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ARMINGTON SUBSTITUTION ELASTICITIES AND TECHNICAL EFFICIENCY FOR VEGETABLE PRODUCTION IN MONGOLIA

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CONTENTS

I. INTRODUCTION

Vegetables are one of the main varieties of vitamin food sources for humans and the main part of the staple diet. In Mongolia, vegetables are one of the main products of crop production after wheat and potato. After the crop production sector was established in 1957, Mongolian people started to mostly used potatoes and vegetables in the intake. Nowadays, Mongolian vegetable consumption has been 6 times lower than the recommended intake by the World Health Organization (WHO). Also, it has been 3 times lower than the Ministry of Health of Mongolia (MOH). For example, monthly vegetable consumption per capita (by equivalent adults) was 2.1 kg in 2019 (National Statistics Office of Mongolia, 2019). In recent years, half of the population live in the urban area, who is commonly used to potato, cabbage, carrot, turnips, onion, garlic, cucumber, tomato, beets, and pepper. On the other hand, population food structure has been improving who has been using many types of vegetables in daily diet.

In Mongolia, there are planting a few varieties of vegetables due to the climatic extreme condition such as potato, cabbage, carrots, turnips, onions, garlic, cucumber, tomatoes, watermelon, and a small number of peppers, beet, etc. Potato is one of the main vegetables in Mongolia. In 2019, total vegetable production was 291.7 thousand tons, the potato production constituted 65.9% of its and while the remaining 34.1% accounted for vegetables. The Central and Western regions constituted 84.5% of its and while the remaining 15.5% accounted for East, Khangai, and Ulaanbaatar regions. Therefore, Selenge, Darkhan-Uul, Tuv (Central region), and Khovd (Western region) are the four main growing areas of vegetable production (including potato) composition with a share of 22.8%, 7.0%, 41.2%, and 7.6%, respectively (National Statistics Office of Mongolia, 2019). Also, the households' production dominates in vegetable production (approximately 77% of total vegetable production).

After a political and economic transition time, the crop sector has dropped, which was causing increasing vegetables import to supply excess demand of the population. After a massive collapse, the Mongolian government paid attention to this recession, the crop sector was substantially revived through a national campaign that was titled the "Atar-3 Land Rehabilitation" and implemented between 2008 and 2010. As a result of this program, we became fully self-sufficient in wheat and potato production. But until now, the vegetable market is a high reliance on vegetable imports such as a self-sufficient rate was approximately 60 percent (National Statistics Office of Mongolia, 2019). Also, there were implemented many projects to increase vegetable domestic production and possibly to supply domestic consumption. For example, “Mongol potato” (2004) and “Inclusive and sustainable vegetable production and marketing” (2016) projects by SDC (Swiss Agency for Development and Cooperation, 2015), “Vegetable value chain program in Mongolia” project by (USAID, 2014), “Current situation analysis of vegetable value chain in Mongolia” (2016) Support to Employment Creation in Mongolia (SECiM) project by FAO and European Union (SECiM, 2016), “Community vegetable farming for livelihood improvement” (2017) project by Japan Fund (Japan Fund for Poverty Reduction, 2017), and Asian Development Bank (ADB) project for improving vegetable value chain to increasing income-generating and employment opportunities in rural areas (Asian Development Bank, 2020), etc. All the projects focused on how to improve the vegetable market situation especially, vegetable value chain mapping (sales, transportation), how to increase household revenue, and to determine faced challenges to household vegetable production. Such as, according to the SDC report, the vegetable sector has a lot of challenges, for instance, there is a lot of old sorts of vegetable, lack of machinery, equipment and warehouse, profession and technical advice is not enough, households' cooperative is low, lack of market information and lack of correspondence between household and public sector (Swiss Agency for Development and Cooperation, 2015). Therefore, as a result of the SDC project, there has improved seed production of vegetables, brought about a more convenient market for vegetables, and increased household production. However, agricultural productivity and efficiency studies (exception Bayarsaihan and Coelli, 2003) still seem to be rare but, there is no complex analysis for vegetable production.

This dissertation focused on the vegetable market analysis (especially substitution elasticity between import and domestic vegetable), and vegetable production technical efficiency (especially household level by using the Stochastic Frontier Analysis). Substitution elasticity called the Armington model is based on the assumption of products distinguished by place of production. In other words, it depends on the degree of substitutability between domestic products and import products (Armington, 1969). A greater elasticity indicates that consumers did not differentiate between domestic and imported products and consumers considered them similar. Therefore, this dissertation provides to define the home bias value using substitution elasticities. Finally, vegetables' production efficiency has estimated by SFA (Aigner et al., 1976) method. Consequently, reliable our research results on the efficiency of vegetable production can help to contribute to policies that increase vegetable production, improving domestic food supplies for policymakers.

1.1 Problem statement

According to Maslow (1943) hierarchy of needs, foods are one of the physiological needs. Thus, peoples always face the challenges of using quality, nutrition, and safe food every day. Nowadays, food security, food safety, and sufficiency are considered to be very important concepts in every country. These concepts are defined as being able to access adequate food, available sufficient quantities of food on a consistent basis and obtain appropriate foods for a nutritious diet, and not being at risk of losing. According to the definition of the World Food Summit (1996), food security

> " *exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life*".

In Mongolia, according to the "Law of Food", food security has defined as *"All people consume to sufficient, quality, safe and nutritious food that does not matter economic, social and geographic conditions"* (Mongolian Government, 2012). Therefore, a standard population's optimal consumption was identified by Nutrition Research Center and by the statement of the Ministry of Health and Social Protection (former name) in 1997 which was defined 13 commodity groups (namely, meat and meat products, milk, dairy products, flour and flour products, all types of rice, sugars and sweeteners, potato, vegetables, fruits and berries, pulses, egg, and edible oil) by the National Statistical Organization, Ministry of Agriculture and Food, Nutrition Research Center associated with Mongolian Government announced "Food security year" of 2008.

Vegetables are more important components of a healthy diet. The main crops of Mongolia comprise the staple food of Mongolians are wheat, potato, and vegetables (Park et al., 2016). Currently, wheat and potato consumption has supplied 100 percent of domestic production but vegetable supply is still has been imported. However, vegetable production increased to meet approximately 60 percent of the supply level of domestic production in 2019 (National Statistics

Office of Mongolia, 2019). Such as approximately 57.3 percent of cabbage, 64.1 percent of onion and garlic, 51.9 percent of melons, 20.7 percent of tomato, 9.3 percent of cucumber, and 5.2 percent of carrot and turnips consumptions provided by import vegetables in 2019. Therefore, most of the vegetables were imported from the People's Republic of China. For example, 80 % of the onion, garlic import, 99% of the cabbage, 60% of the carrot, turnips were imported from the People's Republic of China last year.

Based on the 2019 data from the National Statistical Office (NSO) of Mongolia, the monthly per capita consumption rates were about 2.6 kg/month for potatoes and 1.8 kg/month for vegetables, which is less than the 3.6 kg/month of potatoes and 7.2 kg/month of vegetables recommended by the Ministry of Health. While current potato production almost meets the per capita recommendation, vegetable production needs to be increased by around 75%. Also, vegetable consumption is 6 times lower than the recommended intake by WHO. Therefore, Mongolia has one of the highest incidences of cardiovascular disease (rank was #14 in the world), which is also the country's leading cause of death. One of the main reasons is lower fruit and vegetable consumption to increase the risk of noncommunicable diseases. It is evidenced that Mongolian people do not use to not too many vegetables every daily diet.

Thus, the Mongolian government attention to this situation, there were implemented many projects to increase vegetable domestic production and possible to supply domestic consumption. Mongolia has made strides to become self-sufficiency potato production, but until now, vegetable farming has received undeveloped and inefficient. However, agricultural productivity and efficiency studies (including Bayarsaihan and Coelli, 2003) still seem to be rare but, there is no efficiency analysis of household-level vegetable production. Many policymakers need to focused on improving productivity and efficiency as an important source of potential growth in vegetable production. Because vegetable production development causes vegetable household production regarding dominant vegetable production.

Nowadays, food safety and food sufficiency are considered very important, and as well as consumer consumption has been increasing. Indeed, we need to pay attention to the increase of food production (especially vegetable production) that meets the food hygiene standard, its consumption increase, and the full supply of domestic production.

1.2 Significance of the study

The vegetable is a primary healthy food staple. It shares a little part of the Mongolian's daily diet. But last a few years it has been changing due to urbanization and concentration. Such as, half of the population of Mongolian (approximately 1.5 million people) live in the urban area. For this reason, policymakers have become particularly concerned with vegetable domestic production. Thus, our research focuses on a substitute to possible domestic vegetable for import vegetable and focus on the efficiency of vegetable production. Also, our study characteristics are never being applied to a comprehensive study of vegetable production in Mongolia. Therefore, our study's significances are as follows:

First, it is determined a complex analysis of the vegetable market. Especially, it is characterized that estimated of substitution elasticity between import and domestic vegetable production using the Armington model. Also, we determined home bias value for vegetable consumption which indicates consumers' preference.

Second, the Armington model is characterized by product level. Most of the previous studies were focused on the industry level.

Finally, our study was characterized by applied technical efficiency analysis using household-level data.

1.3 Objectives of the study

In correspondence to the previously mentioned problems, the overall objective of this study is to analyze the current situation of the vegetable market, and determine technical efficiency level and investigate a recommendation for vegetable production for policymakers in Mongolia. The objective of this study will serve four main purposes:

First, it will describe an analysis of the vegetable market situation and main production location in Mongolia.

Second, it will present an estimation elasticity of substitution for import vegetables using the Armington model and home bias value in Mongolia.

Third, it will investigate the technical efficiency of vegetable household production and determine impact factors to technical efficiency in Mongolia.

Four, it will define recommendations for policymakers to make a consistent policy for increasing vegetable production, improving food supplies, and increasing household income in Mongolia.

1.4 Research questions and hypotheses

Based on the estimation of substitution elasticity using the Armington model objectives and the literature review the following hypotheses were formulated:

> *Hypotheses 1:* Long-run substitution elasticity higher than short-run substitution elasticity of vegetables
>
> *Hypotheses 2:* Home bias value in long-run is higher than short-run home bias value in vegetables
>
> *Hypotheses 3:* Vegetable import price elasticities are higher than domestic price elasticities.

Based on the technical efficiency of the household vegetable production objectives the below research questions:

1. Are vegetable household producers in Mongolia technically efficient?
2. What are the main influencing factors to vegetable household production? Does vegetable household's (smallholder) output value significantly and positively increase with the increase in inputs?
3. Is there any relationship between a vegetable household size (smallholder size is depending on land size) and technical efficiency?
4. What are the main factors that influence the technical efficiency of vegetable household production levels?

II. RESEARCH MATERIALS AND METHODS

2.1 Determinants of the Armington substitution elasticities

Since the seminal work conducted by Armington (1969), the Armington model has been widely used to evaluate international trade policy in applied international economics.

2.1.1 Armington model

In a country that has an open economy and free liberalization trade, it is influencing to expanding the consumer choice of country and consumer's basket constitutes from home goods and foreign goods. Thus, consumer utility is based on consuming between domestic goods and foreign goods. In other words, consumer distributes their spending between domestic and various import goods and they may reconsider their choice whenever relative international prices change. Armington formulated the demand theory for tradable goods in 1969. After that, so-called Armington elasticities are based on the differentiation of products with respect to their origin and the imperfect substitution in demand between domestic products and import supply. Using a two-stage budgeting method, he supposed in the first stage that a buyer (or importing country) determines the total quantity to buy to maximize the utility, and in the second stage, allocates shares of the total quantity to individual suppliers (or exporting countries) in order to minimize the costs. In the first-stage equation, he specifies the total demand for both foreign and domestic products as the dependent variable (Huchet and Pishbahar, 2008). For the second-stage equation, Armington (1969) made two main assumptions:

1. The elasticity of substitution for each market are constant
2. The elasticity of substitution between any two products competing in a market is the same as that between any other pair of products competing in the same market.

These two assumptions, which are together regarded as the 'single CES assumption, allow us to reduce the number of coefficients to be estimated and make the estimation process easier. Armington elasticity is an indication of the degree of substitution between domestic products and imported products. Higher elasticity indicates greater substitution between domestically produced products and imported products which means these products are identical. On the other hand, lower elasticity means that these products are dissimilar and weak substitutes. Product differentiation does not turn on physical differences between goods alone. Physical identical goods may be differentiated by availability in time, the convenience of purchase, after-sales service, or even consumers' perceptions of inherent. But, consumer' perception of inherent quality has been shown to be strong in some cases, even when they are shown that they cannot distinguish between the two products when using them. However, Blonigen and Wilson (1999) have studied influencing factors to the difference of Armington elasticity across industrial sectors. They found that strong support variable foreign-owned industries affect substitution between domestic and import goods. Based on the Armington approach, the structure of Armington demand has succinctly been described by following Figure 1. In other words, consumer demand constitutes domestic products and import products. In the Armington model, consumers have a two-stage budgeting process. In the first stage, consumers (or importing country) decide between domestically produced and imported products (macro elasticity), and in the second-stage, imported products are differentiated by country of origin (micro elasticity).

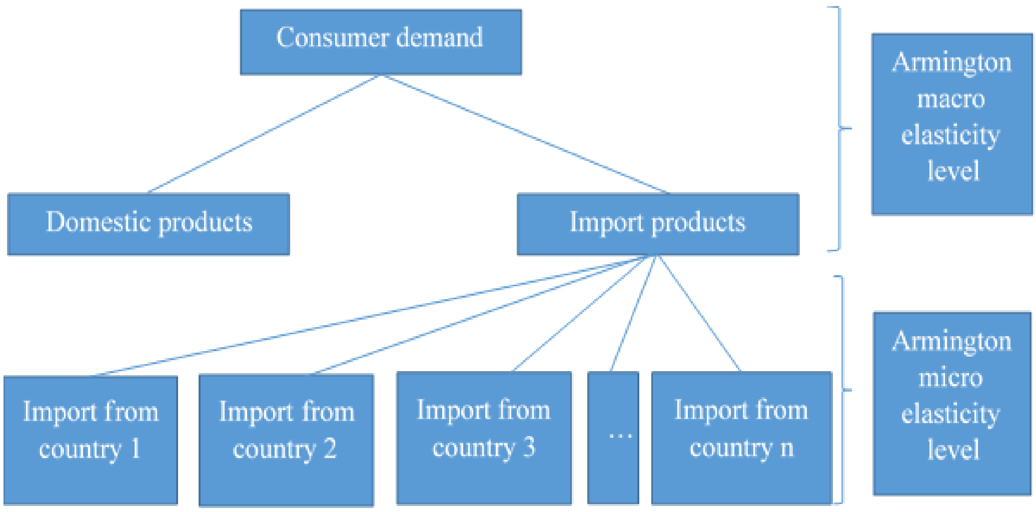

Figure 1. Structure of Armington demand
Source: Wunderlich and Kohler, (2018)

According to Armington's theory, much of the occurring literature in assuming that consumer utility is given in the form of a constant elasticity of substitution (CES) sub-utility function in order to model the demand for domestic and imported products. If consumers are to be satisfied, demand functions state relationships that must exist among specific variables. Consumer satisfaction depends on getting the most for their money, given the available selection of products and their prices. Demand functions may along these lines be seen as statements of conditions under which an index of consumer's satisfaction is high as restricted incomes and given prices permit (Armington, 1969).

2.1.2 Empirical specification

The elasticity of substitution between home goods and import goods can be derived from the two-stage budgeting process. In the first stage, the consumer determines the total quantity to buy to maximize the utility. In the second stage, the consumer allocates a share of the total quantity to the individual supplier in order to minimize the costs. Armington models typically specify a constant elasticity of substitution (CES) function. Previous studies related to the Armington model have been using base CES sub-utility function in order to model such as (Wunderlich and Kohler, 2018; Olekseyuk and Schürenberg-Frosch, 2016; Welsch, 2008; Reinert and Roland-Holst, 1992) et al. Therefore, we assume that consumer maximizes sub-utility U, who use domestic products and foreign products at the same time and same products. Our CES (Constant elasticity of substitution) sub-utility function is based on Blonigen and Wilson (1999) approach (also used in Wunderlich and Kohler, 2018) follow as:

$$\mathrm{U} = (\beta \mathrm{M}^{\frac{\sigma-1}{\sigma}} + (1-\beta)\mathrm{D}^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma-1}} \tag{2.1}$$

$$\text{s.t} \qquad I = P_M M + P_D D$$

Where U is consumer sub-utility, M is *the* quantity of import goods, D is *the* quantity of domestic goods, β is a parameter that weights the import good relative to domestic good, σ is the elasticity of substitution between imports and domestic goods, I is the consumers' total income, P_M is the import price, and P_D is the domestic price. Additionally, we assumed that the CES sub utility function is homothetic that is means the share of income spent on domestic and imported goods does not change with income. In order to maximize utility, prices are made equal to the marginal utility derived from purchasing the associated products so that $\frac{\partial U}{\partial M} = P_M$ and $\frac{\partial U}{\partial D} = P_D$. The solution to the optimization problem is to choose a combination of imported and domestically produced goods to function written as:

$$\frac{P_M}{P_D} = \frac{\beta}{1-\beta}\left(\frac{M}{D}\right)^{\frac{-1}{\sigma}} \quad (2.2)$$

Therefore, to see the implication from equation (2.2), we obtain the ratio of domestic goods and import goods

$$\frac{\mathrm{M}}{\mathrm{D}} = \left[\frac{\beta}{1-\beta} \cdot \frac{\mathrm{P_D}}{\mathrm{P_M}}\right]^{\sigma} \quad (2.3)$$

Where P_D is the price of domestic goods, P_M is the price of import goods. Taking natural logarithm yields:

$$\ln(\frac{\mathrm{M}}{\mathrm{D}}) = \sigma \ln\left(\frac{\beta}{1-\beta}\right) + \sigma \ln(\frac{\mathrm{P_D}}{\mathrm{P_M}}) \quad \text{or} \quad \ln(\frac{\mathrm{M}}{\mathrm{D}}) = a_0 + a_1 \ln(\frac{\mathrm{P_D}}{\mathrm{P_M}}) + \varepsilon \quad (2.4)$$

Equation (2.4) is our general econometric estimation model, where $a_0 = \sigma \ln\left(\frac{\beta}{1-\beta}\right)$, a_1 is short-run substitution elasticity. The short-run Armington elasticity can be derived directly from the estimated coefficient of the price relation between domestically produced and imported products. However, long-run elasticity can be derived from three different ways (McDaniel and Balistreri, 2002; Wunderlich and Kohler, 2018). First, our data (time series of quantity and price series) are stationary log-level data I (0), we estimate using the parsimonious geometric lag model (eq. 3.8) which is easy to extract short-run and long-run estimates. In other words, if 0<a_2<1 is long-run elasticity can be estimated $\sigma^* = \frac{a_1}{1-\ a_2}$.

$$\ln\left(\frac{M}{D}\right)_t = a_0 + a_1 \ln\left(\frac{P_D}{P_M}\right)_t + a_2 \ln\left(\frac{M}{D}\right)_{t-1} + \varepsilon \quad (2.5)$$

Second, if data are both stationary I(1) and cointegrated, we use a single-equation error correction model that determines the long-run elasticity (equation 2.6 is unrestricted error correction model).

$$\Delta\ln\left(\frac{M}{D}\right)_t = a_0 + a_1 \Delta\ln\left(\frac{P_D}{P_M}\right)_t + a_2 \ln\left(\frac{M}{D}\right)_{t-1} + a_3 \ln\left(\frac{P_D}{P_M}\right)_{t-1} + \varepsilon \quad (2.6)$$

Finally, our data are stationary I(1), but not cointegrated or one series is stationary, we able to determine only short-run Armington elasticity. However, we determine short-run elasticity using the following equation.

$$\Delta\ln\left(\frac{M}{D}\right)_t = a_0 + a_1 \Delta\ln\left(\frac{P_D}{P_M}\right)_t + \varepsilon \quad (2.7)$$

Home bias value

The home bias concept is consumer preferences in favor of home-produced over foreign-produced goods (Whalley and Xin, 2009). The literature contains a variety of characterizations of home bias. For example, some researchers have studied home-bias related to geography (Hillberry and Hummels, 2002). Blonigen and Wilson (1999) discussed home bias exclusively in terms of preferences in the home country and provide a measure of home bias that links the elasticity of substitution. In other words, it has estimated intercept from Armington elasticity regression. We can calculate a home bias using substitution elasticity following as: $1-\beta=\frac{1}{1+\exp(\frac{a_0}{a_1})}$. β is indicated import weight on consumer total demand. In other words, β coefficient is defined by equation 2.8.

$$\beta=\frac{\exp(\frac{a_0}{a_1})}{1+\exp(\frac{a_0}{a_1})} \quad (2.8)$$

Estimating the price elasticities of import demand and domestic demand

The price elasticities of demand measure the response of consumers to changes in prices. Such elasticities give the percentage change in demand for a product in the case of a 1% change in the price for the particular good. Typically, price elasticities of demand for consumer goods and services are estimated between 0 and more than −1. A price elasticity larger than −1 is elastic. If the demand for a good is inelastic (price elasticity is close to zero), the changes are small in the case of increasing prices. Specifically, the necessities of daily life and goods with fewer substitutes are inelastic and have lower elasticities. I try to define elasticities for the price of import demand and domestic demand in the short-run and long-run using the home bias parameter. The import and domestic production causes by the price of import and demand, which is is shown below in equations (2.9) and (2.10).

$$lnM=\frac{1}{1-\rho}ln\beta-\frac{1}{1-\rho}lnP_M+lnD-\ln\left(\beta^{\frac{1}{1-\rho}}P_M^{-\frac{1}{1-\rho}}+\ (1-\beta)^{\frac{1}{1-\rho}}P_D^{-\frac{\rho}{1-\rho}}\right) \quad (2.9)$$

$$lnD=\frac{1}{1-\rho}\ln(1-\beta)-\frac{1}{1-\rho}lnP_D+lnM-\ln\left(\beta^{\frac{1}{1-\rho}}P_M^{-\frac{1}{1-\rho}}+\ (1-\beta)^{\frac{1}{1-\rho}}P_D^{-\frac{\rho}{1-\rho}}\right)$$

(2.10)

The solution to the price elasticities of import and domestic demand, whose derivatives by the price of import and domestic from equation (2.11) and (2.12).

$$E_{P_M}^{M} = -\frac{1}{1-\rho} + \left(\frac{\rho}{1-\rho}\right) \frac{\beta^{\frac{1}{1-\rho}} P_M^{\frac{\rho}{1-\rho}}}{\left(\beta^{\frac{1}{1-\rho}} P_M^{-\frac{1}{1-\rho}} + (1-\beta)^{\frac{1}{1-\rho}} P_D^{-\frac{\rho}{1-\rho}}\right)} \tag{2.11}$$

$$E_{P_D}^{D} = -\frac{1}{1-\rho} + \frac{(1-\beta)^{\frac{1}{1-\rho}} P_D^{-\frac{\rho}{1-\rho}}}{\left(\beta^{\frac{1}{1-\rho}} P_M^{-\frac{1}{1-\rho}} + (1-\beta)^{\frac{1}{1-\rho}} P_D^{-\frac{\rho}{1-\rho}}\right)} \tag{2.12}$$

The σ and ρ are relative below the equation.

$$\frac{1}{1-\rho} = \frac{\sigma}{2\sigma-1}, \ \frac{\rho}{1-\rho} = \frac{1-\sigma}{2\sigma-1}$$

Where ρ, σ- elasticities of substitution, $E_{P_M}^{M}$- elasticity of import price, $E_{P_D}^{D}$- elasticity of domestic price, P_M- average price of import, P_D −average price of domestic, β- optimal allocation parameter.

2.1.3 Data collection

This study estimates the substitution macro elasticity (see figure 1) and uses time-series data series. There are need to require four data series which are vegetables import and domestic production and the prices of those products. I choose the six vegetables due to a lack of information. These vegetables are potato, tomato, garlic and onion, cabbage, carrot and turnips, and cucumber. This study uses the yearly data of the National statistical yearbook, Customs yearbook (https://customs.gov.mn/statistics/, Harmonized System (HS) code was 07 categories products), and Mongol Bank (Central bank of Mongolia) yearbook data from 1995 to 2019. All quantities are given in a thousand tons and prices in real (base period was chosen 2015 values) MNT (Mongolian currency tugrik) per ton. Vegetables domestic production quantity was collected from Statistical yearbook for Agriculture sector, Mongolian Statistical yearbook and www.1212.mn official statistical website for each product. Wunderlich and Kohler, (2018) have estimated Armington elasticities using a retail price measured in stores barcode scanner. Thus, I am able to use retail prices for domestic vegetables which are published by National Statistical Offices (NSO). Furthermore, vegetable import quantity gathered from Customs yearbook for each product. The import unit price was calculated as the ratio between the customs value of these vegetables and quantity multiplied by the exchange rate. In other words, the import price for each vegetable constructed from: $P_M = \frac{\sum Customs\ value\ of\ each\ prodct}{import\ quantity\ of\ each\ product} \cdot exchange\ rate$. The annual exchange rate data is used for converting US $ to MNT. The final step is all prices converted to real prices using the Laspeyres index.

2.2 Determinants of technical efficiency

The efficiency concept is pioneered by Farrell, (1957), there are two widely used methods of measuring the efficiency of a decision-making unit: The Data Envelopment Analysis (DEA) - non-parametric approach and the Stochastic Frontier Analysis (hereafter SFA)- parametric approach. My research determines the technical efficiency of vegetable smallholder production in Mongolia using the SFA. Thus, this part describes the SFA.

2.2.1 Stochastic frontier analysis (SFA)

The stochastic frontier analysis approach was independently proposed by (Aigner et al., 1976; Meeusen and Broeck, 1977). After that, the SFA model has been widely used to estimate the technical efficiency in applied economic research. The stochastic frontier production function has two error components: One is to account for the existence of technical inefficiency of production and the other one is express random error. Early stochastic frontier analysis applications were based on a two-step estimation method. For example, Bravo-Ureta and Pinheiro, (1993), Kalirajan, (1981) have utilized a two-step estimation method. The first step is to estimate a standard stochastic frontier model. The second step is to estimate the relationship between estimated inefficiency and influencing factors of a firm's characteristics. But this two-step estimation approach contradicts the assumption on the independence of inefficiency effects in the stochastic frontier model. A number of researchers solved this problem in their studies using a single-step estimation approach. For example, Seok et al., (2018), Kumbhakar and Lien, (2010), Nyemeck et al., (2008), Wang and Schmidt (2002), Bozoglu and Ceyhan, (2007), Battese, (1995), etc. The single-step estimation approach with output-oriented technical efficiency function is defined by the following equation.

$$y_i = \exp(f(x_i, \beta) + v_i - u_i) \tag{2.13}$$

$$\varepsilon_i = v_i - u_i \tag{2.14}$$

Where y_i represents output, x_i denotes a set of inputs and β is parameters to be estimated, i is the i^{th} firms or individuals, ε_i is error term which is indicated a composed error, difference between stochastic error and technical inefficiency, v_i is the random error (stochastic), and u_i is the non-negative random variable of the technical inefficiency part. The error component u_i needs to satisfy the assumption $u_i \geq 0$. The technical inefficiency part is defined by the following equation:

$$u_i = \alpha z_i + w_i \qquad (2.15)$$

Where u_i is represented the mean of αz_i with truncated normal distribution at zero and σ^2 variance, α is estimated parameters, z_i is the technical inefficiency explanatory variables, and w_i is determined by the truncated normal distribution with non-zero mean and variance, σ^2. The technical efficiency of the firm i is indicated in the following equation:

$$TE_i = \exp(-u_i) \qquad (2.16)$$

The value of the technical efficiency takes between 0 and 1. If the firm is fully efficient that TE_i is equal to 1.

My study has used truncated-normal distribution to estimate technical efficiency. The truncated-normal distribution approach proposed by Stevenson (1980) which allows the inefficiency distribution has a nonzero (μ) mean and variance σ^2. In other words, u_i can be defined as $N^+(\mu_i, \sigma_u^2)$. If $\mu = 0$, it collapses to a half-normal distribution model. The function of exogenous variables for technical efficiency is defined by following general function form.

$$\mu_i = \alpha z_i' \qquad (2.17)$$

Where, z_i' is the vector of exogenous variables, α is the estimating parameter. The single-step estimation approach is more preferably used in efficiency analysis.

3.2.2 Empirical specification

The Cobb-Douglas production function mostly dominates in stochastic frontier analysis using cross-section and panel data. My stochastic production frontier model in the following equation (2.18) is estimated using the form of the Cobb-Douglas production function. The Cobb-Douglas production function is described by the following function. The SFA model can be written as:

$$lny_i = \beta_0 + \sum_{j=1}^{5} \beta_j \, lnx_{ij} + v_i - u_i \quad (2.18)$$

Where, ln- is expressed natural logarithm, y_i- is the total income from vegetable production of i^{th} household (smallholder), x_{ij}- is denotes of j^{th} inputs of the i^{th} household j is the number of inputs variables, j= 1, 2, 3 …. 5, namely, sown area (ha), seed cost (million MNT, MNT is the abbreviation of Mongolian currency tugrik, hereafter MNT), labor (man/days), used manure (ton), capital (million MNT) is aggregated value of total machinery cost plus total expenditure on machinery rent cost for cultivation, harvesting, manure, pesticide and diesel cost on cultivation, harvesting and transportation cost to market. β_0, β_j are to be estimated coefficients. v_i is the random error that was assumed to be independently and identically distributed with $N(0, \sigma_v^2)$, u_i is a non-negative random variable, which is assumed distribution of truncated distribution with $N^+(\mu_i, \sigma_u^2)$. The elasticity of inputs x_j is given by

$$E_j = \frac{\partial lny_i}{\partial lnx_j} = \beta_j \quad (2.19)$$

Vegetable household production's return to scale (RTS) is defined by

$$RTS = \sum_j^5 \beta_j \quad (2.20)$$

The technical inefficiency function is defined as:

$$u_i = \alpha_0 + \alpha_1 size + \alpha_2 age + \alpha_3 sex + \alpha_4 edu + \alpha_5 exp + \alpha_6 nfi + \alpha_7 cre + + \alpha_8 lfi + w_i \quad (2.21)$$

Where, α is estimated parameters, *size* is the number of family members, *age* is the age of household heads, *sex* is household head's sex, which is dummy variable value is one if has female, two is male, *edu* is the household head's education level i.e. value of one if household head is illiterate, two if has a primary school, three if has a secondary school, four if has associated and five is a bachelor (graduate university), *exp* is the experience of household heads in vegetable production, *nfi* is the non-farm income dummy variable (non-vegetable income=1, otherwise 0), *cre* is the credit also dummy variable (if the household has a credit =1, otherwise 0) and *lfi* is the land fragmentation index. Maximum-likelihood estimates of the parameters for the stochastic frontier production function were obtained using the Stata.14 computer program. An important test to check the existence of technical inefficiency exists is one-sided error specification. This amount to a test for the presence of u_i in the model, and a generalized likelihood ratio (LR) test for the null hypothesis of no one-sided error can be constructed based on the log-likelihood values of the OLS (restricted) and the SF (unrestricted) model. The LR test statistic is $-2[L(H_0) - L(H_1)]$, where $L(H_0)$ and $L(H_1)$ are log-likelihood values of the restricted model and the unrestricted model, respectively, and the degree of freedom equals the number of restrictions in the test (Kumbhakar et al., 2015).

2.2.3 Study population

The research population for this study was vegetable households (smallholder farmers) in Mongolia. Private vegetable household production is a relatively new industry in Mongolia. Mongolia is located in Central Asia and has a total area of 1564.2 thous.km square. It is divided into five sized economic regions, namely Western, Khangai, Central, Eastern, and Ulaanbaatar area. The country consists of 21 provinces and the capital city. The provinces are divided into 330 soums (sub-provinces). The Mongolian population is nearly 3.2 million, while the population density was 2 persons per kilometer square, but 311 persons per kilometer square in Ulaanbaatar (National Statistics Office of Mongolia, 2019). Mongolia has an extreme climatic condition. The country is dryland and has a low level of precipitation, and absolutely temperature is from -28°to -54° Celsius in winter and from +30°to +45° Celsius in the summer.

Currently, vegetable household production consists of approximately 80 percent of total vegetable production in Mongolia (Table 1). Vegetable household is mainly growing potato, carrot, turnips, cabbage, onion, garlic, cucumber, tomato, watermelon, and melons. In 2019, there are approximately 14728 households and 1401 companies are engaged in crop production. About the household covered by a region, it locates 63.2 percent in Western and Central regions, 18.4 percent in the Khangai region, 9.3 percent in the Eastern region, and 9.2 percent in the Ulaanbaatar region (National Statistics Office of Mongolia 2019).

Table 1. Vegetable production, by producers, national level

Types	Company		Household		Total, thousand ton
	Thousand ton	Share, %	Thousand ton	Share, %	
Potato	44.8	23.3	147.5	76.7	192.2
Vegetables	22.9	23.0	76.6	77.0	99.5

Source: Mongolian statistical yearbook, 2019

2.2.4 Sample size

According to the Agriculture statistics report of Mongolia (2019), there was 14728 vegetable household (smallholder farmers). My study could not be studied in entirely the population. Therefore, in this research, the total random sample was 300 vegetable households from the Khovd and the Selenge provinces in the Western and the Central regions. These regions are the main vegetable-producing regions in Mongolia. In 2019, the Central region produced 76.7% of the potato and 62.4% of the vegetables followed by the Western region 9.5% of the potato and 18.9% of the vegetable production. The Central region was the largest producer in Mongolia, with a total of 147.4-thousand-ton potato and 62.1-thousand-ton vegetable. The second-largest producer in vegetable production was the Western region, with a total of 18.9 thousand tons (National Statistics Office of Mongolia 2019). Thus, my study data collection's sample distribution showed in Table 2. I used a multi-stage stratified random sampling technique to select the respondents following principles. First, I choose the dominant regions (namely, Central and Western regions) in vegetable production using secondary data. Second, I determined 2 provinces based on vegetable output. Third, I identified soums in provinces. Lastly, I selected randomly 300 households in these soums and selected the equal number of households from each soum.

Table 2. Sample distribution

Regions	Provinces	No. of households (vegetable farmers)	Sample households
Western	Khovd	860	150
Central	Selenge	3386	150
Total		4246	300

Source: www.1212.mn, field survey conduct in Mongolia

The study collected data from all the 300 households from 9 soums (Buyant, Myangad, Jargalant, Khovd, Zuunburen, Mandal, Sant, Khushaat, Sukhbaatar) in two provinces.

2.2.5 Data collection

My data used in the study was collected from household growing vegetables in the Khovd and Selenge provinces. To examine the technical efficiency of vegetable household production, primary data was collected through a semi-structured questionnaire using a random sample technique. The semi-structured questionnaire is including respondents related to vegetable production quantity, vegetable price, inputs (seed quantity and price, used manure, pesticide, herbicide's quantity and price, diesel cost, maintenance cost, etc. Also, the household's main characteristics indicators age, sex, education, non-farm income, distance to water, distance to market, etc. My research field survey was carried out in two stages. In the first stage, my questionnaire was pre-tested 100 randomly selected vegetable households in Khovd province between July and August in 2019. This pre-tested survey helped to improve and ascertain my questionnaire. After that, second stage, my research was carried out between November 2019 and January 2020 including 300 vegetable households in Khovd and Selenge provinces in Mongolia. Specialists of the Agriculture Administration Office (AAO) of Province helped me to collect my data during this period.

2.2.6 Descriptive statistics and variable meaning

For the household production function, my study used one output (sales income of the household) and five inputs including sown area, seed cost, manure cost, labor, and capital. Table 3 shows the summary statistics of our variables. The sampled vegetable households are growing comparative many vegetables including potato, carrot, cabbage, onion, garlic, tomato, cucumber, watermelon, and melons. The dependent variable for the production function to estimate technical efficiency is sales income of household (output value) in currency (MNT). The monetary value as a dependent variable has been addressed in some empirical studies (Seok et al., 2018; Kovács and Pandey, 2017). Sales income is calculated by household vegetable sales income. The output price and sales quantities were gathered from the household. All vegetable sales of the household were aggregated into one output value (Mongolian tugrik, hereafter MNT). Therefore, I divided it into 2 sections to collect price information in my questionnaire. Because the wholesale vegetable price and retailed prices are different. In other words, the wholesale price is lower than the retail price. Because the harvesting period is very short (between May to September) in Mongolia and some of the households keep vegetables to sell at a higher price in winter and spring time. Sample vegetable household revenue averaged approximately 12.02 million MNT.

Land is the one of important main inputs in vegetable production. Thus, my study collected sown area (used land size) of the vegetable household production. The average sown area for the sample household was 2.04 ha, the minimum sown area was 0.09 ha and the maximum sown area was 10 ha. Some of the households could not able to use the whole of the land. Because they face too many challenges to use total land for vegetable production. For example, lack of money, lack of labor, lack of machinery and tractor, seed price is higher, etc. land input expected to have a positive effect on household vegetable production.

Table 3. Descriptive statistics of households' vegetable production in 2019

Variables	Mean	Standard deviation	Minimum	Maximum
Sales income, million MNT	12.02	11.26	1.40	74.20
Sown area, ha	2.04	1.62	0.088	10.00
Seed cost, million MNT	2.05	1.87	0.037	12.72
Labor man/days	179.57	140.27	25.00	873.62
Used manure, ton	24.14	28.30	2.00	160.00
Capital, million MNT	11.87	8.00	1.08	50.07
Family size	4.33	1.69	1	10
Household head's age	46.73	11.10	24	74
Household head's sex	1.95	0.21	1	2
Education	3.60	0.94	1	5
Owner's experience	15.34	9.61	2	42
Non-farm income	0.37	0.48	0	1
Credit use	0.73	0.44	0	1
Land fragmentation index	0.54	0.29	0.11	1.25

Source: Randomly selected 260 households' observations

Labor input variable measured man/days. Total labor indicated as total annual working days, including family member's working days and hiring workers working days on the cropland. Most of the households responded that hiring workers during the cultivating and harvesting period otherwise, family members work on the cropland. The average labor was 179.6 man/day. Some of the researchers mentioned that labor negative effect on agricultural production. Because, in developing countries, most of the labors in agricultural production such as rice production, vegetable production, palm production et.al are unskilled, low productivity, and not well educated (Kea et al., 2016). Conversely, most of the researchers revealed that labor positive effect on production. In other words, labor is input to participating in the production process. Therefore, labor was expected to have a positive effect on household vegetable production.

Seed cost input was the total amount of expenses for vegetable seed in MNT. Most of the household was sowing by average 4 to 6 kinds of vegetables. Thus, this input could not indicate quantity. Therefore, I asked that bought see quantity and price. After that, I calculated the total seed cost for every household. Most of the households responded that to buy seed on sowing period. Because they do not have enough warehouse but some household has a warehouse. Fifty-two percent of the sampled household responded that had a warehouse. Seed cost was expected to have a negative and positive effect on vegetable production. Because, if seed cost is higher which causes a reduction of the vegetable output. Manure is one of the main inputs in vegetable production in Mongolia. Most of the households used organic manure during the sowing period. Used manure quantity is measured as a ton. The maximum used manure quantity was 160 tons; the minimum used manure quantity was 2 tons. Average quantity is 24.1 tons. Manure is expected to have a positive effect on vegetable output.

The capital was calculated the aggregate value of machinery and technical equipment and total expenses for diesel cost, maintenance cost for machinery, rented machines cost, seed cost, manure cost, pesticide, and herbicide cost, labor safety cost within a year. In other words, machinery and technical equipment are including agricultural machinery (tractors, trucks for transportation, car, pumping machines, pesticide prayers, and motorcycles) owned by the household. I calculated the net value for total machinery with total expenses for purchasing and annual depreciation. Capital investment was expected to have a positive effect on vegetable production. In other words, the more capital household has a generate higher opportunities than a few capital households.

In the technical inefficiency model, there were eight factors of household vegetable production. Exogenous variables that we hypothesize will affect technical inefficiency based on previous studies. Household characteristics are including family size (number of a family member), household's head age, sex, education and experience, non-farm income, credit use, and land fragmentation.

Sample vegetable households averaged 4.33 family members and 95% of the total household head was male. My study hypothesis between family size and technical efficiency is that the larger families are more efficient with fewer families. Because most of the household members work in the field of vegetables. Some empirical studies result show larger families appear to be more efficient than smaller families. This finding is consistent with the work of (Bravo-Ureta and Pinheiro, 1993; Abdulai and Eberlin, 2001). When they could not able enough family members, they hire a worker for the harvesting and cultivating period. Therefore, family size is expected to have a positive effect on technical efficiency. The household head's sex is male which means that males decision more than females in the household. This hypothesis is confirmed by (C.Kumbhakar et al., 1991).

For the education variable, if have education level has higher, it enhances farm technical efficiency (Fuwa et al., 2007; Seok et al., 2018). It shows that the education of the household head and, i.e. education value of one if household head is illiterate, two if has a primary school, three if has a secondary school, four if has associated and five if a bachelor (graduate university).

Household head's averaged 46.7 years old and their experience in vegetable production was 15.3 years. Age and experience variables are indicated the possibility of farmers adopting innovations and more technical skills. But some of the authors such as Bozoglu and Ceyhan, (2007) mentioned that younger farmers are more quickly adapted to innovations. Thus, these variables positively affected technical efficiency confirmed by (Seok et al., 2018; Anang et al., 2016; Mwajombe and Mlozi, 2015), etc. My study hypothesis is household heads older and more experience are more technically efficient. In other words, these variables are expected to a positive impact on technically efficient. We gathered data on non-farm income, it represents the relationship between technical efficiency and the existence of non-farm income. Because some of the households have another source of income. For example, in the exception of vegetable production, there has livestock and some of the family members work public sector and retire. The non-farm income variable was a dummy if the household has a non-farm income is equal to 1, otherwise 0. The previous empirical studies results are ambiguous that non-farm income how to affects production efficiency. For example, some of the researchers' non-farm income revealed a negative effect on production efficiency. Contrary to other researchers, non-farm income positive effect on production efficiency.

Also, we estimate the relationship between technical inefficiency and credit use. Credit can help to increase technical efficiency because the household decides to overcome financial constraints for the purchase of inputs (Abdulai and Eberlin, 2001). For example, seed, rent a tractor during the cultivating period. Credit use indicates dummy variable if the household used credit to 1, otherwise 0. The household land fragmentation average index was 0.54. I calculated the land fragmentation index in vegetable household production in Mongolia using the respondent's response. Most of the sampled household was planted potato, turnips, carrot, cabbage, watermelon, and onion. The relationship between land fragmentation and technical efficiency is ambiguous. For example, some of the authors Tan et al., (2010) mentioned that an increase in the number of plots causes an increase in technical efficiency. Rahman and Rahman, (2009), Kiprop et al., (2015) argue that increasing land fragmentation goes down technical efficiency. But if the household could manage that, land fragmentation positively affected technical efficiency. Table 4 shows that summary of the hypotheses expected sign.

Table 4. Summary of the hypotheses expected sign of the household vegetable in Mongolia

Variables	Expected sign
Sown area, ha	+
Seed cost, million MNT	+
Labor man/days	+
Used manure, ton	+
Capital, million MNT	+
Family size	+
Household head's age	-
Household head's sex	+/-
Education	+
Owner's experience	+
Non-farm income	+
Credit use	+
Land fragmentation index	-

Source: Own description

III. RESULTS AND DISCUSSION

3.1 Estimation of the Armington substitution elasticities of vegetable products in Mongolia

This part discusses estimating substitution elasticity between domestic vegetables and importing vegetables using the Armington model. A greater Armington model shows that consumers did not discriminate between domestic and imported vegetables. In other words, consumers considered these vegetables are same. Also, this part indicates home bias value and vegetables price elasticities (depend on import and domestic price). Home bias value is higher it means that consumers more used domestic produced products compared to importing products. And price elasticity indicates the measure of the change in the quantity of a purchased product in relation to a change in its price.

3.1.1 Substitution elasticities in short-run and long-run

According to the general econometric model equation (2.4), we estimated Armington elasticities for vegetables in Mongolia. We choose six types of vegetables namely potato, tomato, garlic and onion, cabbage, carrot and turnips, and cucumber with related to the lack of data. But these vegetables were commonly used in the household diet. To estimate elasticities was to check whether our time series data are stationary and integrated. Indeed, if our data are stationary or the same integrated of order log level I(0) or one I(1), it is possible to determine the relationship between these two variables in the long-run. Additionally, the cointegration relationship is defined by the Engle-Granger test. The Engle-Granger test is only valid that all variables are I(1). In other words, two variables are integrated into the same order but non-stationary (please see empirical specification).

Prior to estimation, we tested data stationery or integrated using Augmented Dickey-Fuller (ADF) test. Non-stationary variables imply the risk of spurious regression unless they are cointegrated. An ADF test for identifying the order of integration for the price and quantity ratio is conducted to determine the order of integration. Most of the series are non-stationary, but integrated of order one, excluding garlic and onion. For the cucumber series, two variables are not cointegrated, only one variable is stationary. Indeed, there is no long-run relationship between these two variables. Also, we tested the Engle-Granger test for integrated variables, we found a cointegrating relationship in other vegetables. Therefore, we estimate elasticities for the short-run and long-run using the approach of (McDaniel & Balistreri, 2002).

Table 5 reports the estimation result of short-run and long-run substitution elasticities derived from the models (equation 2.5-2.7) described in the previous section (see 2.1.2). Of the six types of vegetables short-run elasticities, five vegetable elasticities had positive and significant at 1 %, 5 %, and 10 %. Cabbage's short-run elasticity was not significant. The mean value of the estimated average short-run elasticity of substitution is 1.32, with a significant range between 0.86 and 2.57. The average long-run elasticity is 2.21, with a range between 1.34 and 3.26. Our estimation results are vegetable's long-run average substitution elasticities approximately 2 times higher than short-run average elasticities. This finding is similar to one of the emerged findings from McDaniel & Balistreri, (2002). Also, this result confirmed from other authors' results such as Elena & Emilio, (2002) obtained a coefficient between 0.09 and 5.93 for food manufacturing industries, Abiodun Akintunde Ogundeji, (2007) estimates range between 0.6 and 3.31 for agriculture some products, Kapuscinski & Warr, (1999) indicated average elasticity of 1.5 for vegetables.

Table 5. Armington elasticities estimation result in the short and long run

Vegetable name	Short-run elasticity	Long run elasticity	Ad. R2	DW
Potato	2.571**	1.343**	0.45	1.54
Tomato	1.929**	3.26**	0.45	1.52
Garlic and onion	0.858**	1.808**	0.32	2.01
Cabbage	0.112	2.149	0.24	2.73
Carrot and turnips	1.171***	2.471***	0.18	1.93
Cucumber	-0.412*	-	0.12	1.97

Source: 'Stata' software result

***, **, * -1%, 5%, 10% significance. DW- Darwin Watson

In reviewing the short-run elasticities, garlic, onion, and cabbage's elasticities were ≤ 1, it appears to be a quite difference between domestic and import goods. This means that substitution is becoming harder between these products in Mongolia. This result was reported by Wunderlich and Kohler, (2018) who obtained from fruits and vegetables especially, tomato's elasticities of substitution estimates are quite lower for Switzerland's some agriculture products. In other words, they concluded Swiss people exhibit a strong tendency to buy domestically produced products. Potato, tomato, garlic and onion, carrot, and turnips long-run substitution elasticities were estimated excluding cucumber. For the long-run elasticity, vegetables are tomato, garlic, and onion, cabbage, carrot, and turnips, long-run elasticities are higher than short-run elasticities. The higher elasticity of substitution in the long-run leads to more substitutability between domestic vegetables and imported vegetables. In other words, a greater elasticity indicates that consumers did not discriminate between domestic and imported vegetables and the consumers considered them the same. In this case, these vegetable imports will rise in the long-run in Mongolia. The only potato, import potato will decrease because short-run elasticity is higher than long-run elasticity. In other words, consumers more prefer domestic growing potatoes to import potatoes.

3.1.2 Calculation of home bias value

Table 6 shows the home bias value for vegetables in the short-run and long-run. According to the approach of Blonigen and Wilson, (1999), calculated to home bias value using the Armington elasticities in the short-run and long-run. We found that all the vegetable home bias value was higher ($1-\beta \geq 0.58$), which suggested a higher relative weight on the home good in the short-run and long-run. The short-run home bias value was estimated higher than the import value in the short-run. In other words, consumers express a stronger preference for domestic vegetables for the short-run in Mongolia. The long-run home bias value was estimated lower than the short-run value of all vegetables with the exception of potato, carrot, and turnips. For example, the tomato's home bias value is decreasing from 0.73 to 0.64 (Table 6). Blonigen and Wilson, (1999) primarily discussed home bias value with Armington elasticities. They found that 66 percent of total industries take a higher home bias value of 0.85 or higher.

Table 6. The home bias value result

Vegetable name	Short-run		Long run	
	Import share	Domestic share	Import share	Domestic share
Potato	21.6	78.4	7.8	92.2
Tomato	27.5	72.5	36.1	63.9
Garlic and onion	4.5	95.5	18.9	81.1
Cabbage	10.8	89.2	24.4	75.6
Carrot and turnips	11.2	88.8	3.8	96.2
Cucumber	41.1	58.9	-	-

Source: Own calculation

I calculated vegetable price elasticities using the home bias values. Price elasticity of demand measures the change in consumption of vegetables as a result of a change in price. Thus, I calculated vegetable price elasticities are depending on import price and domestic price using averaged price. Overall, the domestic price of the 1 ton for vegetables is higher than the import price of vegetables. For example, the potato domestic price for 1 ton is 2.7 higher than the import price. Table 7 shows that vegetable price elasticities result. Overall average vegetable price elasticities are -0.625 and -0.306 in the short-run and long-run. Vegetable price elasticity of demand is lower than 1 which means that vegetable is a normal good. Vegetable domestic price elasticity is lower than import price elasticity. On the other hand, elasticities for import prices are higher than domestic price elasticities in Mongolia. It means that with a 1 percentage increase in price, consumers prefer import vegetables more than domestic vegetables.

Table 7. Price elasticities

Vegetable name	Short-run		Long-run	
	P_M elasticity	P_D elasticity	P_M elasticity	P_D elasticity
Potato	-0.622	-0.378	-0.485	-0.246
Tomato	-0.677	-0.324	-0.591	-0.409
Garlic and onion	-1.193	-0.089	-0.804	-0.017
Cabbage	0.144	-0.144	-1.184	-0.642
Carrot and turnips	-0.890	-0.127	-0.656	-0.373
Cucumber	-0.226	-0.774	-	-
Average elasticities	-0.625	-0.306	-0.744	-0.337

Source: Own calculation

The elasticities of import price for garlic and onion in short-run which has highest one elasticity. The elasticity of cabbage import price is the lowest elasticity but insignificant. In the long run, cabbage price elasticity is highest, which is higher than one (-1.184). Potato elasticity is lowest in compared to other vegetables. The elasticities of the domestic price for cucumber in the short run which has the highest (-0.774) in compared to other vegetables. Garlic and onion’s domestic price elasticity is lowest (-0.089). In the long run, the price elasticity of garlic and onion is keeping the lowest elasticity. The cabbage price elasticity is highest in compared to others. Overall estimated vegetable price elasticities are lower than one, which is confirmed by previous some of researchers result. For example, Nzaku et al., (2010) found that fresh fruit and vegetables price elasticities range between -0.541 and -1.099 in the United States, while Wunderlich and Kohler,

(2018) revealed that fruits and vegetables price elasticities are approximately between −0.6 and -0.5 in Switzerland.

3.2 Estimating technical efficiency of vegetable household production in Mongolia

This part shows that some main characteristics of vegetable household production and estimation of technical efficiency for vegetable production in Mongolia.

3.2.1 Some main characteristics of vegetable household production

My study data collected 300 vegetable household production in Khovd and Selenge provinces in Mongolia. The response rate was 86.7%. In Mongolia, vegetable household production has a relatively small land of vegetable production compared to other large-scale farmers (company). Based on the responses of vegetable household production, the household sowing land size was grouped into three categories small (land size between 0 and 2 ha), medium (2 ha≤ land size<5 ha), and large (more than 5 ha). The majority of the household (49.6 %) in the sampled household was 0-2 ha land, 43.5% of the sampled household in medium-sized category (2-5 ha land) and the remaining (6.9 %) were having large-sized (more than 5 ha) category in Table 8. In other words, the majority of the sampled vegetable household (86%) land size was lower than 5 ha.

Table 8. Land size categories for vegetable household production

Types	Percentage of the sampled household
Small (0-2 ha)	49.6
Medium (2-5 ha)	43.5
Large (more than 5 ha)	6.9

Source: Survey result

From the research, 68.5% of the respondents were could not fully use the land for vegetable production. They responded that could not be fully used land for the following reason including seed cost is higher, scarcity of machinery, tractor and other equipment, inadequate financial resource, limited water resources, lack of labor, and land's characteristics (such as stone, bush, etc.). Figure 2 illustrates determining the main reasons based on the survey. Following figure 2, the most important main reason is the inadequate financial resource (the majority of the vegetable household (76.5%)), followed by lack of labor (72.2%), land characteristics (60.1%), scarcity of machinery and tractor (18.7%), the higher price of seed (15.6%) and poor water supply availability (access to water, 8.2%).

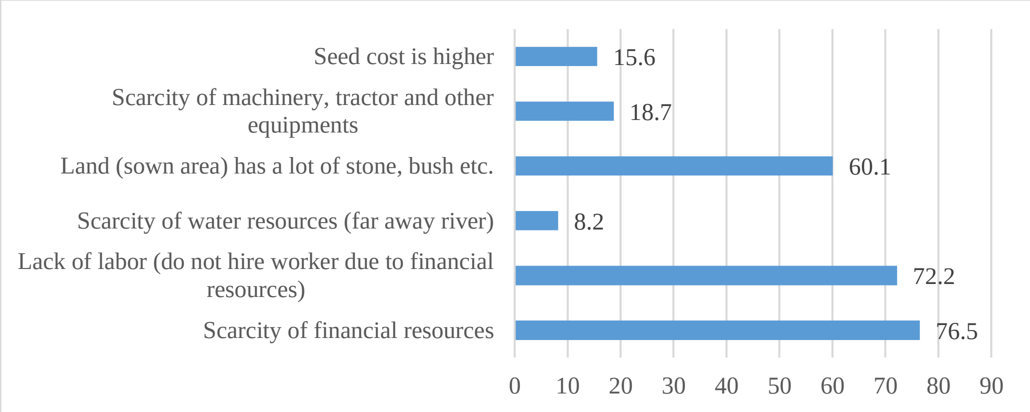

Figure 2. Main reasons for cannot fully use total land, percentage of the sampled household production
Source: Survey result

The sampled vegetable households are growing comparative many vegetables including potato, carrot, cabbage, onion, garlic, tomato, cucumber, watermelon, and melons. Most of the vegetable household was planting approximately five to six types of vegetables. For example, approximately 28.8-85.8 percent of the total sampled household planted potato, turnips, carrot, cabbage, watermelon, and onion, tomato, cucumber, garlic, and melons (Table 9).

Table 9. Percentage of the planting vegetable

Types of planting vegetable	Percentage of the household
Potato	85.8
Carrot	62.4
Turnips	40.4
Cabbage	33.8
Watermelon	43.2
Onion	28.8
Tomato	16.6
Cucumber	16.2
Garlic	15.8
Melons	14.3

Source: Own calculation based on the survey

3.2.2 Measuring the technical efficiency and determining the inefficiency determinants

In this analysis, I estimated the technical efficiency (inefficiency) for vegetable household production in Mongolia using the stochastic frontier production function. A stochastic production frontier model with output-oriented technical efficiency (inefficiency) function was estimated in this analysis. The results of the estimated stochastic frontier function are presented in Table 10. I used the Maximum Likelihood Estimation method to estimate the parameters of the stochastic production frontier and inefficiency effect models jointly in a single-stage estimation procedure. The single-stage estimation procedure is solved the econometric problem which is the assumption of independence. The estimated value of γ close to 1 (γ=0.89), indicating that an inefficiency exists. Based on the likelihood ratio (LR) test was higher than the critic value (LR=36.28) and the LR test rejected the null hypothesis (Kumbhakar et al., 2015). In other words, there are inefficiency effects that exist and stochastic.

Table 10. Maximum likelihood estimation of the Cobb-Douglas stochastic frontier model

	Variables	Coefficient	Standard error
Frontier function	lnland	0.256***	0.054
	lnlabor	0.418***	0.032
	lnseedcost	0.131***	0.035
	lnmanure	0.122***	0.033
	lncapital	0.135***	0.049
Inefficiency effect	Family size	0.131*	0.069
	Household head's age	-0.232	0.153
	Household head's sex	-0.02	0.133
	Education	0.012	0.063
	Household head's experience	-0.102**	0.052
	Non-farm income	-0.155**	0.066
	Credit use	-0.078	0.067
	Land fragmentation index	0.205***	0.065
	Constant	1.526**	0.632
	Observations	260	
	σ_u^2	1.68	
	σ_v^2	0.2***	
	Log-likelihood	-160.19	

Source: Stata 's result with truncated normal distribution

*Notes: *, **, *** are 10, 5 and 1% significance levels respectively. A negative sign for a parameter in the inefficiency model indicates that the associated variable has a positive impact on technical efficiency.*

The result of the estimation showed an expected sign of variables in the frontier function. For the frontier function, all variables were significant. For example, the estimated values of land, labor, seed cost, manure, and capital were 0.26, 0.42, 0.13, 0.12, and 0.14, respectively. It showed that returns to scale were increasing (sum of elasticity>1). The land and labor elasticity were highest in our estimation result. It means that land and labor are major effects inputs in total vegetable production. This finding confirmed the result of (Bozoglu and Ceyhan, 2007; Abdulai and Eberlin, 2001; Aruna, 2018). The technical efficiency score was estimated between 43.2% and 99.9% (average 0.646). It is implied that the vegetable household produces 64.6 percent of the maximum output, or about 35.4 percent of the potential output is lost due to technical inefficiency. This mean of technical efficiency confirmed as “poor but efficient” defined by (Schultz, 1964).

Also, I defined technical efficiency for clarified household’s land size (Table 11). My study results showed that larger farms (more than 5 ha land) are more efficient than smaller farms in my research result. These results are confirmed by (Battese Coelli, 1996; Abdulai and Tietje, 2007). Some of the authors such as Bozoglu and Ceyhan, (2007) stated a negative relationship between technical efficiency and farm size.

Table 11. Mean efficiency level, by household’s land size

	Technical efficiency
Small (0-2 ha)	0.64
Medium (2-5 ha)	0.65
Large (more than 5 ha)	0.67

Source: Calculation result

Figure 3 illustrated the technical efficiency distribution of sample vegetable household production in Mongolia. The 5.8 percent of the sample households had technical efficiency below 0.5(or 50%), whereas 8.8 percent of the household had technical efficiency between 0.81-1.00 (or between 81-100%), the rest of households (85% of sample vegetable household) had technical efficiency level between 0.51 and 0.8 (or between 51-80%).

The result of the inefficiency model (Table 10) indicated the effect of explanatory variables on technical inefficiency, and the number of the variables including family size, household head’s experience, non-farm income, and land fragmentation index were significant with the exception of the household head’s age, sex, education, and credit use. A negative sign on a parameter that is explaining technical inefficiencies means that the variable is decreasing technical inefficiency (or improving efficiency), while for a positive sign the reverse is true. The family size positively affected technical inefficiency. This means that a smaller family (fewer members) is more efficient than a larger family.

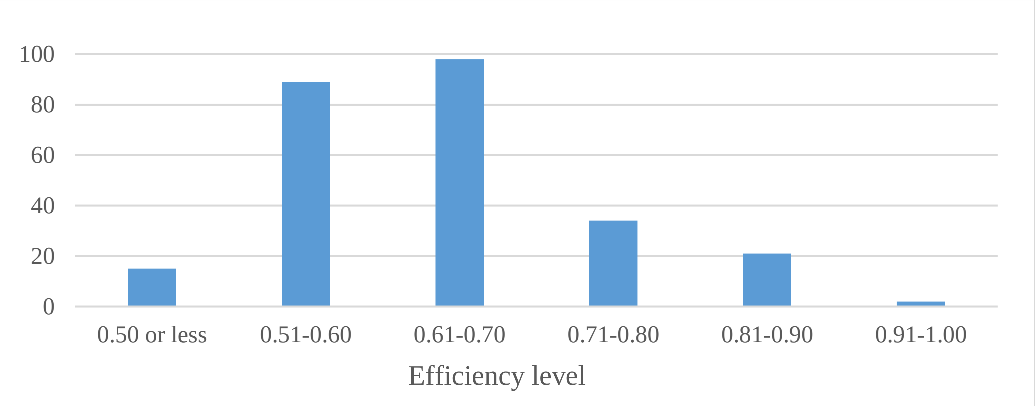

Figure 3. Technical efficiency distribution of vegetable household's production in Mongolia, 2019

Source: Estimation result

Some empirical studies result show smaller families appear to be more efficient than larger families. This finding is consistent with the work (Bozoglu and Ceyhan, 2007). The negative sign for experience, which indicated that households head had more experience led to improving efficiency, a finding that is consistent with the results reported by (Bozoglu and Ceyhan, 2007; Anang et al., 2016). Non-farm income had a negative coefficient and highly affected technical inefficiency more than other variables. In other words, if a household earns more non-farm income that is causing more efficient production. For our sampled household answered to non-farm income (including salary, pension, and other activity income) spend on vegetable production activities. But most of the empirical results have shown a positive relationship between non-farm income and technical inefficiency (Laha, 2006; Asefa, 2011; Anang et al., 2016; Abdulai and Eberlin, 2001; Addai and Owusu, 2014).

Besides, the land fragmentation index also has a significant and positive sign of the coefficient. It means that larger plots may cause an increase in inefficiency. But if the management is better, it causes a positive impact on technical efficiency (Tan et al., 2010; Kiprop et al., 2015). Household head's age, sex, education, and credit use were negative and insignificant. But the negative relationship between age, sex, and inefficiency, a finding similar result reported by (Battese and Broca, 1997; Abdulai and Tietje, 2007). The Mongolian government implements low-interest-rate credit with long-term machinery loan programs to increase vegetable production. Thus, we examined that credit how affected vegetable household technical efficiency. The credit use coefficient sign was negative but insignificant, this means that credit is showed that gives good opportunities for improving technical efficiency. For example, most of the sample households access to credit-only cultivating period to purchasing seed and financing for other costs (rent a tractor to cultivation). These findings were very similar to the result from (Bozoglu and Ceyhan, 2007; Asefa, 2011; Laha, 2006; Addai and Owusu, 2014).

Table 12 shows the differences between technically efficient and inefficient vegetable household production characteristics. The technically efficient vegetable household level is more than 90 percent, otherwise technically inefficient vegetable household level lower than 90 percent. There is a small difference between technically efficient and inefficient vegetable households. For example, the land size of the technically efficient vegetable household is higher (7.2 %) than the technically inefficient vegetable household land size. Family member for the technically efficient vegetable household is approximately 4 members which fewer than technically inefficient vegetable household.

Table 12. The differences between technically efficient and inefficient vegetable household production

Characteristics	Technically efficient<90 %	Technically efficient ≥90 %	Differences (%)
Land size, ha	2.04	2.18	+7.2
Sales income, million MNT	12.00	13.14	+9.5
Family size, (member)	4.35	4.00	-7.9
Household heads sex	0.82	1.00	+21.5
Household head's age (years)	46.71	47.67	+2.05
Household head's experience (years)	15.31	16.83	+9.9
Non-farm income (%)	37.00	33.00	-10.8
Credit use (%)	73.00	100.00	+37.3
Land fragmentation index	0.54	0.48	-12.3

Source: Own illustration based on own technical efficiency estimation

The household head’s age and more experience are confirmed that the household head has an older and more experience cause to increase technical efficiency. The credit non-used vegetable household is that 27 percent of technically inefficient vegetable household.

IV. CONCLUSION AND RECOMMENDATION

Vegetables are one of the more important components of a more balanced healthy diet. Currently, Mongolian vegetables' consumption has been 6 times lower than the recommended intake by the World Health Organization (WHO). Thus, increased vegetable production will provide to opportunity for increased vegetable consumption. In 2019, potato consumption has supplied 100 percent of domestic production. However, the vegetable supply is still has been imported (vegetable self-sufficient rate 53%). The Mongolian government paid attention to this situation, there have been implementing many projects to increase vegetable domestic production and enhance supply domestic consumption.

The main objective of this study is to estimate substitution elasticity between domestic vegetables and imported vegetables and to determine technical efficiency and exploring inefficiency determinants of the vegetable household production in Mongolia. My study has divided into 2 sections. The first section was estimating substitution elasticity using the Armington model, the second part was analyzing technical efficiency using the Stochastic Frontier Analysis model. I conclude the following conclusions in my study results.

- On average substitution elasticity for vegetables, the long-run estimates are approximately two times larger than short-run estimates.
- The estimated home bias value is higher, which means that consumer's consumption is reflected a higher relative weight on the domestic vegetables.
- Averaged vegetables' price elasticity is lower than one, which means that vegetables are low elastic.
- The mean technical efficiency of vegetable household production was 0.646. The vegetable household producer produces 64.6% of the maximum output or approximately 35.4% of the potential output is lost associated with technical inefficiency. This level of efficiency is confirmed as "poor but efficient".
- The land and labor inputs had the highest elasticity value which means that land and labor are the main influencing factors in vegetable household production.
- The positive effect of farm size, household head's experience, and non-farm income on technical efficiency indicate that increase in household production will improve technical efficiency. For example, larger-scale

vegetable household producer appears to be more efficient than small scale household producer. The positive relationship between non-farm income and technical efficiency suggests that increases in non-farm income improve the vegetable household financial ability.

- The relationship between family size (number of the family member) and technical efficiency is a negative effect on technical efficiency. In other words, fewer families are more efficient than large families.
- Household head's age, household head's sex, and credit access variables were positive to technical efficiency but insignificant.
- The education variable was insignificant. The negative sign for the education variable indicates that higher levels of education decrease technical efficiency.

The following hypotheses evidenced on the study result of vegetables in Mongolia.

Table 13. The verification of hypotheses

Number	Hypotheses	**Overall elasticity**	Potato	Tomato	Garlic and onion	Cabbage	Carrot	Cucumber
H1	Long-run substitution elasticity higher than short-run substitution elasticity of vegetables	**Accepted**	Rejected	Accepted	Accepted	Accepted	Accepted	Rejected
H2	Home bias value in long-run is higher than short-run home bias value in vegetables	**Accepted**	Accepted	Rejected	Rejected	Rejected	Accepted	Rejected
H3	Vegetable import price elasticities are higher than domestic price elasticities.	**Accepted**	Accepted	Accepted	Accepted	Rejected	Accepted	Rejected

4.1 Recommendations

Based on my study result, I suggested the following recommendations.

- Result of the Armington substitution elasticity, Mongolian consumers exhibit more preference for home-growing vegetables. Increased domestic production will provide the opportunity for increased vegetable consumption. Therefore, policymakers should focus on increasing domestic vegetable production. For example, improving the quality of vegetable seeds, supporting subsidy especially, diesel consumption, increasing storage of vegetable household producers, improving irrigation system, etc.
- Efficient vegetable household production had a smaller family, household head's age older, more experience, greater non-farm income, and better access to credit than inefficient vegetable household production. Thus, the vegetable household producer needs another source of income such as livestock production and greenhouse production, etc.
- It is organized training to enhancing household producer's education and skills should be provided in vegetable producer agrotechnical knowledge for improving the technical efficiency.
- Inclusive providing access to credit would require government support through a law. The Mongolian government has been implementing a low-interest rate credit program to support small and medium enterprises. Unfortunately, this credit could not be adequate. Thus, it is necessary to increase the sufficiency of credit.

V. NEW SCIENTIFIC RESULTS

My study's main characteristic is the first time attempting to complex analysis of vegetable production in Mongolia. Some below findings are investigated based on the results of my studies.

1. In my empirical research, it has been revealed that vegetable substitution elasticities in long run higher than vegetable substitution elasticities in the short run. A greater elasticity shows that closer the degree of substitution between domestic produced vegetables and importing vegetables in the long run.
2. Another important result is found that the overall estimated vegetable substitution elasticity value is lower, which means that Mongolian consumers more prefer domestic vegetables than importing vegetables. Also, this result is confirmed by the home bias value.
3. My study result is proved that the elasticity of import price for vegetables higher than the elasticity of domestic price for vegetables. On the other hand, importing vegetables are more sensitive than domestic vegetables in relation to change its price.
4. In my empirical research result, land and labor inputs have evidenced the main influencing factors in vegetable household production in Mongolia.

In my study result, farm size (depend on the land size of household vegetable production) was found to have a positive relationship with technical efficiency in Mongolia.

VI. SUMMARY

This dissertation focuses on the substitution elasticity of main vegetables (hereafter vegetable) for importing vegetables and the technical efficiency of vegetable production. Using the Armington model, which indicates the degree of substitutability between domestic vegetables and importing vegetables. Additionally, my study explored to determine the technical efficiency of vegetable household production.

Agriculture is a traditional sector of Mongolia and it is still a dominant role in its economy. It has been providing food for the population and raw materials for manufacturing industries. The crop sector is one of the main sectors to supply the population with safe and quality food. After shifted to political and economic transition in 1990, the crop sector had been dropped in 2005. Mongolian Government started to pay attention to this situation and implemented the 3rd Land Rehabilitation Programme between 2008 and 2010. As a result, the crop sector was substantially revived, the total sown area increased to a fully supplied level for wheat, potato demand, and approximately 50 % supplied for vegetable demand. But until now, the vegetable sector has a high reliance on imported vegetables. Therefore, population vegetable consumption is 6 times lower than the recommended intake by WHO. Increased vegetable production will provide the opportunity for increased vegetable consumption. The aim of this study is to estimate substitution elasticity of vegetables for importing vegetables using the Armington model and measure technical efficiency and determine influencing factors inefficiency on vegetable household production in Mongolia by using Stochastic production frontier analysis (SFA).

The first part of the dissertation is to estimate the Armington substitution elasticity for vegetables. Secondary data was used to estimate the substitution elasticity of vegetables between 1995 and 2019. The empirical result shows that the Armington elasticities in the long-run higher than the short-run with exception of potato which means that products are similar in the long-run. Therefore, my study has determined home bias value using substitution elasticity. We found that the home bias value is high, this appears to be a higher relative weight on home vegetables. Also, we identified that vegetable price elasticity was lower than one.

The second part of the dissertation is to measure technical efficiency and to determine influencing factors inefficiency on vegetable household production. Primary data was collected from randomly selected 260 vegetable households of

Mongolia in 2019. The empirical result indicated that the average technical efficiency of the sampled vegetable household was 64.6 % (range between 43.2% and 99.9%) or they lost about 35.4% of the potential output due to technical inefficiency. We found that land and labor are the main influencing input factors of the household's vegetable production. Also, the result of the technical inefficiency model, variables of age, sex, experience, and credit use obtained a negative relationship with inefficiency. The other variables are family size, education level, land fragmentation index were positively affected by technical inefficiency.

VII. PUBLICATIONS

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