WDEF_f$, $ETA_r$, $WSI_h$, $WDEF_t/vert$, $ETA_r/eval$ and $P_5$ were the most correlated index variables with the wheat yield. The linear regression fit results were given in Table 3.12.

Table 3.12: Linear regression fit results for Çankırı

| Index | Adj. R-square | RMS value | P> $\|t\|$ |
|---|---|---|---|
| $WDEF_f$ | 0.1315 | 0.18859 | 0.092 |
| $ETA_r$ | 0.1801 | 0.18323 | 0.057 |
| $WSI_h$ | 0.1075 | 0.19118 | 0.116 |
| $WDEF_t/vert$ | 0.1980 | 0.18123 | 0.048 |
| $ETA_r/eval$ | 0.0700 | 0.19515 | 0.167 |
| $P_5$ | 0.1530 | 0.28047 | 0.006 |

The numerical results of regression fit in the Table 3.12 denote that among the index variables, only $WDEF_t/vert$ can be accepted even if the significancy was much lower than Ankara. The linear regression estimation for this index variable will be used to design an insurance contract for Çankırı. The Figures 3.4(a) summarize linear fit plot for this regression.




(a) $WDEF_t/vert$

Figure 3.4: Linear fit plots for Çankırı

For Eskişehir, just eval was the most correlated index variable with the wheat yield. The linear regression fit result was given in Table 3.13.

Table 3.13: Linear regression fit results for Eskişehir

| Index | Adj. R-square | RMS value | P> $\|t\|$ |
|---|---|---|---|
| eval | -0.0514 | 0.12146 | 0.614 |

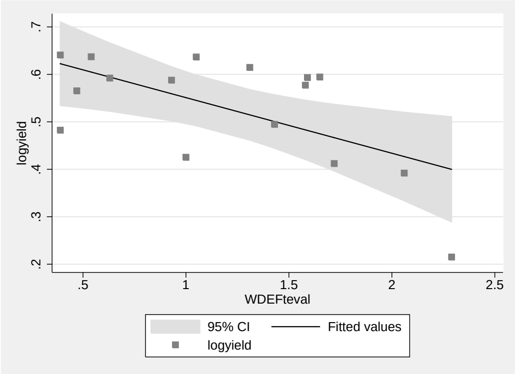
The numerical results of regression fit in the Table 3.13 denote that regression fit result for index variable eval was very poor so linear model was not suitable for Eskişehir under this index variable. Because of this poor linear fit result, there will be no insurance contract for this province under linear regression approach.

For Kayseri, just $WDEF_t/eval$ was the most correlated index variable with the wheat yield. The linear regression fit result was given in Table 3.14.

Table 3.14: Linear regression fit results for Kayseri

| Index | Adj. R-square | RMS value | P> $\|t\|$ |
|---|---|---|---|
| $WDEF_t/eval$ | 0.3180 | 0.09717 | 0.013 |

The numerical results of regression fit in the Table 3.14 denote that $WDEF_t/eval$ give a significant result under regression fit but the parameter values was not good as the case of Ankara. However, linear regression estimation for this index variable will be used to design an insurance contract for Kayseri. The Figures 3.5(a) summarize linear fit plot for the given regression.




(a) $WDEF_t/eval$

Figure 3.5: Linear fit plots for Kayseri

For Kırşehir, just $P_4$ was the most correlated index variable with the wheat yield. The linear regression fit result was given in Table 3.15.

Table 3.15: Linear regression fit results for Kırşehir

| Index | Adj. R-square | RMS value | P> $\|t\|$ |
|---|---|---|---|
| $P_4$ | -0.0159 | 0.24981 | 0.561 |

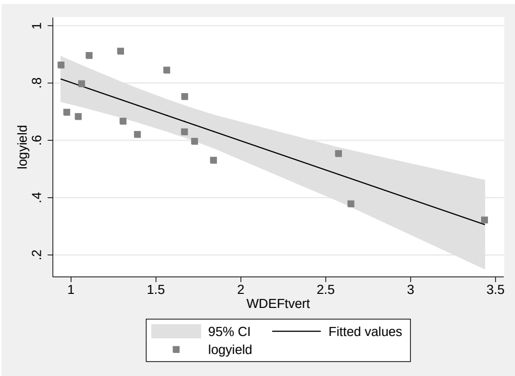
The numerical results of regression fit in the Table 3.15 denote that regression fit results for the index variable $P_4$ was very poor so linear model was not suitable for Kırşehir under this index variables. Because of this poor linear fit result, there will be no insurance contract for this province under linear regression approach.

For Konya, $WDEF_t$, $ETA_r$, $WSI_h$, $WDEF_t/vert$, $ETA_r/eval$ and $P_4$ were the most correlated index variables with the wheat yield. The linear regression fit results were given in Table 3.16.

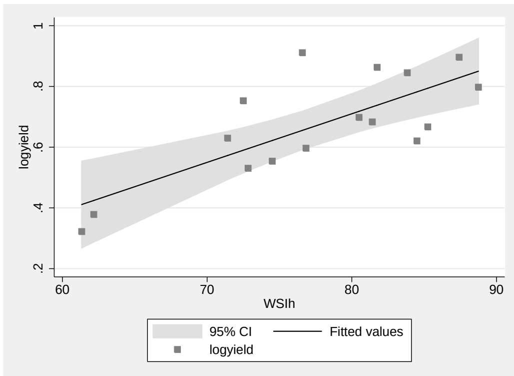
Table 3.16: Linear regression fit results for Konya

| Index | Adj. R-square | RMS value | P> $\|t\|$ |
|---|---|---|---|
| $WDEF_t$ | 0.5272 | 0.11904 | 0.001 |
| $ETA_r$ | 0.3867 | 0.13557 | 0.006 |
| $WSI_h$ | 0.5437 | 0.11694 | 0.001 |
| $WDEF_t/vert$ | 0.6558 | 0.10157 | 0.000 |
| $ETA_r/eval$ | 0.3040 | 0.14443 | 0.016 |
| $P_4$ | 0.1867 | 0.26123 | 0.002 |

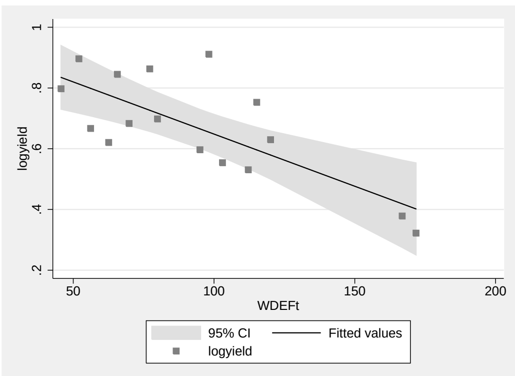
The numerical results of regression fit in the Table 3.16 denote that regression fit results for all index variables were significant, but some of them were better like $WDEF_t/vert$, $WSI_h$ and $WDEF_t$. All these index variables will be used to design alternative insurance contracts for Konya except $P_4$ since its linear fit result was poorer than the others . The Figures 3.6(a)-3.6(e) summarize linear fit plots for these regressions.



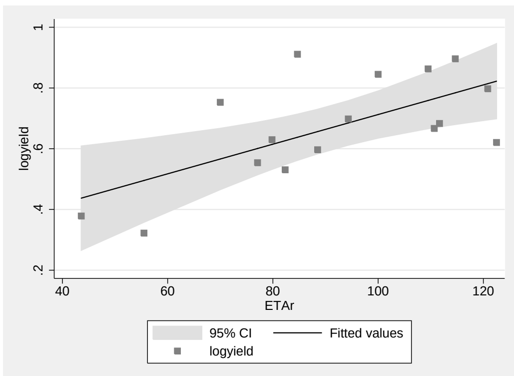

(a) $WDEF_t/vert$



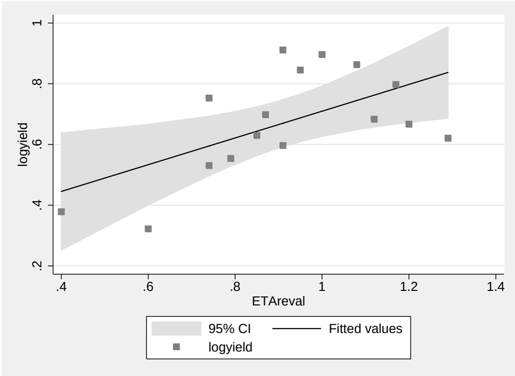

(b) $WSI_h$




(c) $WDEF_t$




(d) $ETA_r$




(e) $ETA_r/eval$

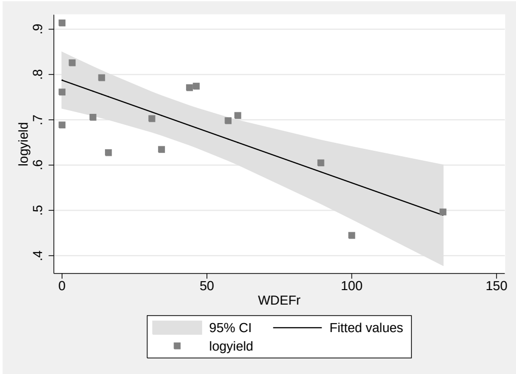
Figure 3.6: Linear fit plots for Konya

For Nevşehir, $WDEF_r$, $WDEF_t$, $ETA_r$, $WSI_h$, $WDEF_r/vert$ were the most correlated index variables with the wheat yield. The linear regression fit results were given in Table 3.17

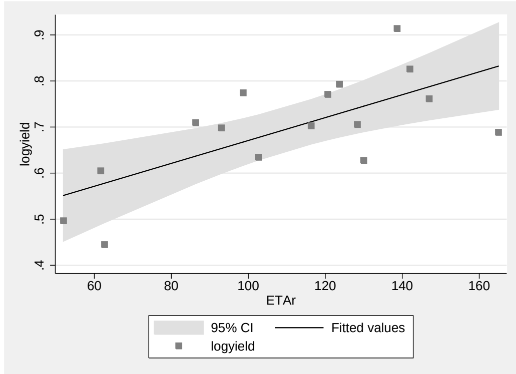
Table 3.17: Linear regression fit results for Nevşehir

| Index | Adj. R-square | RMS value | P> $\|t\|$ |
|---|---|---|---|
| $WDEF_r$ | 0.5461 | 0.07969 | 0.001 |
| $WDEF_t$ | 0.5398 | 0.08024 | 0.001 |
| $ETA_r$ | 0.4417 | 0.08838 | 0.003 |
| $WSI_h$ | 0.5487 | 0.07947 | 0.001 |
| $WDEF_r/vert$ | 0.5580 | 0.07864 | 0.001 |

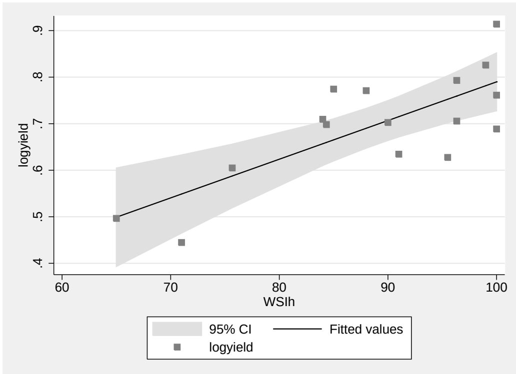
The numerical results of regression fit in the Table 3.17 denote that regression fit results for all index variables are significant, but some of them were better, i.e. $WDEF_r/vert$ was the best one. All these index variables will be used to design alternative insurance contracts for Nevşehir except $WDEF_t$ since it was almost the same as $WDEF_r$. The Figures 3.7(a)-3.7(d) summarize linear fit plots for these regressions.



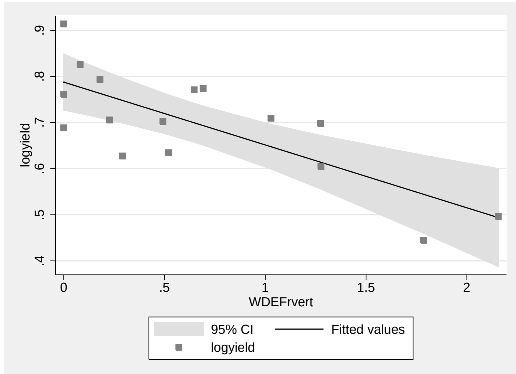

(a) $WDEF_r$




(b) $ETA_r$




(c) $WSI_h$




(d) $WDEF_r/vert$

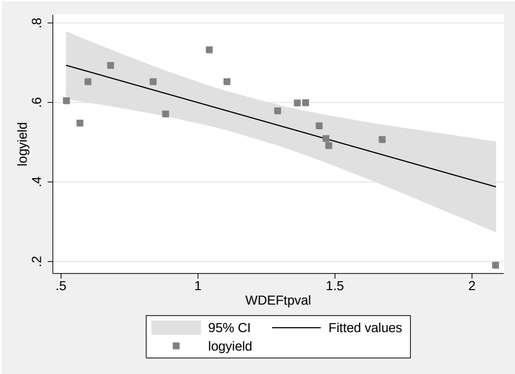
Figure 3.7: Linear fit plots for Nevşehir

For Niğde, $WDEF_t$, $ETA_t$, $WSI_h$ and $WDEF_t/pval$ were the most correlated index variables with the wheat yield. The linear regression fit results were given in Table 3.18.

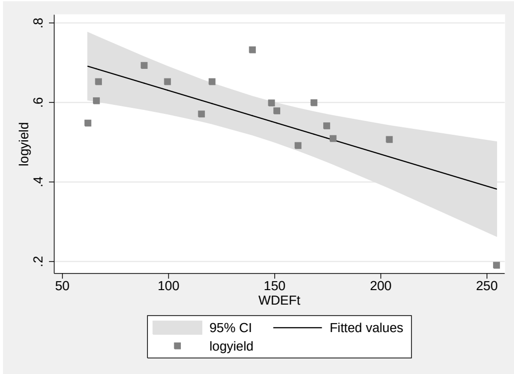
Table 3.18: Linear regression fit results for Niğde

| Index | Adj. R-square | RMS value | P> $\|t\|$ |
|---|---|---|---|
| $WDEF_t$ | 0.4615 | 0.08965 | 0.002 |
| $ETA_t$ | 0.3270 | 0.10023 | 0.012 |
| $WSI_h$ | 0.4019 | 0.09448 | 0.005 |
| $WDEF_t/pval$ | 0.4756 | 0.08847 | 0.002 |

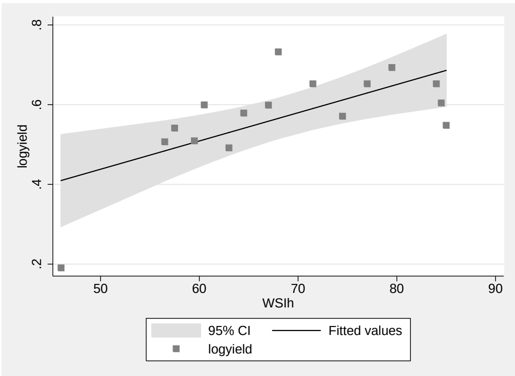
The numerical results of regression fit in the Table 3.18 denote that regression fit results for all index variables were significant, but some of them were better, i.e. $WDEF_t/pval$ was the best one. All these index variables will be used to design alternative insurance contracts for Niğde. The Figures 3.8(a)-3.8(d) summarize linear fit plots for these regressions.



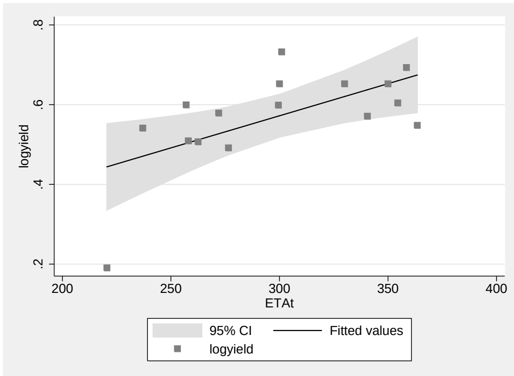

(a) $WDEF_t/pval$




(b) $WDEF_t$




(c) $WSI_h$




(d) $ETA_t$

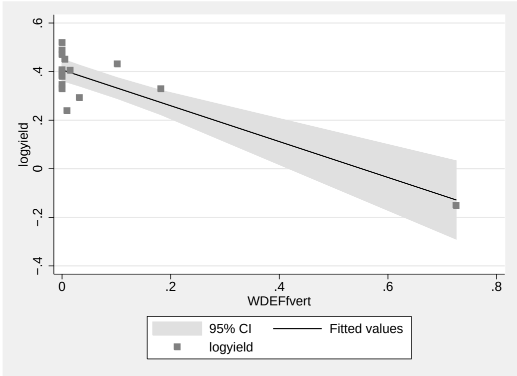
Figure 3.8: Linear fit plots for Niğde

For Sivas, $WDEF_f$, $WDEF_f/vert$, $WDEF_f/pval$ and $P_6$ were the most correlated index variables with the wheat yield. The linear regression fit results were given in Table 3.19

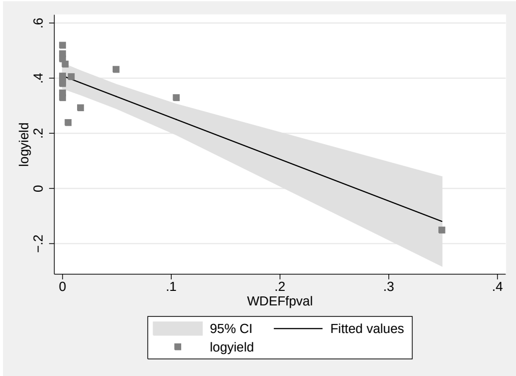
Table 3.19: Linear regression fit results for Sivas

| Index | Adj. R-square | RMS value | P> $\|t\|$ |
|---|---|---|---|
| $WDEF_f$ | 0.7260 | 0.08069 | 0.000 |
| $WDEF_f/vert$ | 0.7459 | 0.0777 | 0.000 |
| $WDEF_f/pval$ | 0.7371 | 0.07904 | 0.000 |
| $P_6$ | 0.0491 | 0.33036 | 0.083 |

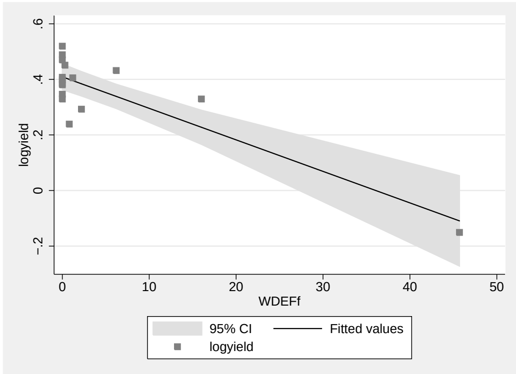
The numerical results of regression fit in the Table 3.19 denote that regression fit results for all index variables were significant except $P_6$. All these index variables will be used to design alternative insurance contracts for Sivas except $P_6$ since its linear fit result was poorer than the others. The Figures 3.9(a)-3.9(c) summarize linear fit plots for these regressions.




(a) $WDEF_f/vert$




(b) $WDEF_f/pval$




(c) $WDEF_f$

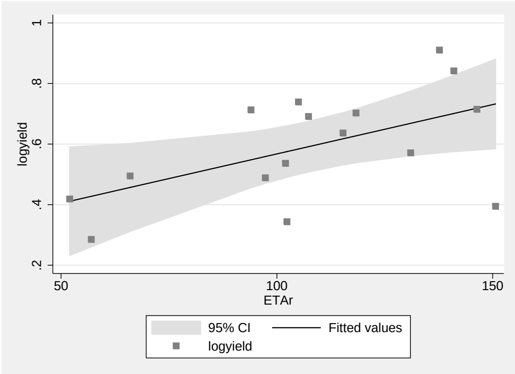
Figure 3.9: Linear fit plots for Sivas

For Yozgat, $ETA_r$, $WDEF_r/vert$ and $P_4$ were the most correlated index variables with the wheat yield. The linear regression fit results were given in Table 3.20.

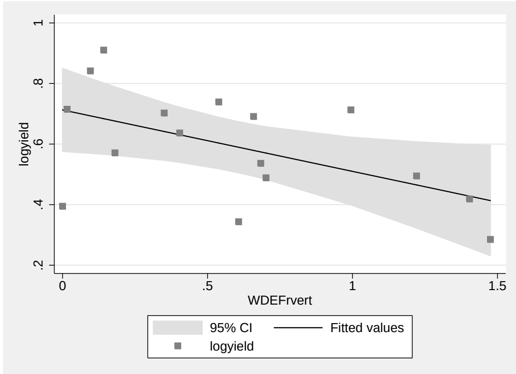
Table 3.20: Linear regression fit results for Yozgat

| Index | Adj. R-square | RMS value | P> $\|t\|$ |
|---|---|---|---|
| $ETA_r$ | 0.2509 | 0.15603 | 0.028 |
| $WDEF_r/vert$ | 0.2376 | 0.15741 | 0.032 |
| $P_4$ | 0.1610 | 0.25353 | 0.004 |

The numerical results of regression fit in the Table 3.20 denote that regression fit results for all index variables can be accepted apart from $P_4$, but the significancy of them were lesser. The index variables $ETA_r$ and $WDEF_r/vert$ will be used to design alternative insurance contracts for Yozgat even if they do not have so much significancy. The Figures 3.10(a)-3.10(b) summarize linear fit plots for these regressions.




(a) $ETA_r$




(b) $WDEF_r/vert$

Figure 3.10: Linear fit plots for Yozgat

The following Table 3.21 summarizes alternative linear prediction models of the wheat yield for all provinces.

Table 3.21: Linear Fit Selection for provinces

| Province | Linear fit equation |
|---|---|
| Ankara | -0.01199184*$WDEF_f$ + 0.8000297 |
| | 0.0032436*$ETA_t$ - 0.3059467 |
| | 0.0104401*$WSI_h$ - 0.111148 |
| | 0.0083535*pval - 0.4796559 |
| | -0.2184799*$WDEF_r/vert$ + 0.9829972 |
| Çankırı | -0.1730209*$WDEF_t/vert$ + 0.7358953 |
| Kayseri | -0.1171359*$WDEF_t/eval$ + 0.6681247 |
| Konya | -0.0034352*$WDEF_t$ + 0.9917338 |
| | 0.0048794*$ETA_r$ + 0.2246093 |
| | 0.0160108*$WSI_h$ - 0.5708398 |
| | -0.2034786*$WDEF_t/vert$ + 1.005281 |
| | 0.4403745*$ETA_r/eval$ + 0.2691891 |
| Nevşehir | -0.0022657*$WDEF_r$ + 0.7873841 |
| | 0.0024844*$ETA_r$ + 0.4223687 |
| | 0.0083101*$WSI_h$ - 0.041132 |
| | -0.1362573*$WDEF_r/vert$ + 0.7876893 |
| Niğde | -0.0016037*$WDEF_t$ + 0.7904473 |
| | 0.0016107*$ETA_t$ + 0.0888489 |
| | 0.0070835*$WSI_h$ + 0.0838149 |
| | -0.1948883*$WDEF_t/pval$ + 0.7945301 |
| Sivas | -0.0113422*$WDEF_f$ + 0.4090986 |
| | -0.7379142*$WDEF_f/vert$ + 0.4071058 |
| | -1.512743*$WDEF_f/pval$ + 0.4083332 |
| Yozgat | 0.0032557*$ETA_r$ + 0.2419648 |
| | -0.2027838*$WDEF_r/vert$ + 0.7127003 |

### 3.2.4 Discussions

Firstly, different ARIMA processes were used for wheat yield prediction of each province. The data range was enough for this analysis and then model performance were tested by using some important parameters. The more complicated forecast methods can give more accurate results to design insurance product. In this study, one of the simplest time series processes was preferred to predict yield for 2007. Moreover, no obvious periodic behavior was detected for logyield data of each province, so the seasonality effect, i.e. periodic fluctuations, was not considered. However, for further studies, the wheat yield estimation must be studied in detailed, since it deserves special attention to increase the capability of index-based insurance policies.

As it was mentioned above, while modelling the wheat yield and weather index simply, it was observed that there was no proper index variable for provinces Eskişehir and Kırşehir because of the poor correlation power. Moreover, linear model under the selected index variable was not suitable for this provinces. For the remaining provinces, it was concluded that distinct linear models were possible for the selected index variables. Especially, AMS outputs were most correlated predictors with the wheat yield. As a result, the efficiency of these linear models will be tested by calculating the premium and indemnity amounts in the following sections. However, the data range for AMS outputs and NDVI values were limited so the correlation coefficients might be superior for this study. For this reason, the panel data analysis was also considered to identify the real effects of index variables on the wheat yield.

Contrary to the higher correlation power of AMS outputs and its combination with NDVI values, $SPI'3$ values and precipitation amounts were not so correlated with the wheat yield in April, May and June. Even if the data range was large enough, the results did not meet our expectations. The first reason for this unsatisfactory conclusion can be related to missing data for $SPI'3$ values and precipitation amounts at some weather stations. As a second reason, the spatially interpolated mean value of these values for each province might be inadequate to explore the correct relationship with the wheat yield.

The most important part then, before going further for insurance design, the feasibility of linear regression modelling should be interpreted carefully. The assumptions of the ordinary least squares (OLS) method cannot be violated, i.e. there must be no outliers and the variance of error terms must be constant (homoscedastic variables). On the other hand, for some provinces, when the residual versus fitted values plots were considered, there seems to be some abnormal points. However, these abnormalities cannot be detected as whether it is an outlier or random error because of the limited data size in this study. Moreover, there might be some possible heteroscedasticity and some points could be influential on the regression results. To overcome these important problems, alternative regression models might be used instead of usual Ordinary Least Square (OLS) method. For instance, Tobit Regression fit might be more suitable for the province Sivas because of the dispersion of data points. However, such problems were not studied yet in this study. Certainly, such problems should be solved carefully to increase the efficiency of the index based insurance products for future works.

## 3.3 Panel Data Analysis Approach

### 3.3.1 A Short Overview

In this section, the repeated cross sectional time-series of logyield versus alternative index variables were analyzed for Central Anatolia region because of the limited data set. The primary reason for the choice of panel data analysis was to interpret the causal effects of index variables on wheat yield. Surely, panel data analysis endows regression analysis with both a spatial and temporal dimension [14]. On this account, the usage of this method while studying the behavior of the wheat yield can be beneficial for reducing basis risk for the implementation of drought insurance.

As a brief introduction, general benefits of panel data approach can be listed as follows [12].

- Estimations of this method is more accurate since it permits multicollinearity and autocorrelation lesser, variability and degrees of freedom more.
- It is capable of taking into account of certain individual heterogeneities while giving information about events.
- It allows for econometric analysis when there are short and inadequate time series.
- This method provides estimations with controlled individual unobserved heterogeneity.

Table 3.22: Panel Data Set Structure

| Province | Year | logyield | $WDEF_r$ | $ETA_r$ |
|---|---|---|---|---|
| Ankara | 1991 | 0.895 | 26 | 126.7 |
| Ankara | 1992 | 0.388 | 80.5 | 76.5 |
| . | . | . | . | . |
| . | . | . | . | . |
| Ankara | 2006 | 0.825 | 78 | 87.4 |
| Çankırı | 1991 | 0.661 | 8 | 138 |
| Çankırı | 1992 | 0.032 | 40.7 | 101 |
| . | . | . | . | . |
| . | . | . | . | . |
| Çankırı | 2006 | 0.532 | 109.7 | 59.7 |
| . | . | . | . | . |
| . | . | . | . | . |
| Yozgat | 2006 | 0.691 | 56 | 107.3 |

The last benefit is especially useful because of the fact that unobserved heterogeneity is the biggest problem of non-experimental research [12].

In this study, linear panel models were studied to understand the behaviour of the wheat yield series of provinces over time as repeated observations. The alternative index variables in Table 3.10 in 3.2.2 were selected to study their effects on the wheat yield. The panel data set was balanced since it was a set of collection of 10 provinces with same weather parameters collected for 16 years annually, i. e. it was pooled data that includes 160 observations without any missing values. Generally, panel data structure defined by the following sequential blocks of data in literature.

The well known types of panel models are Fixed Effects (FE) and Random Effects (RE) model. These different models are basically linear panel estimations for the outcome variable by using a set of explanatory variables. They are used to explore the relationship between the predictor and the response variable within an entity [20]. These models were considered while analyzing the effects of variables that are changing over time. Linear panel regressions based on similar assumptions almost but they use different individual effects modelling. The more precisely, these models differ in how they captured the unobserved heterogeneity of individuals.

The fixed effect (FE) model assumes that the individual effect is captured by only intercept term in the linear panel model. In other words, while analyzing how predictor variables influence the response variable, individual characteristics are explained by its own intercepts with the constant slope coefficients. It is also called as the Least Square Dummy Variable estimator (LSDV) since it assigns a dummy variable for each individual in the model. Moreover, it is beneficial for the predictor's net effect since it removes time-invariant properties of every individual. In general, the fixed effect model has an equation;

$$Y_{it} = \beta.X_{it} + \alpha_i + \epsilon_{it}, \epsilon_{it} = \mu_i + v_{it}, and \mu_i = 0 \tag{3.5}$$

where $\alpha_i$ is the unknown intercept for each entity, $Y_{it}$ represents the outcome value, $X_{it}$ is the predictor variables, $\beta$ is the coefficient of $X_{it}$ and $\epsilon_{it}$ is the error term for the given model.

There is an important restriction for the FE models. There must be some changes in $X_{it}$ to identify the effect of given predictors on the variation of response variable. Namely, if only few observations represent changes in $X_{it}$ it makes difficult to estimate the outcome [12]. In this study, among the most correlated predictors, $WDEF_f$, $WDEF_f/vert$ and $WDEF_f/pval$ variables have very small variations and most of the time their values are 0. These predictors were not used for panel analysis because of their impractical observed values.

Unlike the Fixed Effect (FE) model estimation, the logic behind the Random Effect (RE) models is that the individual heterogeneity is identified by the its own intercept and a random component. It has an advantage that the effect of time invariant factors can be considered in RE models, absorbed by the intercept values in FE models. The equation 3.6 represents the Random Effect (RE) estimation method basically [20].

$$Y_{it} = \beta_i.X_{it} + \alpha + \epsilon_{it}, \epsilon_{it} = \mu_i + v_{it}, \tag{3.6}$$

where $\alpha$ is the constant intercept for each entity, $Y_{it}$ represents the outcome value, $X_{it}$ is the predictor variables, $\beta_i$ is the coefficient of $X_{it}$, $\mu_i$ is the entity-specific error and $v_{it}$ is the idiosyncratic error.

Actually, $\mu_i$ is the same for both models, it captures the individual effects. However, it is assumed to be fixed in the FE models whereas it is stochastic and distributed in the RE models. Similarly, individual characteristic are not correlated with the error term but with the regressor in the FE models and vice versa for RE models. The following graphs 3.11, 3.12 and 3.13 basically represent the differences between the models stated above.

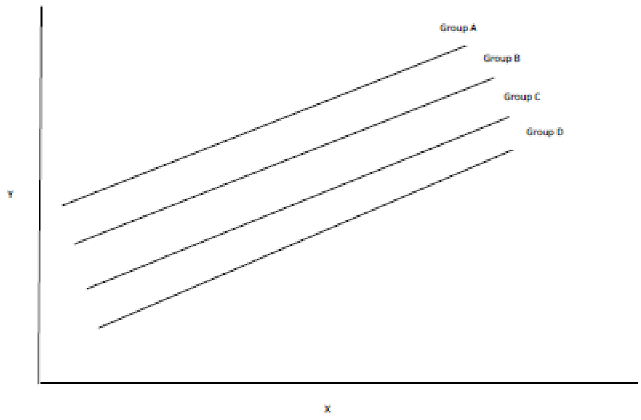



Figure 3.11: Varying Intercept Models

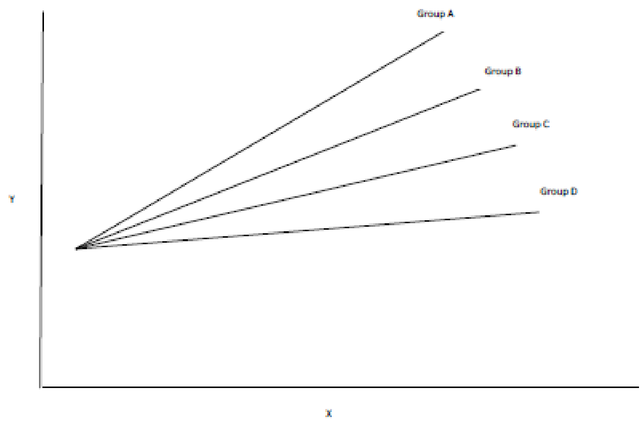



Figure 3.12: Varying Slope Models

In this pilot study, these important techniques of panel data analysis were used to observe the casual impacts of our independent variables on the wheat yield. By using these different

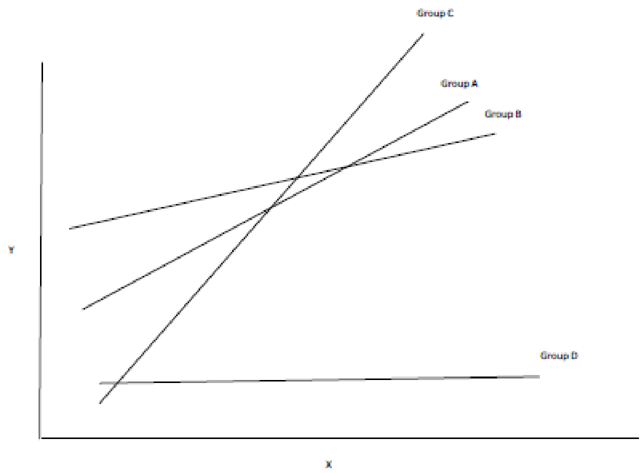



Figure 3.13: Varying Slope and Intercept Models

models, alternative wheat yield estimators were derived for provinces in Central Anatolia Region. These obtained linear models will be also used to design insurance contracts for this region.

### 3.3.2 FE and RE Estimation Results

In this study, the FE and RE models with one predictor variable were used to get wheat yield prediction equations. Since the explanatory variable data set were composed of AMS outputs and its derivatives, there exists multicollinearity problem related to these predictors. For this reason, the usage of multiple panel regression under FE and RE models were not meaningful. The comparison for FE and RE models were investigated in R by using the lmer function contained in the lme4 package. FE with individual intercept models and RE with individual intercept and slope models were compared and the best model was selected for each province. Finally, alternative linear equations were derived for the wheat yield prediction for each province under panel data approach. R-code for linear panel model fitting and the output example for a predictor variable was listed in Appendix B.

According to the results of linear panel model fitting, the value of the correlation of FE model gives the collinearity between the explanatory variables and error terms. When this value is higher than especially 0.8 or less than -0.8, there might be multicollinearity problem in the the linear model. Besides this correlation, t-value for the intercepts and predictors should lie outside of the interval (-1.96 , 1.96) for the significance of the coefficient of parameters. Moreover, anova test between these two specified models identify the significance of the random coefficients for the predictor variables in the individual intercept and slope RE model. If the Pr(>Chisq) > 0.05 ( % 95 Confidence interval) it fails to reject the null hypothesis, $H_0$ = The coefficients of extra parameter are all zero. In other words, adding random slopes in the model resulted in small variations in the response variable, this means that FE with individual intercept models should be preferred. The following Table 3.23 summarizes the results of these values for each index variable.

Table 3.23: Important Parameters for the model selection

| | Correlation of index | | t-value | | Anova Test |
|---|---|---|---|---|---|
| Index Measure | FE model | RE model | FE model | RE model | Prob(>Chisq) |
| $WDEF_r$ | -0.412 | -0.009 | -7.36 | -6.662 | 0.3697 |
| $WDEF_t$ | -0.381 | -0.011 | -8.337 | -7.569 | 0.4389 |
| $ETA_r$ | -0.593 | -0.848 | 7.219 | 6.353 | 0.2871 |
| $ETA_t$ | -0.906 | -0.927 | 7.588 | 7.255 | 0.8879 |
| $WSI_h$ | -0.871 | -0.932 | 8.328 | 7.663 | 0.4751 |
| $eval$ | -0.790 | -0.740 | -0884 | -0.862 | 0.6355 |
| $pval$ | -0.960 | -0.976 | 3.411 | 2.173 | 0.2716 |
| $WDEF_r/vert$ | -0.375 | -0.109 | -8.341 | -6.574 | 0.2167 |
| $WDEF_t/vert$ | -0.342 | -0.116 | -9.518 | -7.409 | 0.2826 |
| $WDEF_t/eval$ | -0.378 | -0.014 | -8.414 | -7.693 | 0.4843 |
| $WDEF_t/pval$ | -0.367 | -0.110 | -9.03 | -7.886 | 0.5582 |
| $ETA_r/eval$ | -0.615 | -0.893 | 6.621 | 5.466 | 0.1245 |

The results of Table 3.23 show that the coefficients of all parameters apart from *eval* value were significant for both models. However, the variables $ETA_t$, $WSI_h$ and *pval* had multi-collinearity problems for both models so these predictors were not used for the wheat yield modelling under panel approach. Furthermore, anova test results implied that random slope models are not necessary since the coefficients of extra parameters were not significant in the model for all index variables. In other words, most random slopes for predictor parameters are almost zero while the intercepts are varying from one province to another. For this reason, FE with individual intercept models were used to derive alternative estimations for provinces.

The following Tables 3.24 and 3.25 shows the estimation for the FE with province-specific intercept models for all predictor variables to describe the wheat yield.

Table 3.24: Panel model results for each province (1)

| Coefficient | Provinces | | | | |
|---|---|---|---|---|---|
| Estimations | Ankara | Çankırı | Eskişehir | Kayseri | Kırşehir |
| $WDEF_r$ | -0.0017988 | -0.0017988 | -0.0017988 | -0.0017988 | -0.0017988 |
| Intercept | 0.8481 | 0.7150 | 0.9305 | 0.7278 | 0.8309 |
| $WDEF_t$ | -0.0017251 | -0.0017251 | -0.0017251 | -0.0017251 | -0.0017251 |
| Intercept | 0.8568 | 0.7136 | 0.9307 | 0.7361 | 0.8351 |
| $ETA_r$ | 0.0021754 | 0.0021754 | 0.0021754 | 0.0021754 | 0.0021754 |
| Intercept | 0.4891 | 0.3836 | 0.5858 | 0.3825 | 0.4653 |
| $WDEF_r/vert$ | -0.12543 | -0.12543 | -0.12543 | -0.12543 | -0.12543 |
| Intercept | 0.8611 | 0.7047 | 0.9593 | 0.7371 | 0.8459 |
| $WDEF_t/vert$ | -0.11970 | -0.11970 | -0.11970 | -0.11970 | -0.11970 |
| Intercept | 0.8693 | 0.7029 | 0.9580 | 0.7449 | 0.8488 |
| $WDEF_t/eval$ | -0.17634 | -0.17634 | -0.17634 | -0.17634 | -0.17634 |
| Intercept | 0.8601 | 0.7063 | 0.9239 | 0.7400 | 0.8314 |
| $WDEF_t/pval$ | -0.24723 | -0.24723 | -0.24723 | -0.24723 | -0.24723 |
| Intercept | 0.8620 | 0.7093 | 0.9366 | 0.7523 | 0.8387 |
| $ETA_r/eval$ | 0.21690 | 0.21690 | 0.21690 | 0.21690 | 0.21690 |
| Intercept | 0.4962 | 0.4114 | 0.5990 | 0.3779 | 0.4745 |

Table 3.25: Panel model results for each province (2)

| Coefficient | Provinces | | | | |
|---|---|---|---|---|---|
| Estimations | Konya | Nevşehir | Niğde | Sivas | Yozgat |
| $WDEF_r$ | -0.0017988 | -0.0017988 | -0.0017988 | -0.0017988 | -0.0017988 |
| Intercept | 0.8134 | 0.7684 | 0.7978 | 0.4858 | 0.6797 |
| $WDEF_t$ | -0.0017251 | -0.0017251 | -0.0017251 | -0.0017251 | -0.0017251 |
| Intercept | 0.8285 | 0.7687 | 0.8045 | 0.4891 | 0.6816 |
| $ETA_r$ | 0.0021754 | 0.0021754 | 0.0021754 | 0.0021754 | 0.0021754 |
| Intercept | 0.4684 | 0.4539 | 0.4298 | 0.1484 | 0.3627 |
| $WDEF_r/vert$ | -0.12543 | -0.12543 | -0.12543 | -0.12543 | -0.12543 |
| Intercept | 0.8479 | 0.7805 | 0.8710 | 0.4809 | 0.6724 |
| $WDEF_t/vert$ | -0.11970 | -0.11970 | -0.11970 | -0.11970 | -0.11970 |
| Intercept | 0.8642 | 0.7802 | 0.8784 | 0.4838 | 0.6735 |
| $WDEF_t/eval$ | -0.17634 | -0.17634 | -0.17634 | -0.17634 | -0.17634 |
| Intercept | 0.8322 | 0.7743 | 0.8182 | 0.4887 | 0.6774 |
| $WDEF_t/pval$ | -0.24723 | -0.24723 | -0.24723 | -0.24723 | -0.24723 |
| Intercept | 0.8404 | 0.7760 | 0.8505 | 0.4926 | 0.6781 |
| $ETA_r/eval$ | 0.21690 | 0.21690 | 0.21690 | 0.21690 | 0.21690 |
| Intercept | 0.4697 | 0.4457 | 0.4217 | 0.1586 | 0.3829 |

## 3.4 Index-based Insurance Contract Design

In this section, the weather index based drought insurance contracts for provinces of Central Anatolia Region were modeled based on the relationship between the yield and weather parameters under different approaches made in the previous sections. The indemnity and pure premium calculations were presented here according to the assumed trigger points for each province. Moreover, the basis risk comparison for different insurance contracts were made based on a simple ratio.

### 3.4.1 Wheat Price

In this study, the wheat price belonging to year 2006 was used in the weather index based insurance design for 2007. The average price of durum and other wheat types in 2006 were considered and used for designing a drought insurance contract for 2007.The average wheat price for each province was listed here in Table 3.26.

Table 3.26: Wheat Prices for provinces in 2006

| | Wheat Price (TL/kg) | | |
|---|---|---|---|
| Province | Durum Type | Other Type | Average |
| Ankara | 0,37 | 0,36 | 0,365 |
| Çankırı | 0,38 | 0,35 | 0,365 |
| Eskişehir | 0,36 | 0,35 | 0,355 |
| Kayseri | 0,33 | 0,34 | 0,335 |
| Kırşehir | 0,39 | 0,36 | 0,375 |
| Konya | 0,36 | 0,35 | 0,355 |
| Nevşehir | 0,38 | 0,34 | 0,360 |
| Niğde | 0,39 | 0,37 | 0,380 |
| Sivas | 0,38 | 0,33 | 0,355 |
| Yozgat | 0,37 | 0,35 | 0,360 |

The percentage of the planting area for durum and other wheat type for each province in Central Anatolia was not known exactly. For this reason, the equally weighted average price for year 2006 was calculated in designing the index based insurance contract for 2007.

### 3.4.2 Indemnity Calculation

As it was defined in Function 2.4 in Chapter 2, the indemnity calculation was based on the strike level S for the given index measure and the tick size $\gamma$. Firstly, a trigger point S was set for a selected index variable. To determine this value, the expected or predicted wheat yield value for year 2007 was used relying on past information, i.e. predicted values in section 3.2.1 under different ARIMA processes. Moreover, Linear Regression (LR) and Fixed Effect (FE) models obtained in section 3.2.3 and 3.3.2 were used alternatively for each province. All calculations were exemplified for province Nevşehir and results of remaining provinces were summarized in the Appendix part. Strike level for different index variables was denoted for Nevşehir in Table 3.27.

Table 3.27: Strike Levels for Nevşehir

| | Prediction |
|---|---|
| Index Measure | 2.000 ton/ha |
| $WDEF_r$ | > 41.6207 |
| $ETA_r$ | < 108.9599 |
| $WSI_h$ | < 88.3503 |
| $WDEF_r/vert$ | > 0.6943 |

According to the linear estimation equations, when the absolute value of $WDEF_r$ is more than 41.6207, the wheat yield loss occurs. Similarly, if the absolute value of $WDEF_r/vert$ is more than 0.6943, again the wheat yield loss exists. On the other hand, if $ETA_r$ is less than 108.9599 and $WSI_h$ is less than 88.3503, the wheat yield is dropped below the forecasted values for year 2007 and the farmers receive a payout.

For 2007, the observed values for $WDEF_r$, $ETA_r$, $WSI_h$ and $WDEF_r/vert$ were 42.3, 117.3, 89.3 and 2.2281 respectively. Under the payout structure defined above, the indemnification occurs except $ETA_r$ and $WSI_h$. The table 3.28 below summarizes the wheat yield loss based on strike levels for different index variables.

In a similar way, FE with individual intercept linear models obtained in section 3.3.2 was also used to derive different insurance contracts. The strike levels and indemnification schedule were prepared by using these equations too. For example, the Table 3.29 below summarizes these results for Nevşehir.

Table 3.28: Indemnification scheme for Nevşehir in 2007

| Index Measure | Prediction 2.000 ton/ha |
|---|---|
| $WDEF_r$ | Payout |
| $ETA_r$ | No Payout |
| $WSI_h$ | No Payout |
| $WDEF_r/vert$ | Payout |

Table 3.29: Strike Level and Indemnification under FE model for Nevşehir

| | Prediction 2.000 ton/ha | |
|---|---|---|
| Index Measure | Strike Level | Indemnity |
| $WDEF_r$ | > 41.8350 | YES |
| $WDEF_t$ | > 43.7692 | NO |
| $ETA_r$ | < 109.9785 | NO |
| $WDEF_r/vert$ | > 0.6964 | YES |
| $WDEF_t/vert$ | > 0.7273 | YES |
| $WDEF_t/eval$ | > 0.4602 | YES |
| $WDEF_t/pval$ | > 0.3351 | YES |
| $ETA_r/eval$ | < 1.1408 | NO |

In 2007, the observed values for $WDEF_r$, $WDEF_t$, $ETA_r$, $WDEF_r/vert$, $WDEF_t/vert$, $WDEF_t/eval$, $WDEF_t/pval$ and $ETA_r/eval$ were 42.3, 42.3, 117.3, 2.2281, 2.2281, 0.9845, 0.6414 and 2.7287 respectively. Under the payout structure defined above, the indemnification occurs at least one time for all index measures apart from $ETA_r/eval$. Strike level calculations for other provinces were indicated in Appendix C.

By using these strike levels for different index variables, the indemnity calculation was made according to the function 2.4 in chapter 2. The tick size $\gamma$ was obtained by using simulation method. Firstly, it is assumed that the values of index variables in 2007 were unknown. Afterwards, a suitable distribution to each index variable was fitted for each province. Particularly, Generalized Extreme Value (GEV) is the most suitable distribution for the selected index variables. Afterwards, random numbers for index variables were generated according to fitted distribution and the differences between the strike levels and the produced index variable were calculated. Moreover, the corresponding wheat yield was compared with the forecasted wheat yield value for 2007 and possible yield loss for 2007 was obtained. For these calculations, the size of 1000000 random index variables were generated. Finally, the thick size value was derived as a ratio of the average yield loss and the average variation from the strike level for the selected index variable. The simple Matlab-code for thick size calculation by simulation method was reported in Appendix D.

The Table 3.30 stated the final indemnity amount function under different index-based insurance contracts for Nevşehir.

Table 3.30: Indemnity amount functions for Nevşehir

| Index Measure | FE Panel model | LR model |
|---|---|---|
| $WDEF_r$ | 0.936*max((X-41.8350),0) | 1.152*max((X-41.6207),0) |
| $WDEF_t$ | 0.864*max((X-43.7962),0) | - |
| $ETA_r$ | 1.476*max((109.9785-X),0) | 1.656*max((108.9599-X),0) |
| $WDEF_r/vert$ | 62.388*max((X-0.6964),0) | 66.564*max((X-0.6943),0) |
| $WDEF_t/vert$ | 57.852*max((X-0.7273),0) | - |
| $WDEF_t/eval$ | 85.176*max((X-0.4602),0) | - |
| $WDEF_t/pval$ | 116.712*max((X-0.3351),0) | - |
| $ETA_r/eval$ | 52.236*max((1.1408-X),0) | - |
| $WSI_h$ | - | 5.616*max((88.3503-X),0) |

Certainly, the strike level S can be set as different values in the policy design to satisfy different coverage demands of farmers. For instance, if the farmers are risk taker they will buy insurance product when there exists a severe reduction on the wheat yield. In other words, the strike level can be calculated when the wheat yield loss is deceased below a certain high level. Under such insurance schemes, farmers pay lower premiums whereas they must bear some wheat yield risk individually. For this reason, the strike level S needs to be decided carefully according to the farmers behaviour before underwriting the contract. In this study, it is assumed that all farmers are potential risk averse clients. The strike level of different policies were based on the wheat yield reduction from the forecasted yield for 2007.

For 2007, the indemnification amount for Nevşehir was calculated by using simple functions in Table 3.30. For instance, when $WDEF_r/vert$ ratio is higher than the value 0.694 under LR model, then the farmers will get payout for this year. The observed value of $WDEF_r/vert$ is 2.228 in 2007 so indemnification occurs and the insured farmer receives ;

$$I(2.228) = (66.564TL/ha) \times ((2.228 - 0.694), 0) = 66.564 \times (1.534) = 102.096TL/ha \quad (3.7)$$

The indemnity payment can be summarized by the following Table 3.31 for Nevşehir under different insurance contracts.

Table 3.31: Indemnity amount for Nevşehir

| | Indemnity Amount (TL/ha) | |
|---|---|---|
| Index Measure | LR model | FE model |
| $WDEF_r$ | 0.783 | 0.435 |
| $WDEF_t$ | - | 0 |
| $ETA_r$ | 0 | 0 |
| $WDEF_r/vert$ | 102.096 | 95.560 |
| $WDEF_t/vert$ | - | 86.824 |
| $WDEF_t/eval$ | - | 44.658 |
| $WDEF_t/pval$ | - | 35.749 |
| $ETA_r/eval$ | - | 0 |
| $WSI_h$ | 0 | - |

The results implied that FE models were better than the LR linear models with for all predictors except $WDEF_r$ and $WDEF_r/vert$. Moreover, the generated drought indicator $WDEF_r/vert$ were seemed to be succeeded in covering some part of the expected wheat yield income loss 199.800 TL/ha.

By using the same rationale behind these calculations, the indemnity amount functions for all provinces were also derived under linear regression (LR) and (FE) panel models. The detailed calculations were summarized in Appendix E. Moreover, the payout schemes for other provinces were tabulated in detail in Appendix F.

### 3.4.3 Pure Premium

In Chapter 2, the Function 2.3 defined the pure premium, given as the sum of indemnity occurred in our past data times the probability of its occurrence. LR and FE estimation equations were used to calculate the pure premium under different index variable selections. If the predicted wheat yield exceeded the actual wheat yield value, there was no yield loss i. e. the annual yield loss was set to value 0. On the other hand, some yield loss arose when the wheat yield estimation was fallen below the observed wheat yield. For example, the following Tables 3.32-3.35 represent the detailed calculations for pure premium amount for the province Nevşehir according to the distinct index variable. The abbreviations AWY, PWY and AYL represent actual wheat yield, predicted wheat yield and annual yield loss respectively in Tables 3.32-3.35.

Table 3.32: AYL calculation for Nevşehir under $WDEF_r$

| Year | $WDEF_r$ | AWY(ton/ha) | PWY(ton/ha) | AYL(ton/ha) |
|---|---|---|---|---|
| 1991 | 16 | 1.873 | 2.119 | 0 |
| 1992 | 3.5 | 2.284 | 2.180 | 0.104 |
| 1993 | 0 | 2.141 | 2.198 | 0 |
| 1994 | 131.5 | 1.643 | 1.631 | 0.012 |
| 1995 | 0 | 1.991 | 2.198 | 0 |
| 1996 | 57.333 | 2.010 | 1.930 | 0.080 |
| 1997 | 10.667 | 2.025 | 2.145 | 0 |
| 1998 | 0 | 2.494 | 2.198 | 0.296 |
| 1999 | 34.333 | 1.886 | 2.033 | 0 |
| 2000 | 13.667 | 2.210 | 2.131 | 0.079 |
| 2001 | 100 | 1.560 | 1.752 | 0 |
| 2002 | 31 | 2.019 | 2.049 | 0 |
| 2003 | 89.333 | 1.831 | 1.795 | 0.036 |
| 2004 | 60.667 | 2.033 | 1.915 | 0.118 |
| 2005 | 46.333 | 2.169 | 1.979 | 0.190 |
| 2006 | 44 | 2.162 | 1.989 | 0.173 |
| Average | 2.021 | | 2.015 | **0.068** |

Table 3.33: AYL calculation for Nevşehir under $ETA_r$

| Year | $ETA_r$ | AWY(ton/ha) | PWY(ton/ha) | AYL(ton/ha) |
|---|---|---|---|---|
| 1991 | 130 | 1.873 | 2.107 | 0 |
| 1992 | 142 | 2.284 | 2.171 | 0.113 |
| 1993 | 147 | 2.141 | 2.198 | 0 |
| 1994 | 52 | 1.643 | 1.736 | 0 |
| 1995 | 165 | 1.991 | 2.299 | 0 |
| 1996 | 93 | 2.010 | 1.922 | 0.088 |
| 1997 | 128.333 | 2.025 | 2.099 | 0 |
| 1998 | 138.667 | 2.494 | 2.153 | 0.341 |
| 1999 | 102.667 | 1.886 | 1.969 | 0 |
| 2000 | 123.667 | 2.210 | 2.074 | 0.136 |
| 2001 | 62.667 | 1.560 | 1.783 | 0 |
| 2002 | 116.333 | 2.019 | 2.037 | 0 |
| 2003 | 61.667 | 1.831 | 1.778 | 0.053 |
| 2004 | 86.333 | 2.033 | 1.891 | 0.142 |
| 2005 | 98.667 | 2.169 | 1.949 | 0.220 |
| 2006 | 120.667 | 2.162 | 2.059 | 0.103 |
| Average | 110.542 | 2.021 | 2.014 | **0.075** |

Table 3.34: AYL calculation for Nevşehir under $WSI_h$

| Year | $WSI_h$ | AWY(ton/ha) | PWY(ton/ha) | AYL(ton/ha) |
|---|---|---|---|---|
| 1991 | 99.5 | 1.873 | 2.122 | 0 |
| 1992 | 99 | 2.284 | 2.185 | 0.099 |
| 1993 | 100 | 2.141 | 2.203 | 0 |
| 1994 | 65 | 1.643 | 1.647 | 0 |
| 1995 | 100 | 1.991 | 2.203 | 0 |
| 1996 | 84.333 | 2.010 | 1.934 | 0.076 |
| 1997 | 96.333 | 2.025 | 2.137 | 0 |
| 1998 | 100 | 2.494 | 2.203 | 0.291 |
| 1999 | 91 | 1.886 | 2.044 | 0 |
| 2000 | 96.333 | 2.210 | 2.137 | 0.073 |
| 2001 | 71 | 1.560 | 1.731 | 0 |
| 2002 | 90 | 2.019 | 2.027 | 0 |
| 2003 | 75.667 | 1.831 | 1.800 | 0.031 |
| 2004 | 84 | 2.033 | 1.929 | 0.104 |
| 2005 | 85 | 2.169 | 1.945 | 0.224 |
| 2006 | 88 | 2.162 | 1.994 | 0.168 |
| Average | 88.823 | 2.021 | 2.015 | **0.067** |

Table 3.35: AYL calculation for Nevşehir under $WDEF_r/vert$

| Year | $WDEF_r/vert$ | AWY(ton/ha) | PWY(ton/ha) | AYL(ton/ha) |
|---|---|---|---|---|
| 1991 | 0.291 | 1.873 | 2.113 | 0 |
| 1992 | 0.081 | 2.284 | 2.174 | 0.110 |
| 1993 | 0.000 | 2.141 | 2.198 | 0 |
| 1994 | 2.156 | 1.643 | 1.639 | 0.004 |
| 1995 | 0.000 | 1.991 | 2.198 | 0 |
| 1996 | 1.274 | 2.010 | 1.848 | 0.162 |
| 1997 | 0.227 | 2.025 | 2.131 | 0 |
| 1998 | 0.000 | 2.494 | 2.198 | 0.296 |
| 1999 | 0.520 | 1.886 | 2.048 | 0 |
| 2000 | 0.180 | 2.210 | 2.145 | 0.065 |
| 2001 | 1.786 | 1.560 | 1.724 | 0 |
| 2002 | 0.492 | 2.019 | 2.056 | 0 |
| 2003 | 1.276 | 1.831 | 1.847 | 0 |
| 2004 | 1.028 | 2.033 | 1.911 | 0.122 |
| 2005 | 0.692 | 2.169 | 2.001 | 0.168 |
| 2006 | 0.647 | 2.162 | 2.013 | 0.149 |
| Average | 0.666 | 2.021 | 2.015 | **0.067** |

Now, the following pure premium results were obtanied for Nevşehir shown in Table 3.36

Table 3.36: Pure Premium under LR models for Nevşehir

| | $WDEF_r$ | $ETA_r$ | $WSI_h$ | $WDEF_r/vert$ |
|---|---|---|---|---|
| Expected Annual Yield Loss (ton/ha) | 0.068 | 0.075 | 0.067 | 0.067 |
| Pure Premium (TL/ha) | 24,480 | 27 | 24,120 | 24,120 |

The above computations were made by using the linear regression equations for the selected province. Besides these results, the FE with individual intercept linear panel models were also used to construct alternative insurance products. Moreover, the similar calculation method was used and corresponding pure premium amount were derived for other provinces. The results of the expected annual yield loss amount and the corresponding pure premium belonging to different index variables were summarized in Appendix F.

### 3.4.4 Basis Risk Comparison

In this study, a simple parameter was developed to compare the basis risk of distinct index based insurance policies against the drought. The following ratio in equation (3.8) was defined to test the basis risk performance of different insurance contracts that already designed in previous sections.

$$\text{Basis Risk Reduction Power} = BRRP = I(X)/ELOP \tag{3.8}$$

where I(X) represents the any payout under constructed insurance policy and ELOP is the expected provincial wheat yield loss for given year. For simplicity, ELOP was calculated as a multiplication of the wheat price and the difference of forecasted and observed wheat yield for year 2007. If the BRRP = 0 , which means that the insurance policy produces the maximum basis risk, i. e. there is no indemnity payment even if the policyholder faced with an income loss. On the other hand, if the BRRP = 1 then the constructed insurance policy is accomplished at the covering of all possible income loss. Whenever BRRP $\rightarrow \infty$, it means that the clients already get payment whereas there was no expected wheat yield reduction. According to this straightforward calculation, when the value of BRRP is close enough or equal to value 1, it is interpreted as the lower basis risk for the given insurance contract.

For year 2007, the predicted wheat yield is 2.000 ton/ha under ARIMA(2,1,0) model. This forecasted value were compared with the actual or reported wheat yield 1.445 ton/ha to calculate the ELOP value. As it was defined above,

$$ELOP = WheatPrice.max((FWY - OWY), 0) \tag{3.9}$$

where FWY and OWY represents the forecasted and observed wheat yield in 2007.

For ARIMA(2,1,0);

$$ELOP = 360TL/ton.max((2.000 - 1.445), 0) = 199.800TL/ha \tag{3.10}$$

Afterwards, the basis risk reduction power (BRRP) was computed by the formula (3.8) for different insurance contracts. The comparison of BBRP values were made under different index-based insurance contracts. Consequently, the index based insurance contract with the lowest BRRP values was selected as a final insurance decision for each province. The following Table 3.37 demonstrates the BRRP values of each insurance policy for Nevşehir.

Table 3.37: BRRP values for Nevşehir

| Index Measure | LR model | FE model |
|---|---|---|
| $WDEF_r$ | 0.004 | 0.002 |
| $WDEF_t$ | - | 0 |
| $ETA_r$ | 0 | 0 |
| $WDEF_r/vert$ | **0.511** | 0.478 |
| $WDEF_t/vert$ | - | 0.435 |
| $WDEF_t/eval$ | - | 0.224 |
| $WDEF_t/pval$ | - | 0.179 |
| $ETA_r/eval$ | - | 0 |
| $WSI_h$ | 0 | - |

Considering the results of Table 3.37, the best insurance policy were constructed by simple linear regression model with $WDEF_r/vert$ as an weather-index variable for Nevşehir. The indemnity schedule with respect to the predictor $WDEF_r/vert$ was succeeded to cover almost 50 % of the expected wheat yield loss in 2007. The best BRRP value for other provinces were reported in Appendix F.

### 3.4.5 Risk Premium

As it was mentioned above, the pure premium was considered while designing any insurance contract. However, there exists always a risk loading factor which defines risk of the misspecification comes from the uncertainty of the selected index variable in the insurance design. If this risk is not bearable by the insurer, there is an additional risk premium written on insurance policy to share this risk with the potential clients.

To illustrate the importance of risk premium, the annual expected wheat yield loss was calculated under LR model with the predictor coefficient varying within $\mp\sigma$ for some provinces of Central Anatolia. When the coefficient of the intercept are significant for Ankara, Kırşehir, Nevşehir, Niğde, Sivas and Yozgat then it was supposed to be fixed in linear models. Thus, the average annual yield loss was computed with varying predictor coefficient within $\mp\sigma$ for the selected strike level of each insurance product. The variation on the yield loss are represented by Table 3.38 for all provinces according to the best weather-based policy decision in the previous section.

The results in Table 3.38 shows that, when the regressor parameter or the coefficient of predictor varies within $\mp\sigma$, the average annual yield loss resulted in so much deviation. Especially for Ankara and Niğde, there exists higher variations on the percentage of the average yield loss. In other words, the higher changes in the percentage of average annual yield loss equals to the higher changes in the pure premium amount. For this reason, the insurer must carefully decide whether sharing with insured farmers or bearing individually this risk loading of loss coming from the uncertainty of predictor parameter in the selected models. Definitely, the coefficient $\lambda$ should be computed rigorously in formula 2.2. This selection must be studied by insurance companies to apply these models in the market efficiently. Besides the calculation of risk premium, the loss ratio (indemnity over premium) for index-based insurance policies should be considered to understand the actuarial performance.

### 3.4.6 2007 Drought results

A comparison between the average drought support per individual and the indemnity payment amount under the best insurance contract can be made roughly in 2007. The individual farmland area was not known exactly for each province so the average support was used for comparison. The following table 3.39 summarizes the results of this basic comparison.

The results of table 3.39 indicates that the indemnity amounts for provinces lower than the average drought support payments. The indemnification schedule of index-based insurance policies seemed to be nonfactual by taking account of support payments did not cover yield loss as a whole. Nonetheless, this comparison should be improved by using more quality farmland data to derive more reliable results.

Table 3.38: The yield loss variation for provinces

| | | Coeff. parameter | Coeff. parameter + $\sigma$ | Coeff. parameter - $\sigma$ |
|---|---|---|---|---|
| Ankara | Average Annual Yield Loss (ton/ha) | 0.087 | 0.043 | 0.144 |
| | % Change in Annual Yield Loss | | -50.6 % | 65.5 % |
| Kırşehir | Average Annual Yield Loss (ton/ha) | 0.101 | 0.082 | 0.122 |
| | % Change in Annual Yield Loss | | -18.8 % | 20.8 % |
| Nevşehir | Average Annual Yield Loss (ton/ha) | 0.067 | 0.052 | 0.091 |
| | % Change in Annual Yield Loss | | -22.4 % | 35.8 % |
| Niğde | Average Annual Yield Loss (ton/ha) | 0.059 | 0.014 | 0.131 |
| | % Change in Annual Yield Loss | | -76.3 % | 122 % |
| Sivas | Average Annual Yield Loss (ton/ha) | 0.048 | 0.040 | 0.058 |
| | % Change in Annual Yield Loss | | -16.7 % | 20.8 % |
| Yozgat | Average Annual Yield Loss (ton/ha) | 0.117 | 0.112 | 0.124 |
| | % Change in Annual Yield Loss | | -4.3 % | 6 % |

Table 3.39: Comparison of drought support and indemnity amount

| | Under index-based insurance contract | | | |
|---|---|---|---|---|
| Province | # of farmers | average drought support (TL/individual) | pure premium (TL/ha) | Indemnity (TL/ha) |
| Ankara | 42.450 | 897.684 | 31.755 | 384.487 |
| Kırşehir | 20.410 | 549.370 | 38.011 | 180.459 |
| Konya | 62.446 | 823.086 | 35.252 | 282.735 |
| Nevşehir | 18.505 | 743.285 | 24.120 | 114.833 |
| Niğde | 3.212 | 385.151 | 22.230 | 259.709 |
| Sivas | 19.191 | 420.921 | 17.169 | 72.250 |
| Yozgat | 40.897 | 510.257 | 42.124 | 175.703 |

### 3.4.7 Discussions

The simple index-based insurance design for province of Central Anatolia finally finished. Certainly, these basic models must be improved by more detailed actuarial calculations before underwriting in the market. The results of this pilot study can be maintained to develop more efficient and realistic insurance products for the real market. There are various points to be considered extensively to obtain more reliable index-based policies.

Firstly, the more sophisticated wheat yield forecasting should be studied for more feasible insurance design. For instance, the non-linear time series models can be used for wheat yield modelling. Threshold Autoregressive (TAR) method can be used for modelling the increasing and the stationary subpart of the original logyield series for some provinces. Furthermore, structural dynamic modelling can be efficient alternatives by using some important parameters as exogeneous variables such as wheat import in the prediction model. Besides, the stationarity can be considered with structural break based on Chow test. Indeed, there are lots of modelling techniques to estimate the next year's wheat yield before designing insurance policy.

As it was discussed before, the linear regression and linear panel models should be improved to increase the efficiency of the insurance products. These methods are easy to interpret the results, but more complicated estimation equations describe the wheat yield better. Firstly, the robust regression option should be considered to solve the possible heteroscedasticity problems of linear regression equations. Moreover, there are lots of regression methods that can be used to derive wheat yield estimation equations for insurance design.

In this study, a simple ratio was generated to test the basis risk performance of different index-based policies. However, the basis risk detection and reduction deserves more detailed calculations. Since it is the most important disadvantage of the index-based insurance product, the further studies should be concentrated on the reduction of basis risk of the product effectively. Besides this, pure premium calculation made under the assumption of identical weather conditions and its relationship with the wheat yield for 2007 what happened in the past. Nevertheless, the time range of data set very short and there can be some trend in the variation of selected index variables caused by other factors. These troubles should be figured out to design more real index-based insurance contracts against droughts.

# CHAPTER 4

# CONCLUSIONS AND DISCUSSIONS

## 4.1 Results and Conclusions

The weather-index based drought insurance modelling was finished for provinces for Central Anatolia. The wheat yield data was first detrended to remove any time trend for all provinces and the wheat yield in 2007 was predicted by using ARIMA processes. Then, the correlation power of index variables were conducted to obtain alternative predictors for the wheat yield for each province. The relationship between the index variables and the wheat yield were identified by linear regression (LR) and linear FE panel models. Afterwards, the premium and indemnity amount calculations were made under different weather-yield models and simple basis risk comparison were made among these insurance contracts. The one-year insurance product selection were listed by Table 4.1 for provinces of Central Anatolia.

For Ankara, $WDEF_r/vert$ was used as an index variable to design insurance product against drought. It was succeeded to cover almost all the expected wheat yield loss since BRRP=0.939. This insurance model can be improved to derive more efficient and feasible insurance products by further analysis.

For Çankırı, there was no appropriate index variable to design insurance product against drought. It was failed to cover any percentage of the expected wheat yield loss since all BRRP $\approx 0$. This problem should be studied carefully to implement any index-based insurance for this province.

For Eskişehir, there was no appropriate index variable to design insurance product against drought. It was failed to cover any percentage of the expected wheat yield loss since BRRP=0 i. e. there is no indemnity under these products even if the wheat yield loss occurs. This problem should be studied carefully to implement any index-based insurance for this province.

For Kayseri, there was no appropriate index variable to design insurance against drought. The indemnity occurs whereas there was no expected wheat yield loss for 2007 i. e. BRRP $\rightarrow \infty$. This problem should be studied carefully to implement any index-based insurance for this province.

For Kırşehir, $WDEF_r/vert$ was used as an index variable to design insurance product against drought. It was succeeded to cover nearly 50 % of the expected wheat yield loss since BRRP=0.629. This insurance model can be improved to derive more efficient and feasible insurance products by further analysis.

For Konya, $WSI_h$ was used as an index variable to design insurance product against drought. It was succeeded to cover almost all the expected wheat yield loss since BRRP=1.008. This insurance model can be improved to derive more efficient and feasible insurance products by further analysis.

For Nevşehir, $WDEF_r/vert$ was used as an index variable to design insurance product against drought. It was succeeded to cover nearly 50 % of the expected wheat yield loss since BRRP=0.511. This insurance model can be improved to derive more efficient and feasible insurance products by further analysis.

For Niğde, $WDEF_t/pval$ was used as an index variable to design insurance product against drought. It has higher basis risk rather than other provinces that have, since BRRP=2.697. This problem should be studied carefully to implement any index-based insurance for this province.

For Sivas, $WDEF_t/eval$ was used as an index variable to design insurance product against drought. It was succeeded to cover almost all the expected wheat yield loss since BRRP=1.008. This insurance model can be improved to derive more efficient and feasible insurance products by further analysis.

For Yozgat, $WDEF_t/eval$ was used as an index variable to design insurance product against drought. It was succeeded to cover almost all the expected wheat yield loss since BRRP=1.017. This insurance model can be improved to derive more efficient and feasible insurance products by further analysis.

Table 4.1: Index-based insurance contract design for provinces in Central Anatolia

| Province | Index Variable | Strike Level | Thick Size | Indemnity Function | Indemnity Amount for 2007 | Pure Premium |
|---|---|---|---|---|---|---|
| Ankara | $WDEF_r/vert$ | 0.622 | 165.528 TL/index point | 165.528*max((X-0.622),0) | 384.487 TL/ha | 31.755 TL/ha |
| Kırşehir | $WDEF_r/vert$ | 0.215 | 96.938 TL/index point | 96.938*max((X-0.215),0) | 180.459 TL/ha | 38.011 TL/ha |
| Konya | $WSI_h$ | 91.623 | 11.999 TL/index point | 11.999*max((91.623-X),0) | 282.735 TL/ha | 35.252 TL/ha |
| Nevşehir | $WDEF_r/vert$ | 0.694 | 66.564 TL/index point | 66.564*max((X-0.694),0) | 102.096 TL/ha | 24.120 TL/ha |
| Niğde | $WDEF_t/pval$ | 1.523 | 116.964 TL/index point | 116.964*max((X-1.523),0) | 235.753 TL/ha | 22.230 TL/ha |
| Sivas | $WDEF_t/eval$ | 0.449 | 89.460 TL/index point | 89.460*max((X-0.449),0) | 80.183 TL/ha | 17.169 TL/ha |
| Yozgat | $WDEF_t/eval$ | -0.679 | 125.100 TL/index point | 125.100*max((X+0.679),0) | 175.703 TL/ha | 42.124 TL/ha |

## 4.2 Contributions of this Study

This is the first pilot study of index-based insurance design for Turkey. The Central Anatolia region and the wheat crop was selected as location and crop type for implementation of this thesis. Firstly, a wide range of weather index variables were selected and tested for the weather-yield modelling. The more correlated index variables were all used to design alternative insurance contracts for each province. Moreover, the weather-yield modelling was conducted by two different linear models.

Firstly, the results of index-based insurance design emphasized the potential usage of this type of insurance policies for Central Anatolia. In addition, the selected alternative index variables interpreted significant results for some provinces. Especially, the constructed predictors like $WDEF_r/vert$, $WDEF_t/eval$ and $WDEF_t/pval$ have advantages among the others to describe the wheat yield. These ratios offered alternative index-based insurance contracts powerfully.

Secondly, the weather yield modelling constructed under two different ways in this study. The panel linear models were preferred to derive casual effects of predictor measures on the wheat yield and try reducing the basis risk of insurance products. The insurance contract details for Kırşehir, Sivas and Yozgat implied that (FE) linear panel models were successful. However, these models were not as good as the linear regression models for Ankara, Konya, Nevşehir and Niğde. The more reliable prediction equations should be derived to design more feasible index-based insurance contracts.

## 4.3 Problems in this Study

The various problems appeared during the index-based insurance modelling in this study. For this reason, this type of insurance modelling should be enhanced by solving these limitations precisely.

The first and most important problem is the data quality in this pilot study. As it was underlined before, the high quality data set was needed to derive efficient index-based insurance model. Even if the wide range of data set was collected for wheat yield for provinces, the reliability of them still doubtful. The average wheat yield was used for designing insurance products for provinces whereas there was no trusted collection method for these data set. Indeed, to obtain a good quality data set for a big region like Cental Anatolia, there needs to be long term investments to enhance the data collection technique. On the contrary, such an investment can not be implemented by any individual company so the government should take responsibility for the sake of feasible data collecting system. For Central Anatolia, the recently built drought test center in Konya can provide a solution of data collection problem.

Even if the weather data more reliable than the wheat yield data, it does not exist for all weather stations of given province. This missing data leads to inaccurate results for the spatially interpolated mean value of SPI values and rainfall amount for provinces. Thus, the average value for selected province failed to describe the wheat yield in insurance designing. For this reason, all stations with these data was needed to derive more reliable weather index values to model index-based insurance.

In addition to data quality problem, the usage of classical regression for modelling weather-yield relationship has some problems too. When certain assumptions of linear regression is violated, then the results of linear estimation approach might be biased and inconsistent as it was discussed in chapter 3. Moreover, the climate change patterns can lead to variations in the index variables in the future. Due to this fact, historical data for index variables can not be sufficient to predict the future. These problems should be studied further to derive more efficient index-based insurance contracts.

Additionally, one index variable that was most correlated to wheat yield was used for designing insurance product. Nevertheless, the wheat yield can be affected by the interaction of multiple index variables. The insurance product should be design according to this complex relation in such cases, but it is difficult to estimate the efficient insurance model. Recently, there is an upcoming study to predict the wheat yield of 11 different TIGEM farms in Anatolia based on Bayesian estimation. Yıldırak et. al established a prediction function with two predictor variables [29]. They used the ETA and WDEF values in different growth stages for drought based wheat prediction modelling.

Apart from these, the actuarial calculations for insurance pricing should be studied in detail. Especially, risk premium decision deserves careful examining to put these index-based insurance policies in practice. Besides, since it is impossible to eliminate basis risk aroused from insurance products, the insurance models should be designed rigorously.

## 4.4 Proposals for Future Works

- ***Basis Risk***

  The provincial average wheat yield was used for insurance modelling in this study. In other words, all premium and indemnity calculations were made by using this mean wheat yield value for each province. This approach is easy to understand and offers insurance product standardization but it has several basis risks with itself. If the area is reduced to a smaller region then it might offer lower spatial and geographical basis risks for an insurance product. However, this area partitioning leads to practical problems in the insurance design. This dilemma should be solved to increase the accuracy of the index-based insurance modelling. For instance, the smaller farming areas with the same geographical properties, wheat types and cropping seasons might provide reduction of geographical basis risks. The simple clustering methods can be applied to divide Anatolia region as subregions with same meteorological and geographical features. Alternatively, the Geographically Weighted Regression (GWR) methods might be used to mitigate the basis risk of the insurance product.

  Besides these, there are various non-weather related basis risk generators that can affect the wheat yield. These non-weather factors such as the wheat type, the quality of farming laborers, investment in production tools etc should be considered to reduce the basis risk of any product. However, it requires systematic historical data to obtain comprehensive results. An officially created agricultural database system for each province should be considered by the government.

- ***Wheat Pricing***

  Aside from basis risk problem of index-based insurance contracts, the wheat yield forecasting and pricing for the contract needs some improvements to increase the accuracy of results. Since these predictions directly influence the insurance contract design so it needs further studies. Especially, the decision of wheat pricing is a complicated concern and it is affected by several parameters. So, local farmers should be protected against devastating price fluctuations in the market. Moreover, net premium amount for the index-based policies after the appropriate risk premium amount was decided for each province is hard to compensate by individual farmers. For this reason, some part of premiums should be subsidized by the government. In Turkey, TARSIM is already responsible for this subsidization for the existing insurance policies in the market and it can provide also index-based drought insurance premium subsidy support for each policyholder.

  Furthermore, different coverage levels might be set according to the risk attitude of local farmers. In this case, some part of the wheat yield loss is beared by the policyholder. As a result, the potential policyholder pay lower premiums based on the selected coverage level but also they get lower indemnity amount.

- ***Index Selection***

  Instead of using one predictor variable, a set of multiple independent explanatory should be used for designing more complicated insurance products. The layered index-based insurance contract modelling might be considered according to the most important growth stages of the wheat production and the predictor behaviours at these periods. Moreover, the most correlated index variables should be weighted to derive more sophisticated linear equations to calculate indemnity and premium amounts. In such cases, it is difficult to obtain trigger level for the selected index variable, but it might resulted in more accurate insurance contract design. However, the collinearity problem of these predictors should be studied firstly to avoid unreasonable estimation equations.

  Furthermore, specific farm located index variable derivation might provide spatial basis risk reduction. Even if the average value of the weather index for each province provide easier calculations, the basis risk charge of such policies is excessive to cope with. The spatial data analysis should offer more reliable index variable selection for smallholders by using the neighborhood weather stations. For this reason, the quality of weather data collection systems should be developed by technological improvements at these stations as a first step.

- ***Wheat Type***

  For simplicity, the weighted average of durum and other wheat type was used while designing the insurance product in this study. On the other hand, this basic approach can lead to inaccurate results. Firstly, there are various types of wheat seeds planted in Central Anatolia. Moreover, the planted area for these wheat types are varying by region and this results in different wheat yield. Furthermore, the drought tolerance for each wheat type are alternating. For this reason, each wheat type should be considered separately and index-based insurance contracts should differ in premium and indemnity amount.

  Besides the above distinction, the cultivation area for different wheat types has characteristic features such as soil type, irrigation need. In other words, each wheat type can not be planted anywhere in a specified region. Before the insurance design, the local farmers should be informed about these problems and governed by agriculture experts to prevent excessive indemnification.

- ***Risk Sharing***

  The most importantly, these types of insurance contracts pay any indemnity to policyholders at the same time when the index variable falls down the strike level for contract year. As it was discussed in chapter 1, Turkish government provided ex-post financial assistance for all provinces of Central Anatolia Region. This leads to higher amount of payouts for the insurer in one season. For this reason, insurance companies may be able to transfer their risk to reinsurance companies in the market. The complete weather index-based insurance contracts should be introduced and studied to reinsurance companies before implementing.

# REFERENCES


[1] *Agriculture and Climate Change: A Prairie Perspective*, International Institute for Sustainable Development and Institute For Environmental Studies, University of Toronto, March 2007.

[2] J. Skees, A. Murphy and B. Collier, *Scaling Up Index Insurance*, Microinsurance Centre, December 2007.

[3] K. Öztürk, *Global Climatic Changes and Their Probable Effect upon Turkey*, G. Ü. Eğitim Fakültesi Dergisi, vol. 22, number 1, pp. 47-65, 2002.

[4] *State of Knowledge Report Data Requirements for the Design of Weather Index Insurance 1*, GlobalAgRisk Incorporation, June,2010.

[5] P. Hazell, J. Anderson, N. Balzer, A. Hastrup Clemmensen, U. Hess and F. Rispoli, *Potential for scale and sustainability in weather index insurance for agriculture and rural livelihoods*, International Fund for Agricultural Development and World Food Programme, March 2010.

[6] A. Fuchs and H. Wolff, *Drought and Retribution: Evidence from a large scale Rainfall-Indexed Insurance Program in Mexico*, October 2010.

[7] K. Yıldırak, A. S. Kestal, O. Gülseven and B. B. Erkan, *Financial Management of Flood and Drought Risks in Agricultural Sector in Turkey*, Report on Insurance Analysis and Codes of the Algorithm.

[8] O. Şimşek, A. Mermer, H. Yıldız, K. A. Özaydın and B. Çakmak, *Estimation of Wheat Yield for Turkey Using AgroMetShell Model*, Tarım Bilimleri Dergisi, vol. 13, number 3, pp. 299-307, 2007.

[9] B. J. Barnett, C. B. Barrett and J. R. Skees, *Poverty Traps and Index-Based Risk Transfer Mechanism*, Available at SSRN: http://ssrn.com/abstract=999399, July 2006.

[10] M. Burke, A. de Janvry, J. Quintero, *Providing index based agricultural insurance to smallholders: Recent progress and future promise*, May 2010.

[11] *Weather Index-Based Insurance in Agricultural Development: A Technical Guide*, International Fund for Agricultural Development, 2011.

[12] J. Brüderl, *Panel Data Analysis*, March 2005.

[13] A. Ichhino, *Micro-Econometrics: Limited Dependent Variables and Panel Data*, European University Institute course material, Available at http://www2.dse.unibo.it/ichino/metric10.pdf, November 2005.

[14] R. Yaffe, *A Primer for Panel Data Analysis*, Information Technology Services of New York University, September 2003.

[15] R. L. Brown and L. R. Gottlieb, *Introduction to Ratemarking and Loss Reserving for Property and Casualty Insurance*, CTEX Publications, pp.2, 2001.

[16] G. Mızrak, *Buğdayın Hikayesi*, Türkiye Ziraat Odaları Birliği, 2011.

[17] *Tarımsal Kuraklığın Tanımı*, A report from Drought Test Center in Konya, 2011.

[18] A. Kassam and M. Smith, *FAO Methodologies on Crop Water Use and Crop Water Productivity*, Expert Meeting on Crop Water Productivity, Dec. 2001

[19] H. M. Park, *Linear Regression Models for Panel Data Using SAS, Stata,LIMDEP,and SPSS*, The University Information Technology Services (UITS), Sept. 2009.

[20] O. T. Reyna, *Panel Data Analysis Fixed & Random Effects using STATA*, The Princeton University Data and Statistical Service

[21] T. S. Breusch and A. R. Pagan, *The Lagrange Multiplier Test and its Applications to Model Specification in Econometrics*, Review of Economic Studies, vol.47, number 1, pp. 239-253, 1980.

[22] J. A. Hausman, *Specification Tests in Econometrics*, Econometrica, vol.46, number 6, pp. 1251-1271, 1978.

[23] L. Breiman, J. H. Friedman, R. A. Olshen and C. J. Stone, *Classification and Regression Trees*, The Wadsworth Statistics/Probability Series, 358 p. , 1984.

[24] Berk and A. Richard, *Statistical Learning from a Regression Perspective*, Springer Series in Statistics, New York: Springer-Verlag, 2008.

[25] B. H. Baltagi, *Econometric Analysis of Panel Data*, Wiley, 2008

[26] T. B. McKee and D. C. Edwards *Characteristics of 20th Century Drought in the United States at Multiple Time Scales, Atmospheric Science Paper No. 634 Climatology Report No. 97-2*, Department of Atmospheric Science Colorado State University Fort Collins, CO 80523-1371, May 1997.

[27] P. A. Burrough and R.A. McDonnell, *Principles of Geographical Systems*, Oxford University Press, 1998

[28] *Index Insurance Initiatives Worldwide*, Forum for Agricultural Risk Management in Development (FARM), Available at http://www.agriskmanagementforum.org/content/index-insurance-initiatives-worldwide.

[29] K. Yıldırak, Z. Kalaylıoğlu and A. Mermer, *Bayesian Estimation of Crop Yield Function: Drought based Wheat Prediction Model for Tigem Farms*, Environmental and Ecological Statistics, (forthcoming,2012).

[30] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1964.

[31] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1965.

[32] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1966.

[33] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1967.

[34] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1968.

[35] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1969.

[36] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1970.

[37] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1971.

[38] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1972.

[39] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1973.

[40] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1974.

[41] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1975.

[42] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1976.

[43] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1977.

[44] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1978.

[45] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1979.

[46] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1980.

[47] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1981.

[48] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1982.

[49] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1983.

[50] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1984.

[51] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1985.

[52] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1986.

[53] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1987.

[54] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1988.

[55] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1989.

[56] *Yearbook of Agricultural structure and production*, Prime Ministery State Institute of Statistics, Turkey, 1990.

# APPENDIX A

# ARIMA PROCESS SUMMARY

ARIMA(p,1,q) process summary for all provinces listed here in Tables A.1-A.9.

Table A.1: ARIMA process for Çankırı

| | | Model Fit Summary | | | |
|---|---|---|---|---|---|
| | | AIC | SBC | Adj Rsquare | MAE |
| ARIMA(1,1,1) | | -21.211399 | -15.99839 | 0.72921162 | 0.12695313 |
| Coeff. | Lag # | Estimates | Std Error | t ratio | Prob > \|*t*\| |
| AR1 | 1 | 068072929 | 0.1258835 | 5.41 | < 0.0001* |
| MA1 | 1 | 0.99999989 | 0.823208 | 12.15 | < 0.0001* |
| Intercept | 0 | 0.01988886 | 0.0057637 | 3.45 | 0.0014* |

* : Correlation is significant at the 0.05 level
Constant Estimation is 0.00634993

Table A.2: ARIMA process for Eskişehir

| | | Model Fit Summary | | | |
|---|---|---|---|---|---|
| | | AIC | SBC | Adj Rsquare | MAE |
| ARIMA(2,1,2) | | -17.637965 | -8.9496171 | 0.73665218 | 0.14685296 |
| Coeff. | Lag # | Estimates | Std Error | t ratio | Prob> \|*t*\| |
| AR1 | 1 | 0.8208132 | 0.1696932 | 4.84 | <0.0001* |
| AR2 | 2 | -0.8274908 | 0.1596342 | -5.18 | <0.0001* |
| MA1 | 1 | 0.9879914 | 0.2286910 | 4.32 | 0.0001* |
| MA2 | 2 | -0.7046949 | 0.2114035 | -3.33 | 0.0020* |
| Intercept | 0 | 0.0199170 | 0.0190692 | 1.04 | 0.3030 |

* : Correlation is significant at the 0.05 level
Constant Estimation is 0.02005003

Table A.3: ARIMA process for Kayseri

| | | Model Fit Summary | | | |
|---|---|---|---|---|---|
| | | AIC | SBC | Adj Rsquare | MAE |
| ARIMA(2,1,1) | | -44.466491 | -37.515812 | 0.72156456 | 0.09977542 |
| Coeff. | Lag # | Estimates | Std Error | t ratio | *Prob* > \|*t*\| |
| AR1 | 1 | 0.4909470 | 0.1306598 | 3.76 | 0.0006* |
| AR2 | 2 | -0.7011170 | 0.1035414 | -6.77 | <0.0001* |
| MA1 | 1 | 0.4821818 | 0.1714098 | 2.81 | <0.0077* |
| Intercept | 0 | 0.0107681 | 0.0087681 | 1.23 | 0.2270 |

* : Correlation is significant at the 0.05 level
Constant Estimation is 0.01303128

Table A.4: ARIMA process for Kırşehir

| | | Model Fit Summary | | | |
|---|---|---|---|---|---|
| | | AIC | SBC | Adj Rsquare | MAE |
| ARIMA(1,1,1) | | -10.581518 | -5.3685093 | 0.52359764 | 0.16049912 |
| Coeff. | Lag # | Estimates | Std Error | t ratio | *Prob* > \|*t*\| |
| AR1 | 1 | -0.5610102 | 0.1565198 | -3.58 | 0.0009* |
| MA1 | 1 | -0.9497012 | 0.0862728 | -11.01 | <0.0001* |
| Intercept | 0 | 0.0206850 | 0.0376314 | 0.55 | 0.5857 |

* : Correlation is significant at the 0.05 level
Constant Estimation is 0.03228944

Table A.5: ARIMA process for Konya

| | | Model Fit Summary | | | |
|---|---|---|---|---|---|
| | | AIC | SBC | Adj Rsquare | MAE |
| ARIMA(1,1,2) | | 0.29578549 | 7.24646397 | 0.58270221 | 0.18381348 |
| Coeff. | Lag # | Estimates | Std Error | t ratio | *Prob* > \|*t*\| |
| AR1 | 1 | 0.39278062 | 0.1759606 | 2.23 | 0.0316* |
| MA1 | 1 | 0.36935853 | 0.1681280 | 2.20 | 0.0342* |
| MA2 | 2 | 0.63063534 | 0.1556615 | 4.05 | 0.0002* |
| Intercept | 0 | 0.01606514 | 0.0065639 | 2.45 | 0.0191* |

* : Correlation is significant at the 0.05 level
Constant Estimation is 0.00975507

Table A.6: ARIMA process for Nevşehir

| | | Model Fit Summary | | | |
|---|---|---|---|---|---|
| | | AIC | SBC | Adj Rsquare | MAE |
| ARIMA(2,1,0) | | -7.6241383 | -2.4111295 | 0.71778469 | 0.16121255 |
| Coeff. | Lag # | Estimates | Std Error | t ratio | *Prob* > \|*t*\| |
| AR1 | 1 | -0.0451391 | 0.1396620 | -0.32 | 0.7483 |
| AR2 | 2 | -0.4699757 | 0.1370356 | -3.43 | 0.0014* |
| Intercept | 0 | 0.0226085 | 0.0211761 | 1.07 | 0.2922 |

* : Correlation is significant at the 0.05 level
Constant Estimation is 0.03425442

Table A.7: ARIMA process for Niğde

| | | Model Fit Summary | | | |
|---|---|---|---|---|---|
| | | AIC | SBC | Adj Rsquare | MAE |
| ARIMA(1,1,1) | | -0.8393641 | 4.37364475 | 0.53406729 | 0.15876368 |
| Coeff. | Lag # | Estimates | Std Error | t ratio | *Prob* > \|*t*\| |
| AR1 | 1 | -0.5502306 | 0.1365674 | -4.03 | 0.0003* |
| MA1 | 1 | -0.9999995 | 0.0720919 | -13.87 | <0.0001* |
| Intercept | 0 | 0.0110243 | 0.0428349 | 0.26 | 0.7982 |

* : Correlation is significant at the 0.05 level
Constant Estimation is 0.01709028

Table A.8: ARIMA process for Sivas

| | | Model Fit Summary | | | |
|---|---|---|---|---|---|
| | | AIC | SBC | Adj Rsquare | MAE |
| ARIMA(2,1,1) | | 24.2453977 | 31.1960762 | 0.46810581 | 0.20649479 |
| Coeff. | Lag # | Estimates | Std Error | t ratio | *Prob* > \|*t*\| |
| AR1 | 1 | 0.5119931 | 0.1906182 | 2.69 | 0.0107* |
| AR2 | 2 | -0.5940730 | 0.1262169 | -4.71 | <0.0001* |
| MA1 | 1 | 0.5978471 | 0.2552022 | 2.34 | 0.0245* |
| Intercept | 0 | 0.0078083 | 0.0177701 | 0.44 | 0.6629 |

* : Correlation is significant at the 0.05 level
Constant Estimation is 0.0084492

Table A.9: ARIMA process for Yozgat

| | | Model Fit Summary | | | |
|---|---|---|---|---|---|
| | | AIC | SBC | Adj Rsquare | MAE |
| ARIMA(1,1,1) | | -27.003903 | -21.790894 | 0.73524018 | 0.13863568 |
| Coeff. | Lag # | Estimates | Std Error | t ratio | *Prob* > \|*t*\| |
| AR1 | 1 | 0.80298088 | 0.1003788 | 8.00 | <0.0001* |
| MA1 | 1 | 0.99999458 | 0.0682199 | 14.66 | <0.0001* |
| Intercept | 0 | 0.01716259 | 0.0077179 | 2.22 | 0.0320* |

* : Correlation is significant at the 0.05 level
Constant Estimation is 0.00338136

# APPENDIX B

# R-CODE FOR LINEAR MIXED EFFECT MODELS

```
a=read.csv2(”C:/Users/Samsung/Desktop/paneldata.csv”,header=TRUE)
install.packages(”lme4”)
library(lme4)
panel <- lmer(logyield   WDEFr
+ (1 — province), data = a,na.action = na.omit) panel
ranef(panel)
panel2 <- lmer(logyield   WDEFr + (WDEFr — province), data = a,na.action = na.omit)
panel2
ranef(panel2)
anova(panel,panel2)
```

```
Linear mixed model fit by REML
Formula: logyield   WDEFr + (1 — province)
Data: a
AIC BIC logLik deviance REMLdev
-144.2 -131.9 76.1 -171.6 -152.2
Random effects:
Groups Name Variance Std.Dev.
province (Intercept) 0.015582 0.12483
Residual 0.017091 0.13073
Number of obs: 160, groups: province, 10
```

Fixed effects:

Estimate Std. Error t value

(Intercept) 0.7597373 0.0447728 16.97

WDEFr -0.0017988 0.0002444 -7.36

Correlation of Fixed Effects:

(Intr)

WDEFr -0.412

Linear mixed model fit by REML

Formula: logyield  WDEFr + (WDEFr — province)

Data: a

AIC BIC logLik deviance REMLdev

-142.3 -123.8 77.13 -173.6 -154.3

Random effects:

Groups Name Variance Std.Dev. Corr

province (Intercept) 9.4494e-03 0.09720826

WDEFr 1.9286e-07 0.00043916 1.000

Residual 1.6763e-02 0.12947061

Number of obs: 160, groups: province, 10

Fixed effects:

Estimate Std. Error t value

(Intercept) 0.7621216 0.0370117 20.591

WDEFr -0.0018714 0.0002809 -6.662

Correlation of Fixed Effects:

(Intr)

WDEFr -0.009

Data: a

Models:

panel: logyield   WDEFr + (1 — province)

panel2: logyield   WDEFr + (WDEFr — province)

Df AIC BIC logLik Chisq Chi Df Pr(>Chisq)

panel 4 -163.56 -151.26 85.782

panel2 6 -161.55 -143.10 86.777 1.9901 2 0.3697

# APPENDIX C

# STRIKE LEVEL CALCULATIONS

According to the linear regression LR and FE linear panel models, strike levels for the index based insurance policies were calculated for all provinces. Moreover, the contracts resulted in any payout were represented here. The following Tables C.1-C.16 summarizes these results for each province.

Table C.1: Strike Level and Indemnification under LR model for Ankara

| Index Measure | Prediction 2.333 ton/ha | Observed in 2007 | Indemnity |
|---|---|---|---|
| $WDEF_f$ | > -3.936 | 1.300 | YES |
| $ETA_t$ | < 355.500 | 265.000 | YES |
| $WSI_h$ | < 91.790 | 71.286 | YES |
| pval | < 158.832 | 109.000 | YES |
| $WDEF_r/vert$ | > 0.622 | 2.944 | YES |

Table C.2: Strike Level and Indemnification under FE model for Ankara

| Index Measure | Prediction 2.333 ton/ha | Observed in 2007 | Indemnity |
|---|---|---|---|
| $WDEF_r$ | > 0.525 | 106.000 | YES |
| $WDEF_t$ | > 5.591 | 107.300 | YES |
| $ETA_r$ | < 164.593 | 62.900 | YES |
| $WDEF_r/vert$ | > 0.111 | 2.940 | YES |
| $WDEF_t/vert$ | > 0.185 | 2.980 | YES |
| $WDEF_t/eval$ | > 0.073 | 1.430 | YES |
| $WDEF_t/pval$ | > 0.060 | 0.980 | YES |
| $ETA_r/eval$ | < 1.618 | 0.840 | YES |

Table C.3: Strike Level and Indemnification under LR model for Çankırı

| Index Measure | Prediction<br>1.806 ton/ha | Observed in 2007 | Indemnity |
|---|---|---|---|
| $WDEF_t/vert$ | > 0.837 | 0.938 | YES |

Table C.4: Strike Level and Indemnification under FE model for Çankırı

| Index Measure | Prediction<br>1.806 ton/ha | Observed in 2007 | Indemnity |
|---|---|---|---|
| $WDEF_r$ | > 68.871 | 48.700 | NO |
| $WDEF_t$ | > 71.002 | 50.700 | NO |
| $ETA_r$ | < 95.391 | 312.700 | NO |
| $WDEF_r/vert$ | > 0.906 | 0.901 | NO |
| $WDEF_t/vert$ | > 0.934 | 0.938 | YES |
| $WDEF_t/eval$ | > 0.653 | 0.433 | NO |
| $WDEF_t/pval$ | > 0.478 | 0.347 | NO |
| $ETA_r/eval$ | < 0.829 | 0.954 | NO |

Table C.5: Strike Level and Indemnification under FE model for Eskişehir

| Index Measure | Prediction 2.053 ton/ha | Observed in 2007 | Indemnity |
|---|---|---|---|
| $WDEF_r$ | > 117.410 | 29.000 | NO |
| $WDEF_t$ | > 122.542 | 29.000 | NO |
| $ETA_r$ | < 61.369 | 133.500 | NO |
| $WDEF_r/vert$ | > 1.913 | 0.829 | NO |
| $WDEF_t/vert$ | > 1.994 | 0.829 | NO |
| $WDEF_t/eval$ | > 1.330 | 0.333 | NO |
| $WDEF_t/pval$ | > 0.879 | 0.257 | NO |
| $ETA_r/eval$ | < 0.555 | 1.534 | NO |

Table C.6: Strike Level and Indemnification under LR model for Kayseri

| Index Measure | Prediction 1.599 ton/ha | Observed in 2007 | Indemnity |
|---|---|---|---|
| $WDEF_t/eval$ | > 1.696 | 3.242 | YES |

Table C.7: Strike Level and Indemnification under FE model for Kayseri

| Index Measure | Prediction 1.599 ton/ha | Observed in 2007 | Indemnity |
|---|---|---|---|
| $WDEF_r$ | > 146.663 | 138.800 | NO |
| $WDEF_t$ | > 154.612 | 139.400 | NO |
| $ETA_r$ | < 39.937 | 56.600 | NO |
| $WDEF_r/vert$ | > 2.134 | 7.305 | YES |
| $WDEF_t/vert$ | > 2.302 | 7.337 | YES |
| $WDEF_t/eval$ | > 1.535 | 3.242 | YES |
| $WDEF_t/pval$ | > 1.144 | 2.248 | YES |
| $ETA_r/eval$ | < 0.422 | 1.316 | NO |

Table C.8: Strike Level and Indemnification under FE model for Kırşehir

| Index Measure | Prediction 2.268 ton/ha | Observed in 2007 | Indemnity |
|---|---|---|---|
| $WDEF_r$ | > 6.672 | 81.000 | YES |
| $WDEF_t$ | > 9.392 | 81.000 | YES |
| $ETA_r$ | < 162.544 | 87.300 | YES |
| $WDEF_r/vert$ | > 0.215 | 2.077 | YES |
| $WDEF_t/vert$ | > 0.250 | 2.077 | YES |
| $WDEF_t/eval$ | > 0.071 | 1.052 | YES |
| $WDEF_t/pval$ | > 0.080 | 0.704 | YES |
| $ETA_r/eval$ | < 1.588 | 1.134 | YES |

Table C.9: Strike Level and Indemnification under LR model for Konya

| Index Measure | Prediction 2.436 ton/ha | Observed in 2007 | Indemnity |
|---|---|---|---|
| $WDEF_t$ | > 29.5111 | 131.0769 | YES |
| $ETA_r$ | < 136.4406 | 52.3846 | YES |
| $WSI_h$ | < 91.2632 | 67.6923 | YES |
| $WDEF_t/vert$ | > 0.5648 | 4.8547 | YES |
| $ETA_r/eval$ | < 1.4105 | 0.8731 | YES |

Table C.10: Strike Level and Indemnification under FE model for Konya

| Index Measure | Prediction 2.436 ton/ha | Observed in 2007 | Indemnity |
|---|---|---|---|
| $WDEF_r$ | > -42.783 | 121.900 | YES |
| $WDEF_t$ | > -35.857 | 131.100 | YES |
| $ETA_r$ | < 193.968 | 52.400 | YES |
| $WDEF_r/vert$ | > -0.339 | 4.516 | YES |
| $WDEF_t/vert$ | > -0.219 | 4.855 | YES |
| $WDEF_t/eval$ | > -0.330 | 2.185 | YES |
| $WDEF_t/pval$ | > -0.202 | 1.560 | YES |
| $ETA_r/eval$ | < 1.939 | 0.873 | YES |

Table C.11: Strike Level and Indemnification under LR model for Niğde

| Index Measure | Prediction<br>1.645 ton/ha | Observed in 2007 | Indemnity |
|---|---|---|---|
| $WDEF_t$ | > 182.5197 | 138 | YES |
| $ETA_t$ | < 253.8595 | 282.5 | NO |
| $WSI_h$ | < 58.4352 | 69 | NO |
| $WDEF_t/pval$ | > 1.5229 | 3.5385 | YES |

Table C.12: Strike Level and Indemnification under FE model for Niğde

| Index Measure | Prediction<br>1.645 ton/ha | Observed in 2007 | Indemnity |
|---|---|---|---|
| $WDEF_r$ | > 166.811 | 130.500 | NO |
| $WDEF_t$ | > 177.821 | 138.00 | NO |
| $ETA_r$ | < 31.231 | 63.500 | NO |
| $WDEF_r/vert$ | > 2.976 | 11.864 | YES |
| $WDEF_t/vert$ | > 3.180 | 12.546 | YES |
| $WDEF_t/eval$ | > 1.817 | 4.600 | YES |
| $WDEF_t/pval$ | > 1.427 | 3.539 | YES |
| $ETA_r/eval$ | < 0.351 | 2.117 | NO |

Table C.13: Strike Level and Indemnification under LR model for Sivas

| Index Measure | Prediction 1.506 ton/ha | Observed in 2007 | Indemnity |
|---|---|---|---|
| $WDEF_f$ | > -0.0316 | 1.5 | YES |
| $WDEF_f/vert$ | > -0.0032 | 0.0625 | YES |

Table C.14: Strike Level and Indemnification under FE model for Sivas

| Index Measure | Prediction 1.506 ton/ha | Observed in 2007 | Indemnity |
|---|---|---|---|
| $WDEF_r$ | > 42.441 | 71.200 | YES |
| $WDEF_t$ | > 46.167 | 72.700 | YES |
| $ETA_r$ | < 120.004 | 91.700 | YES |
| $WDEF_r/vert$ | > 0.570 | 2.965 | YES |
| $WDEF_t/vert$ | > 0.621 | 3.028 | YES |
| $WDEF_t/eval$ | > 0.449 | 1.346 | YES |
| $WDEF_t/pval$ | > 0.336 | 1.009 | YES |
| $ETA_r/eval$ | < 1.157 | 1.698 | NO |

Table C.15: Strike Level and Indemnification under LR model for Yozgat

| Index Measure | Prediction 2.219 ton/ha | Observed in 2007 | Indemnity |
|---|---|---|---|
| $ETA_r$ | $<$ 170.4985 | 94 | YES |
| $WDEF_r/vert$ | $>$ -0.4160 | 1.3901 | YES |

Table C.16: Strike Level and Indemnification under FE model for Yozgat

| Index Measure | Prediction 2.219 ton/ha | Observed in 2007 | Indemnity |
|---|---|---|---|
| $WDEF_r$ | $>$ -65.242 | 65.300 | YES |
| $WDEF_t$ | $>$ -66.928 | 65.300 | YES |
| $ETA_r$ | $<$ 199.668 | 94.000 | YES |
| $WDEF_r/vert$ | $>$ -0.994 | 1.390 | YES |
| $WDEF_t/vert$ | $>$ -1.032 | 1.390 | YES |
| $WDEF_t/eval$ | $>$ -0.679 | 0.726 | YES |
| $WDEF_t/pval$ | $>$ -0.481 | 0.527 | YES |
| $ETA_r/eval$ | $<$ 1.909 | 1.044 | YES |

# APPENDIX D

# MATLAB M-FILE FOR THICK SIZE CALCULATION

The thick size value for the indemnity function was decided by simulation in Matlab.

dfittool **% distribution fitting for the predictor data set.**

randtool **% generating random number for fitted distribution.**

$\text{yield}_2 007 = (observedyield) * ones(1000000, 1);$ **%Actual yield matrix for 2007**

$b = zeros(1000000, 1);$ **% generate zero matrix for comparison.**

$\text{SL}_{index}$=(trigger point)*ones(1000000,1); **% Strike level matrix for 2007 under linear regression**

$pred_{yield}$=exp(a*$Index_{rand}$+b); **% yield prediction for 2007 under linear regression model with random index variabe, where a is coefficient of predictor, b is the intercept value.**

$YL_{2007}$=max(($yield_{2007}$-$pred_{yield}$),b); **% Annual yield loss under simulation.**

$ID_{2007}$=max(($Index_{rand}$-$SL_{index}$),b); **% Index variable difference for 2007 under simulation.**

$TS_{index}$=mean($YL_{2007}$)/mean($ID_{2007}$);

**% Thick size for the selected index variable**

**defined as simple ratio of averages of yield loss and index difference.**

# APPENDIX E

# INDEMNITY AMOUNT FUNCTIONS FOR EACH PROVINCE

Under different index-based insurance policies, the indemnification equation for each province summarized by Tables E.1-E.9.

Table E.1: Indemnity amount functions for Ankara

| Index Measure | FE Panel model | LR model |
|---|---|---|
| $WDEF_f$ | - | 9.454*max((X+3.936),0) |
| $WDEF_r$ | 1.387*max((X-0.525),0) | - |
| $WDEF_t$ | 1.351*max((X-5.591),0) | - |
| $ETA_r$ | 1.716*max((164.593-X),0) | - |
| $ETA_t$ | - | 2.482*max((355.500-X),0) |
| $WDEF_r/vert$ | 97.528*max((X-0.111),0) | 165.528*max((X-0.622),0) |
| $WDEF_t/vert$ | 92.710*max((X-0.185),0) | - |
| $WDEF_t/eval$ | 136.145*max((X-0.073),0) | - |
| $WDEF_t/pval$ | 190.895*max((X-0.060),0) | - |
| $ETA_r/eval$ | 169.214*max((1.618-X),0) | - |
| $WSI_h$ | - | 7.957*max((91.790-X),0) |
| $pval$ | - | 6.388*max((158.832-X),0) |

Table E.2: Indemnity amount functions for Çankırı

| Index Measure | FE Panel model | LR model |
|---|---|---|
| $WDEF_r$ | 1.022*max((X-68.871),0) | - |
| $WDEF_t$ | 0.986*max((X-71.002),0) | - |
| $ETA_r$ | 1.351*max((95.391-X),0) | - |
| $WDEF_r/vert$ | 74.168*max((X-0.906),0) | 97.455*max((X-0.934),0) |
| $WDEF_t/vert$ | 70.153*max((X-0.934),0) | - |
| $WDEF_t/eval$ | 101.981*max((X-0.653),0) | - |
| $WDEF_t/pval$ | 143.664*max((X-0.478),0) | - |
| $ETA_r/eval$ | 3.120*max((0.829-X),0) | - |

Table E.3: Indemnity amount functions for Eskişehir

| Index Measure | FE Panel model |
|---|---|
| $WDEF_r$ | 1.278*max((X-117.410),0) |
| $WDEF_t$ | 1.207*max((X-122.542),0) |
| $ETA_r$ | 1.527*max((61.369-X),0) |
| $WDEF_r/vert$ | 87.259*max((X-1.913),0) |
| $WDEF_t/vert$ | 83.070*max((X-1.994),0) |
| $WDEF_t/eval$ | 206.965*max((X-1.330),0) |
| $WDEF_t/pval$ | 174.092*max((X-0.879),0) |
| $ETA_r/eval$ | 151.727*max((0.555-X),0) |

Table E.4: Indemnity amount functions for Kayseri

| Index Measure | FE Panel model | LR model |
|---|---|---|
| $WDEF_r$ | 0.938*max((X-146.663),0) | - |
| $WDEF_t$ | 0.871*max((X-154.612),0) | - |
| $ETA_r$ | 1.139*max((39.937-X),0) | - |
| $WDEF_r/vert$ | 65.493*max((X-2.134),0) | - |
| $WDEF_t/vert$ | 60.803*max((X-2.302),0) | - |
| $WDEF_t/eval$ | 89.914*max((X-1.535),0) | 60.836*max((X-1.535),0) |
| $WDEF_t/pval$ | 124.721*max((X-1.144),0) | - |
| $ETA_r/eval$ | 112.192*max((0.422-X),0) | - |

Table E.5: Indemnity amount functions for Kırşehir

| Index Measure | FE Panel model |
|---|---|
| $WDEF_r$ | 1.388*max((X-6.672),0) |
| $WDEF_t$ | 1.313*max((X-9.392),0) |
| $ETA_r$ | 1.688*max((162.544-X),0) |
| $WDEF_r/vert$ | 96.938*max((X-0.215),0) |
| $WDEF_t/vert$ | 92.325*max((X-0.250),0) |
| $WDEF_t/eval$ | 136.125*max((X-0.071),0) |
| $WDEF_t/pval$ | 190.500*max((X-0.080),0) |
| $ETA_r/eval$ | 167.738*max((1.588-X),0) |

Table E.6: Indemnity amount functions for Konya

| Index Measure | FE Panel model | LR model |
|---|---|---|
| $WDEF_r$ | 1.385*max((X+42.783),0) | - |
| $WDEF_t$ | 1.314*max((X+35.857),0) | 2.592*max((X-29.511),0) |
| $ETA_r$ | 1.669*max((193.968-X),0) | 3.692*max((136.441-X),0) |
| $WDEF_r/vert$ | 96.063*max((X+0.339),0) | - |
| $WDEF_t/vert$ | 88.502*max((X+0.219),0) | 141.503*max((X-0.565),0) |
| $WDEF_t/eval$ | 135.291*max((X+0.330),0) | - |
| $WDEF_t/pval$ | 189.144*max((X+0.202),0) | - |
| $ETA_r/eval$ | 167.312*max((1.939-X),0) | 334.907*max((1.411-X),0) |
| $WSI_h$ | - | 11.999*max((91.263-X),0) |

Table E.7: Indemnity amount functions for Niğde

| Index Measure | FE Panel model | LR model |
|---|---|---|
| $WDEF_r$ | 1.102*max((X-166.811),0) | - |
| $WDEF_t$ | 1.026*max((X-177.821),0) | 0.950*max((X-182.520),0) |
| $ETA_r$ | 1.330*max((31.231-X),0) | - |
| $ETA_t$ | - | 0.950*max((253.860-X),0) |
| $WDEF_r/vert$ | 76.190*max((X-2.976),0) | - |
| $WDEF_t/vert$ | 70.300*max((X-3.180),0) | - |
| $WDEF_t/eval$ | 105.070*max((X-1.817),0) | - |
| $WDEF_t/pval$ | 146.186*max((X-1.427),0) | 116.964*max((X-1.523),0) |
| $ETA_r/eval$ | 131.594*max((0.351-X),0) | - |
| $WSI_h$ | - | 4.294*max((58.435-X),0) |

Table E.8: Indemnity amount functions for Sivas

| Index Measure | FE Panel model | LR model |
|---|---|---|
| $WDEF_f$ | - | 5.574*max((X+0.032),0) |
| $WDEF_r$ | 0.923*max((X-42.441),0) | - |
| $WDEF_t$ | 0.852*max((X-46.167),0) | - |
| $ETA_r$ | 1.101*max((120.004-X),0) | - |
| $WDEF_f/vert$ | - | 361.461*max((X+0.003),0) |
| $WDEF_r/vert$ | 63.439*max((X-0.570),0) | - |
| $WDEF_t/vert$ | 59.179*max((X-0.621),0) | - |
| $WDEF_t/eval$ | 89.460*max((X-0.449),0) | - |
| $WDEF_t/pval$ | 122.085*max((X-0.336),0) | - |
| $ETA_r/eval$ | 111.364*max((1.157-X),0) | - |

Table E.9: Indemnity amount functions for Yozgat

| Index Measure | FE Panel model | LR model |
|---|---|---|
| $WDEF_r$ | 1.296*max((X+65.242),0) | - |
| $WDEF_t$ | 1.224*max((X+66.928),0) | - |
| $ETA_r$ | 1.548*max((199.668-X),0) | 2.304*max((170.499-X),0) |
| $WDEF_r/vert$ | 90.108*max((X+0.994),0) | 143.532*max((X+0.416),0) |
| $WDEF_t/vert$ | 85.608*max((X+1.032),0) | - |
| $WDEF_t/eval$ | 125.100*max((X+0.679),0) | - |
| $WDEF_t/pval$ | 175.896*max((X+0.481),0) | - |
| $ETA_r/eval$ | 155.880*max((1.909-X),0) | - |

# APPENDIX F

## INSURANCE CONTRACT SUMMARY FOR EACH PROVINCE

The Average Annual Yield Loss (AAYL) ton/ha, pure premium (PP) TL/ha, indemnity amount (IA) TL/ha and basis risk reduction power (BRRP) values under Linear Regression (LR) and Fixed Effect (FE) panel models for each province were summarized here by the following tables F.1 - F.10.

Table F.1: Insurance contract details for Ankara

| Under Fixed Effect (FE) model | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Index→ | $WDEF_r$ | $WDEF_t$ | $ETA_r$ | $WDEF_r/vert$ | $WDEF_t/vert$ | $WDEF_t/eval$ | $WDEF_t/pval$ | $ETA_r/eval$ |
| AAYL ton/ha | 0.109 | 0.135 | 0.141 | 0.114 | 0.111 | 0.137 | 0.126 | 0.149 |
| PP TL/ha | 39.796 | 49.903 | 51.381 | 41.532 | 40.625 | 50.110 | 45.935 | 54.339 |
| IA TL/ha | 146.293 | 137.358 | 174.454 | 276.316 | 259.143 | 184.762 | 176.444 | 131.970 |
| BRRP | 0.357 | 0.335 | 0.426 | 0.675 | 0.633 | 0.451 | 0.431 | 0.322 |
| Under Linear Regression (LR) model | | | | | | | | |
| Index → | $WDEF_f$ | $ETA_t$ | $WSI_h$ | $pval$ | $WDEF_r/vert$ | | | |
| AAYL ton/ha | 0.091 | 0.123 | 0.110 | 0.104 | 0.087 | | | |
| PP TL/ha | 33.288 | 44.749 | 40.114 | 38.033 | 31.755 | | | |
| IA TL/ha | 49.499 | 224.621 | 163.041 | 318.299 | 384.487 | | | |
| BRRP | 0.121 | 0.548 | 0.398 | 0.777 | **0.939** | | | |

Table F.2: Insurance contract details for Çankırı

| Under Fixed Effect (FE) model | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Index→ | $WDEF_r$ | $WDEF_t$ | $ETA_r$ | $WDEF_r/vert$ | $WDEF_t/vert$ | $WDEF_t/eval$ | $WDEF_t/pval$ | $ETA_r/eval$ |
| AAYL ton/ha | 0.110 | 0.111 | 0.108 | 0.105 | 0.105 | 0.108 | 0.108 | 0.115 |
| PP TL/ha | 40.296 | 40.403 | 39.450 | 38.266 | 38.412 | 39.552 | 39.397 | 41.913 |
| IA TL/ha | 0 | 0 | 0 | 0 | 0.288 | 0 | 0 | 0 |
| BRRP | 0 | 0 | 0 | 0 | 0.001 | 0 | 0 | 0 |

| Under Linear Regression (LR) model | |
|---|---|
| Index→ | $WDEF_t/vert$ |
| AAYL ton/ha | 0.114 |
| PP TL/ha | 41.464 |
| IA TL/ha | 0.400 |
| BRRP | **0.002** |

Table F.3: Insurance contract details for Eskişehir

| Under Fixed Effect (FE) model | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Index → | $WDEF_r$ | $WDEF_t$ | $ETA_r$ | $WDEF_r/vert$ | $WDEF_t/vert$ | $WDEF_t/eval$ | $WDEF_t/pval$ | $ETA_r/eval$ |
| AAYL ton/ha | 0.127 | 0.123 | 0.133 | 0.108 | 0.106 | 0.119 | 0.114 | 0.142 |
| PP YTL/ha | 44.967 | 43.825 | 47.113 | 38.453 | 37.590 | 42.365 | 40.596 | 50.308 |
| IA TL/ha | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BRRP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table F.4: Insurance contract details for Kayseri

| Under Fixed Effect (FE) model | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Index→ | $WDEF_r$ | $WDEF_t$ | $ETA_r$ | $WDEF_r/vert$ | $WDEF_t/vert$ | $WDEF_t/eval$ | $WDEF_t/pval$ | $ETA_r/eval$ |
| AAYL ton/ha | 0.072 | 0.067 | 0.073 | 0.076 | 0.072 | 0.066 | 0.070 | 0.067 |
| PP TL/ha | 23.992 | 22.598 | 24.497 | 25.500 | 24.001 | 22.087 | 23.318 | 22.443 |
| IA TL/ha | 0 | 0 | 0 | 338.636 | 306.153 | 153.510 | 137.691 | 0 |
| BRRP | $\rightarrow\infty$ | $\rightarrow\infty$ | $\rightarrow\infty$ | $\rightarrow\infty$ | $\rightarrow\infty$ | $\rightarrow\infty$ | $\rightarrow\infty$ | $\rightarrow\infty$ |

| Under Linear Regression (LR) model | |
|---|---|
| Index → | $WDEF_t/eval$ |
| AAYL ton/ha | 0.065 |
| PP TL/ha | 21.809 |
| IA TL/ha | 103.865 |
| BRRP | $\rightarrow\infty$ |

Table F.5: Insurance contract details for Kırşehir

| Under Fixed Effect (FE) model | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Index→ | $WDEF_r$ | $WDEF_t$ | $ETA_r$ | $WDEF_r/vert$ | $WDEF_t/vert$ | $WDEF_t/eval$ | $WDEF_t/pval$ | $ETA_r/eval$ |
| AAYL ton/ha | 0.103 | 0.103 | 0.100 | 0.101 | 0.100 | 0.102 | 0.101 | 0.104 |
| PP YTL/ha | 38.625 | 38.780 | 37.554 | 38.011 | 37.568 | 38.191 | 37.920 | 38.876 |
| IA TL/ha | 103.130 | 93.986 | 126.974 | 180.459 | 168.687 | 133.539 | 118.910 | 76.086 |
| BRRP | 0.359 | 0.328 | 0.443 | **0.629** | 0.588 | 0.465 | 0.415 | 0.265 |

Table F.6: Insurance contract details for Konya

| Under Fixed Effect (FE) model | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Index → | $WDEF_r$ | $WDEF_t$ | $ETA_r$ | $WDEF_r/vert$ | $WDEF_t/vert$ | $WDEF_t/eval$ | $WDEF_t/pval$ | $ETA_r/eval$ |
| AAYL ton/ha | 0.128 | 0.121 | 0.132 | 0.119 | 0.109 | 0.120 | 0.113 | 0.137 |
| PP YTL/ha | 45.518 | 43.039 | 46.718 | 42.123 | 38.708 | 42.693 | 40.139 | 48.682 |
| IA TL/ha | 228.003 | 219.298 | 236.206 | 466.309 | 448.986 | 340.174 | 333.366 | 178.404 |
| BRRP | 0.813 | 0.782 | 0.842 | 1.663 | 1.601 | 1.213 | 1.189 | 0.636 |

| Under Linear Regression (LR) model | | | | | |
|---|---|---|---|---|---|
| Index → | $WDEF_t$ | $ETA_r$ | $WSI_h$ | $WDEF_t/vert$ | $ETA_r/eval$ |
| AAYL ton/ha | 0.102 | 1.112 | 0.099 | 0.091 | 0.125 |
| PP YTL/ha | 36.317 | 39.831 | 35.252 | 32.128 | 43.985 |
| IA TL/ha | 263.268 | 310.278 | 282.735 | 607.034 | 179.979 |
| BRRP | 0.939 | 1.106 | **1.008** | 2.164 | 0.642 |

Table F.7: Insurance contract details for Nevşehir

| Under Fixed Effect (FE) model | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Index → | $WDEF_r$ | $WDEF_t$ | $ETA_r$ | $WDEF_r/vert$ | $WDEF_t/vert$ | $WDEF_t/eval$ | $WDEF_t/pval$ | $ETA_r/eval$ |
| AAYL ton/ha | 0.069 | 0.069 | 0.077 | 0.068 | 0.068 | 0.070 | 0.068 | 0.137 |
| PP YTL/ha | 24.851 | 24.703 | 27.738 | 24.588 | 24.437 | 25.054 | 24.413 | 49.312 |
| IA TL/ha | 0.435 | 0 | 0 | 95.560 | 86.824 | 44.658 | 35.749 | 0 |
| BRRP | 0.002 | 0 | 0 | 0.478 | 0.435 | 0.224 | 0.179 | 0 |

| Under Linear Regression (LR) model | | | | |
|---|---|---|---|---|
| Index → | $WDEF_r$ | $ETA_r$ | $WSI_h$ | $WDEF_r/vert$ |
| AAYL ton/ha | 0.068 | 0.075 | 0.067 | 0.067 |
| PP YTL/ha | 24.480 | 27 | 24.120 | 24.120 |
| IA TL/ha | 0.783 | 0 | 0 | 102.096 |
| BRRP | 0.004 | 0 | 0 | **0.511** |

Table F.8: Insurance contract details for Niğde

| Under Fixed Effect (FE) model | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Index → | $WDEF_r$ | $WDEF_t$ | $ETA_r$ | $WDEF_r/vert$ | $WDEF_t/vert$ | $WDEF_t/eval$ | $WDEF_t/pval$ | $ETA_r/eval$ |
| AAYL ton/ha | 0.069 | 0.063 | 0.073 | 0.077 | 0.069 | 0.067 | 0.067 | 0.128 |
| PP YTL/ha | 26.165 | 24.080 | 27.560 | 29.077 | 26.234 | 25.453 | 25.584 | 48.730 |
| IA TL/ha | 0 | 0 | 0 | 677.161 | 658.388 | 292.378 | 308.701 | 0 |
| BRRP | 0 | 0 | 0 | 7.748 | 7.533 | 3.345 | 3.532 | 0 |

| Under Linear Regression (LR) model | | | | |
|---|---|---|---|---|
| Index → | $WDEF_t$ | $ETA_t$ | $WSI_h$ | $WDEF_t/pval$ |
| AAYL ton/ha | 0.059 | 0.062 | 0.062 | 0.059 |
| PP YTL/ha | 22.534 | 23.674 | 23.408 | 22.230 |
| IA TL/ha | 0 | 0 | 0 | 235.753 |
| BRRP | 0 | 0 | 0 | **2.697** |

Table F.9: Insurance contract details for Sivas

| Under Fixed Effect (FE) model | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Index → | $WDEF_r$ | $WDEF_t$ | $ETA_r$ | $WDEF_r/vert$ | $WDEF_t/vert$ | $WDEF_t/eval$ | $WDEF_t/pval$ | $ETA_r/eval$ |
| AAYL ton/ha | 0.048 | 0.046 | 0.049 | 0.051 | 0.048 | 0.048 | 0.046 | 0.044 |
| PP YTL/ha | 16.884 | 16.180 | 17.535 | 18.076 | 17.046 | 17.169 | 16.382 | 15.479 |
| IA TL/ha | 26.545 | 22.606 | 31.149 | 151.980 | 142.425 | 80.183 | 82.163 | 0 |
| BRRP | 0.334 | 0.284 | 0.392 | 1.911 | 1.791 | **1.008** | 1.033 | 0 |
| Under Linear Regression (LR) model | | | | | | | | |
| Index → | $WDEF_f$ | $WDEF_f/vert$ | $WDEF_f/pval$ | | | | | |
| AAYL ton/ha | 0.047 | 0.045 | 0.046 | | | | | |
| PP YTL/ha | 16,650 | 15.833 | 16.259 | | | | | |
| IA TL/ha | 8.536 | 23.748 | 0 | | | | | |
| BRRP | 0.107 | 0.299 | 0 | | | | | |

Table F.10: Insurance contract details for Yozgat

| Under Fixed Effect (FE) model | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Index → | $WDEF_r$ | $WDEF_t$ | $ETA_r$ | $WDEF_r/vert$ | $WDEF_t/vert$ | $WDEF_t/eval$ | $WDEF_t/pval$ | $ETA_r/eval$ |
| AAYL ton/ha | 0.121 | 0.117 | 0.121 | 0.123 | 0.121 | 0.117 | 0.118 | 0.125 |
| PP TL/ha | 43.535 | 42.220 | 43.417 | 44.383 | 43.411 | 42.124 | 42.574 | 44.929 |
| IA TL/ha | 169.182 | 161.846 | 163.573 | 214.808 | 207.368 | 175.703 | 177.321 | 134.836 |
| BRRP | 0.979 | 0.937 | 0.947 | 1.243 | 1.200 | **1.017** | 1.026 | 0.780 |
| Under Linear Regression (LR) model | | | | | | | | |
| Index → | $ETA_r$ | $WDEF_r/vert$ | | | | | | |
| AAYL ton/ha | 0.116 | 0.116 | | | | | | |
| PP TL/ha | 41.652 | 41.904 | | | | | | |
| IA TL/ha | 176.253 | 259.233 | | | | | | |
| BRRP | 1.020 | 1.500 | | | | | | |

The most efficient index-based insurance policy for each province was determined according to the closest BRRP value to 1 as it was mentioned earlier. The closest BRRP value is shown in bold in above tables F.1 - F.10.