CENTRO DE INVESTIGACIÓN Y DOCENCIA ECONÓMICAS, A.C.

CIDE

CONSUMPTION IN COLONIAL MEXICO: MEASURING DEGREE OF SUBSISTENCE

TESINA

QUE PARA OBTENER EL TÍTULO DE

LICENCIADO EN ECONOMÍA

PRESENTA

CARLO ANTONIO ARIAS GUTIÉRREZ

DIRECTOR DE LA TESINA: DR. ALEXANDER DENTLER

CIUDAD DE MÉXICO   JUNIO, 2019

To my family

ABSTRACT

What does individual's consumption in colonial Mexico says about the conditions they lived in? The elasticity of substitution between a series of good tells us about the way individuals perceived goods. This measure can determine the degree of subsistence that individuals faced. Using a structural dynamic model in which the production factors are labor and climatic conditions I estimate the elasticity of substitution for wheat, maize and bean. The results determine that individuals in colonial Mexico chose its consumption based on preferences instead of necessity.

CONTENTS

FIGURES AND TABLES INDEX

MOTIVATION

Preferences guide consumption patterns. However, the path of consumption to be taken by the individuals is determined by the interaction between the goods consumed. From this it is possible to formulate conclusions related to consumption patterns depending on the context analyzed. This text assesses the degree of subsistence in colonial Mexico via the measurement of the elasticity of substitution of a set of goods.

What is the degree of subsistence in colonial Mexico? An analogue question that produces a quantifiable answer is this: what is the elasticity of substitution for different food items in colonial Mexico? I find that wheat, maize and beans were not perfect substitutes, but the estimated elasticity of substitution is about 3.71.

If goods are perfect substitutes individuals choose the cheapest item. This suggests a disregard of differential taste preferences. I interpret differential taste for food as an indicator for development. Vice versa, a lack of differential taste suggests individuals please basic nutritional needs only. So, an answer to the second question approximates an answer to the first question. Hence, this investigation sketches out the patterns of consumption in colonial Mexico. The region covered by today's Mexico was one of the principal colonies of the Spanish Crown between 1521 and 1820 called New Spain. The occupation started after a war between two unequal sides, the Conquistador of Spain and the indigenous population. The conquest of Aztec Empire ended independence for the indigenous population. Expropriation and displacement changed the makeup of society, and diseases shrunk the population. The Spanish Crown established extractive institutions such as forced labor and exploitative taxation. These observations coincide with the "institutional hypothesis" developed by Acemoglu, Johnson and Robinson (2002, AJR from hereon). This hypothesis claims that colonialism caused a reversal of fortune in the following sense: resource-poor regions such as the one covered by the United States of today become rich while resource-rich regions such as Mexico become poor. The mechanism is that extractive institutions were set in place to withdraw wealth from rich regions. The conquest of resource-poor countries required risky expeditions with uncertain rewards. This, in turn, required the protection of private property for member of these expeditions.

There are two literatures that this investigation covers: the institutions and development literature and consumption's elasticity literature. The first works as a motivation, while the second is related to the methods used in this investigation. AJR's: *Reversal of Fortune* (2002), together with Engerman and Sokoloff's (ES): *Factor endowments, institutions, and differential growth paths among new world economies* (1997) form the main institutions literature. Both state conditions and requirements for the decisions of settlement of the colonies. Further, they state that this settlement decisions highly determine the development path of the regions colonized. These texts' conclusions led to the evaluation of the effect that institutions have on the regions' development, mainly on the colonies. Therefore, Arias and Girod's: *Indigenous Origins of Colonial Institutions* (2014), Albouy's: *The Colonial Origins of Comparative Development* (2012), Ertan and Putterman's: *Determinants and Economic Consequences of Colonization* (2012) and Dobado and García's: *Colonial Origins Of Inequality In Hispanic America?* (2010) follow up and evaluate the results obtained by AJR and ES.

The consumption's elasticity literature is mainly composed by: Andreyeva et al: *The Impact of Food Prices on Consumption* (2010), Huang and Lin: *Estimation of Food Demand and Nutrient Elasticities from Household Survey Data* (2000) and French's: *Pricing Effects on Food Choices* (2003). In general, they estimate the effects that price changes have on the consumption behavior of the individuals. This literature is mainly focused on public health issues, such as obesity, or on the evaluation of program effects like *Food Stamp Program* (Huang and Lin, 2000). Thus, this investigation is a review of the effects that extractive institutions had on the regions' development. Specifically, this investigation evaluates the effect that the conditions generated by the extractive institutions had over the consumption of the indigenous populations, mainly.

I use a structural dynamic model with production of three agricultural products, wheat, maize and beans. Labor and climatic conditions determine production levels. I use historical price data and (expectations over) tree-ring measurements as a proxy for (expected) land fertility. Optimality conditions determine labour demand. There is uncertainty about production levels because of shocks to land fertility. Hence, production levels vary according to their respective elasticity to land fertility. This exogenous variation allows an estimation of the elasticity of substitution.

HISTORICAL CONTEXT

The context determines the production process. Mexico was a colony of the Spanish Crown: since the fall of the Aztec Empire in 1521 and the settlement of the Viceroyalty of New Spain. New Spain's destiny was based on the profitability of alternative colonization strategies in the different environments conquered. Following the "institutions hypothesis", AJR state:

> In prosperous and densely settled areas, Europeans introduced or maintained already-existing extractive institutions to force the local population to work in mines and plantations, and took over existing tax and tribute systems. In contrast, in previously sparsely settled areas, Europeans settled in large numbers and created institutions of private property, providing secure property rights to a broad cross section of the society and encouraging commerce and industry. (Acemoglu, Johnson and Robinson 2002, 1235-1237)

In Mexico's case, there were already many prosperous civilizations in the region, tribute systems and high amounts of resources; then, the best strategy was the establishment of extractive institutions. This kind of institutions embrace different features: from the production system, the laws, the property, among others (Nickel 1996,83-84). New Spain's extractive institutions worked as a fief where an individual (or family) holds the control of the land and resources; and the people inside the control of these institutions is subject to the preferences and plans of it.

Mexico's geographic characteristics give way to different activities, mainly: agriculture and mining. This thesis is focusing in the agricultural production in colonial Mexico. Agricultural production before the arrival of the Spanish Empire was labor based (Nickel 1996, 68-69). Though, the indigenous populations had innovative irrigation methods as chinampas, agriculture still was rudimentary. The macehuales (commoners) constituted the workforce. They had its own land to produce and, as members of the community, they hunted, collected, worked in mines and performed services in the institutions of the community (von Wobesser 1989, 55-63). With the arrival of the Spaniards, agriculture continued to be one of the principal sectors of production. Although the methods of production were still based on labor: the organization in which this developed did change.

Hernan Cortés established the Encomiendas and distributed them between the conquerors, with the most important owned by himself (which covered Cuernavaca and most of

Coyoacan). The Encomienda was an extractive land tenure institution already established in The Caribbean where it resulted in abuses for the indigenous population. The Encomienda had its basis on an obligated workforce constituted by the indigenous populations, slaves and some Spanish employees (Riley 1975, 60-61). *the indigenous population insomuch as they represented up to 60% of the total population, even by 1700 (Navarro 1983, 149-154)*. The workforce worked on jobs that depended on the owner of the Encomienda: mining, agriculture, construction, transportation, etc. Even sometimes the owners took their workforce to work in another Encomienda (Riley 1975, 60-61). This mode of production was fruitful for the Spanish because part of the production of the land passed to them through the tribute, a tax on indigenous villages almost free from costs of production. According to Riley (1975), all these characteristics are gathered in Cortés's Encomienda, which later became the prototype for the next system of land tenure and production implemented in New Spain: The *hacienda*.

The hacienda, in general, referred to the goods an individual possessed. Although, according to Herbert Nickel (1996), there exists punctual characteristics that determine this as a system of land tenure: domain over natural resources, workforce and over local markets. The loss over the control of the resources from the indigenous populations left them exposed. These populations were no more self-sufficient, they were induced to a system in which they needed of the haciendas to subsist. With this, the haciendas secured the workforce. Different haciendas were generated according to the goods produced, the amount produced, economic sufficiency, self-consume, technology used, among others. The principals are: sugar plantations, crop plantations, cattle ranchs, tropical products plantations, etc. The ones that required higher investments were the sugar and tropical products plantations, followed by the crop plantations (von Wobesser 1989,69).

There is one kind of hacienda that does not meet all the principal characteristics of a hacienda: Ranchos. These have two principal definitions: either it was a small agricultural production unit destined for self-consumption (or trade), or it defines the small towns inside a hacienda. In Ranchos the family for whom the production was destined forms the workforce (von Wobesser 1989, 53 -54). The difference between Ranchos and haciendas lies in the possession of the lands: you could not be the owner of the lands and still produce with the

permission of the hacienda, which required a payment for the leasing. So, the first definition applies for an owned or leased Rancho.

In general, the hacienda concentrated the whole power over the lands and resources. Then, the indigenous populations lost their independence; thus, generating inequality. These populations were contingent to the requirements and preferences of the hacienda (Schiff 1980, 482). The Ranchos allowed to the indigenous to produce for self-consumption, though it was necessary to pay tribute.

To largely produce the most important products of haciendas (sugar, cereals, etc.), they required large amounts of capital destined mainly for irrigation systems, roads and windmills. Although, recent studies underline haciendas low productivity. This is due to low use of the cultivable area, technology and capitalization. The prior leads to a high dependence on labor (Mörner 1975, 35-39). Though, Juan Carlos Mariastegui (1955) states that the land owner is not worried by the productivity, instead, he worries about the benefits, which leads to the exploitation of the indigenous workforce. The prior can be seen in the wages payed to the workforce. Until 1549 the salaries got normalized for all the workforce, especially for the indigenous populations. Although they got payed for their job, these payments were determined by the owner or the crown. Then, salaries were subject of many abuses from the land owners directed to the indigenous populations: land owners sometimes payed to the indigenous with cacao grains or food instead of coin (Spanoghe 1997, 45-48). The context of the haciendas led them to focus on local markets. This, jointly with the profit seeking behavior, describes that prices were determined by local market mechanisms.

Cereal plantations formed part of the most significant products in haciendas. The suppliers of this goods were in the center of Mexico, mainly in Puebla. The main goods produced in these haciendas were: wheat and maize. There's no doubt about the importance of the maize for the indigenous populations' diet; it is the base of most of the Mesoamerican civilizations. Yet, one of the most important crops, together with maize, for the Mesoamerican populations was the bean, due to its flexibility and exchangeability with the maize in the cultivation process (Barrales 1997, 121-125). Though bean is not the most produced in the haciendas, it was still sowed by the indigenous populations. In the agricultural habits of the Mesoamericans was farming in Milpa. This farming method implies the cultivation of a series of crops at the same

time (maize, bean, pepper, etc.), derived from the domestication process of the crops. This strategy is due to the adjustment in variation of products during the different seasons to keep plenty of all goods along the year (Carrillo 2009, 6-7). The wheat importance lies in the Spanish population because they brought the crop (it did not exist in America) and bread represents a big part in the european diet (von Wobesser 1989, 12). With this, the significance of these three crops to study in the colonialism's populations is clear.

METHODOLOGY

PRODUCTION AND CONSUMPTION MODEL

There exists a market in which individuals and haciendas exchange goods. To assess the elasticity of substitutions between wheat, maize and bean in colonial Mexico, this text leans on a model in which labor (L) and climatic conditions (C) are the principal supplies for the crops' production [1]. The decisions the haciendas make are modelled dynamically [2]. This is because there is interdependency between the wages (w) and the prices (p). Today's marginal productivity of labor determine the wage; at the same time, it hinges on the prices we get tomorrow, and these are determined by the wages of tomorrow. Haciendas are dedicated to sow the crops, hire labor, harvest, and commerce the production or consume it. Given the contextual conditions, the labor supply is inelastic.

$$y_{it} = A_i C_t^{\alpha_i} L_t^{\gamma_i} \tag{1}$$

$$\max V(y_{it}) = y_{it} p_{it} + [-L_t w_t + \beta E[V(y_{it+1})]] \tag{2}$$

$$\frac{w_t}{\beta \gamma_i A_i L_t^{\gamma_i - 1}} = E[C_{t+1}^{\alpha_i} p_{it+1}] \tag{3}$$

Solving the producer's problem leads to the equilibrium condition in [3]. Then, the producers make their decisions based on the expected climatic conditions and prices of the next period. I realize an approximation around the steady state (SS) for the equilibrium condition and, rearranging, I get equation [4]. In general, the goal of this thesis could be achieved using the produced quantities of the crops, though I lack this information together with the labor

supply. Then, from equation [4] I am interested in three results: the coefficients α and γ, which represent the intensity with which each supply is used, and the estimation of the labor supply.

$$\epsilon = \tilde{L}_t(1 - \gamma_i) = 1 - \gamma_i - \alpha_i + E[\alpha_i \tilde{C}_t + \tilde{p}_{it}] - \tilde{w}_t \tag{4}$$

Given the lack of the production quantities, it is necessary to estimate them to obtain the elasticity of substitution. For this, I take an approximation along the SS for the production function [1]. With that, the equation to estimate is [5].

$$\tilde{y}_{it} = 1 + \alpha_i(\tilde{C}_t - 1) + \gamma_i(\tilde{L}_t - 1) \tag{5}$$

Together the estimated production and the Individual's problem make possible the estimation of the elasticity of substitution. Individuals are identical and consume the three goods: wheat (w), maize (m) and bean (b). They are all price takers. They receive a wage from the labor offered to the haciendas, which is distributed for the consumption of the goods. The utility of the individual is modelled as a CES function. Using a CES function derives from its simple formulation, widely usage and it fits for some special cases of its parameters. Then, the maximization problem for the individuals is stated in [6].

$$\max U = (\delta_w c_{wt}^\sigma + \delta_m c_{mt}^\sigma + \delta_b c_{bt}^\sigma) \tag{6}$$

$$st : \sum_i c_{it} p_{it} = w_t$$
$$\forall i = w, m, b$$

Solving this problem leads to the equilibrium condition that determines the relationship between any two of the goods, equation [7]. From this equation, I realize an approximation around the steady state and arranging I get equation [8]. This investigation is looking for the elasticity of consumption ($\epsilon = \frac{1}{1-\sigma}$) of the individuals, that is, if these goods are perfect substitutes ($\epsilon \to \infty$) or complements ($\epsilon \to 1$). The hypothesis is that the crops are substitutes given that the subsistence conditions lead the individuals to consume respect to their necessity instead of their preferences. However, it is not possible to test if ϵ goes to infinity, so I rearrange equation [8] and get [9]. From equation [9] it is possible to test if $\sigma \to 1$, and therefore test if the goods are substitutes.

$$c_{jt} = c_{it}\left(\frac{p_{jt}\delta_i}{p_{it}\delta_j}\right)^{\frac{1}{1-\sigma}} \tag{7}$$

$$\Delta_{ji}^c = \tilde{c}_{jt} - \tilde{c}_{it} = \epsilon(\tilde{p}_{it} - \tilde{p}_{jt}) \tag{8}$$

$$\Delta_{ji}^c - \Delta_{ij}^p = \sigma\Delta_{ji}^c \tag{9}$$

CLIMATIC CONDITIONS MODEL

During colonialism, agriculture was labor intensive and required negligible or null amounts of capital. Instead, the climatic conditions played a big part in the growth of the crops. Three principal environmental factors define crop's growth: Temperature, Soil Moisture and Solar Radiation (Fageria, Baligar and Jones,14-19). Then, one of the interests of this text is to determine the effects of the climatic conditions on the crops' production. For that, tree rings giveaway more information than the age of a tree.

Dendrochronological (Tree Ring analysis) studies divide the growth of the tree rings in a set of characteristics: ring's width, earlywood, latewood, density, callus and healing tissue (Scheiwngruber 1997, 8-20). In general, wood formation is driven by a series of compounds and hormones derived from the environmental conditions and diseases or external shocks. Earlywood is the wood characterized for being the less strong wood, the clearer and the largest part of the tree ring. This type of wood has cells that are large in diameter and have thin cell walls (Scheiwngruber 1997, 8-20), which is due to plenty of soil moisture during spring and summer seasons. Later in those seasons, it is possible to assess the droughts, shortages in sunlight or low temperatures that could hit the trees. These shocks reduce the cell production along with the cells' diameter.

Latewood is the stronger wood, but the smallest part of the Tree Ring. Small diameter cells with thick walls characterize this wood type (Scheiwngruber 1997, 8-20). These characteristics are, in principle, formed due to the seasons in which this wood develops: autumn and winter. In these seasons, the soil moisture has fallen, there are lower temperatures and the days are shorter. This causes the growth of the tree to diminish and the cell production to change. At the beginning of the latewood growth, the tree counts with fully grown needles (leafs) which now produce photosynthates (compounds derived from photosynthesis) dedicated for cell wall synthesis (Larson 1969, 24-32), then the cells produced have small diameter and thick walls. Thus, the latewood and earlywood recover environmental factors that determine the growth of the tree and other flora (including crops) along the different seasons.

According to the research, the information given by the tree rings will be either signals or noise, given their large applicability. As E.Cook and K. Briffa state:

> Signal is defined here, in a hypothesis-testing sense, as the information derived from tree rings that is relevant to the study of a particular problem. [...] the problem of signal extraction in tree ring research is more fundamentally related to the disaggregation of the observed ring widths into a finite number of signals that represent the sum of the environmental influences on tree growth. (Cook and Briffa 2013, 97)

In tree ring series there exists: an age-related trend component, a climatic environmental signal, the disturbance effect caused by endogenous or exogenous disturbances and unexplained year variability (Cook 2013, 98). Recall that to get the information needed, it is required to extract the noise from the tree ring series. As a climatic condition proxy I use the climatic environmental signal derived from the tree ring widths. For this, I extract the climatic component mentioned earlier by the estimation of a linear model as in equation [10]. In this case, a_{it} are dummies that determine the tree's age range for tree i in year t, while t_{is} are dummies for tree i in year $s = t$. The age range variable extracts the age trend component from the growth series, while the year's dummies extract the climactic signal.

$$g_{it} = \sum_{k=1}^{\overline{k}} \beta_k \tilde{a}_{it} + \sum_{s=t}^{\overline{t}} \gamma_s \tilde{t}_{is} + \epsilon_{ti} \qquad [10]$$

The Temperature determines the season when a crop grows; either in spring or autumn when there are cool temperatures for warm season crops and summer temperatures for cool-season crops (Fageria, Baligar and Jones,14-19). With this classification of crops and based on the schedule of sowing and harvesting from Calendario de Proceso Productivo y Comercial de algodón, maíz, sorgo, soya y trigo (SAGARPA 2017) it is possible to figure out which of the woods could explain the growth of each of the crops that we are looking at. In that sense, Wheat is a warm season crop, while maize and beans tend to grow with high temperatures. This classification between wood type and crops can be seen in Table 1. However, Mexico is a country with a great variability of climates. In the Northern part of Mexico there are warm weathers, while in the Southern parts the climate is tempered. This allows to be a great variability in the sowing and harvesting of crops throughout the country because it is possible to grow cool temperature crops at higher altitudes (Fageria, Baligar and Jones,14-19).

Table 1. Wood and Crops classification

Crops	Wood Type	
	Earlywood	Latewood
wheat		X
maize	X	
bean	X	

Source:Author's Elaboration

DATA

As one of the interests of this text is to determine the effect of the climatic conditions in the production of crops, I use tree rings measures as a proxy of the climatic conditions from the data base generated by Therrell, Stahle, Villanueva, Cornejo and Cleveland (2006). This data is a collection of radii measurements in millimeters of 247 Douglas firs from a settlement at nearly 300 km southeast from Mexico City and 16 km northwest from Pico de Orizaba. This data base contains the Earlywood (EW), Latewood (LW) and the Tree Ring Width (TRW) measurements from 1474 to 2001. Then, this is a panel that contains 527 observations for 247 trees. The distributions are described in Table 2.

Douglas fir is one of the most used species in dendrochronological research. Its importance derives, in part, from its geographic variability. This tree species is present in northwest of North America: from southwest Canada, crossing through all the west of United States and finally reaching Mexico with some settlements spread through the country and, so it's exposed to different climates. Coupled with this, this specie has a long-life span: around five hundred years with a maximum of one thousand years. Therefore, Douglas firs fit the long span that this analysis requires.

Table 2. Tree Rings Descriptive Statistics

	Mean	Sd.Dev	Range	Trees
Tree Ring (TRW)	1093.5	311	[256.1, 1900]	247
Latewood (LW)	303.4	97.7	[79, 761.4]	247
Earlywood(EW)	791	255.6	[161, 1618]	247

Source: See Therrel et al's Tree-Ring Reconstructed Maize Yield In Central Mexico: 1474–2001

10

The principal goal of this paper is to assess the elasticity of consumption between wheat, maize and bean. For this, I require the prices of the goods, the wages, labor supply, the climatic conditions and individual's consumption. Though, it is not possible to get data for all given the time analyzed, its estimation is possible.

Then, I take the data base compiled by Arroyo, Davies and van Zanden (2012). This data base contains baskets of goods and wages for several countries in Latin America. The observations vary depending on the country and on the variable that is observed, though, all circle the same periods: 1500-1820. One of the countries in this data is Mexico, which contains wages and prices, reported in Reales, for different goods: maize, wheat, beans, bread, beef, pork, clothing, candles and fuel. Thus, I am fixing the attention to the prices for the crops (maize, wheat and beans). In the case of the wages, there is a series of different kinds of wages collected in this data base, then, I am sticking with the yearly wage.

The descriptive statistics of the variables chosen are shown in Table 3. Given the form of the distributions, I present as measures of central tendency: the median and the mean, while for the dispersion I use the interquartile range. The prices are observed for most of the period of interest; although there can be large jumps at some moments. The most observed is the maize, followed by the wheat and the bean. The yearly wage is a special case, it grows fast during late 1500s and becomes constant at early 1600s. This difference can be seen in the time series of the variables (Figure 2).

Table 3. Prices and Wages Descriptive Statistics

	Mean	Median	IQR	Observations
Real Wage	530.7	625	500	289
Prices				
wheat	45.9	45.22	22	141
maize	11.9	10	6.41	253
bean	13.6	11	9.4	121

Source: See Arroyo et al's Between Conquest And Independence: Real Wages And Demographic Change In Spanish America, 1530–1820

Figure 1. Crops Prices and Wages Time Series
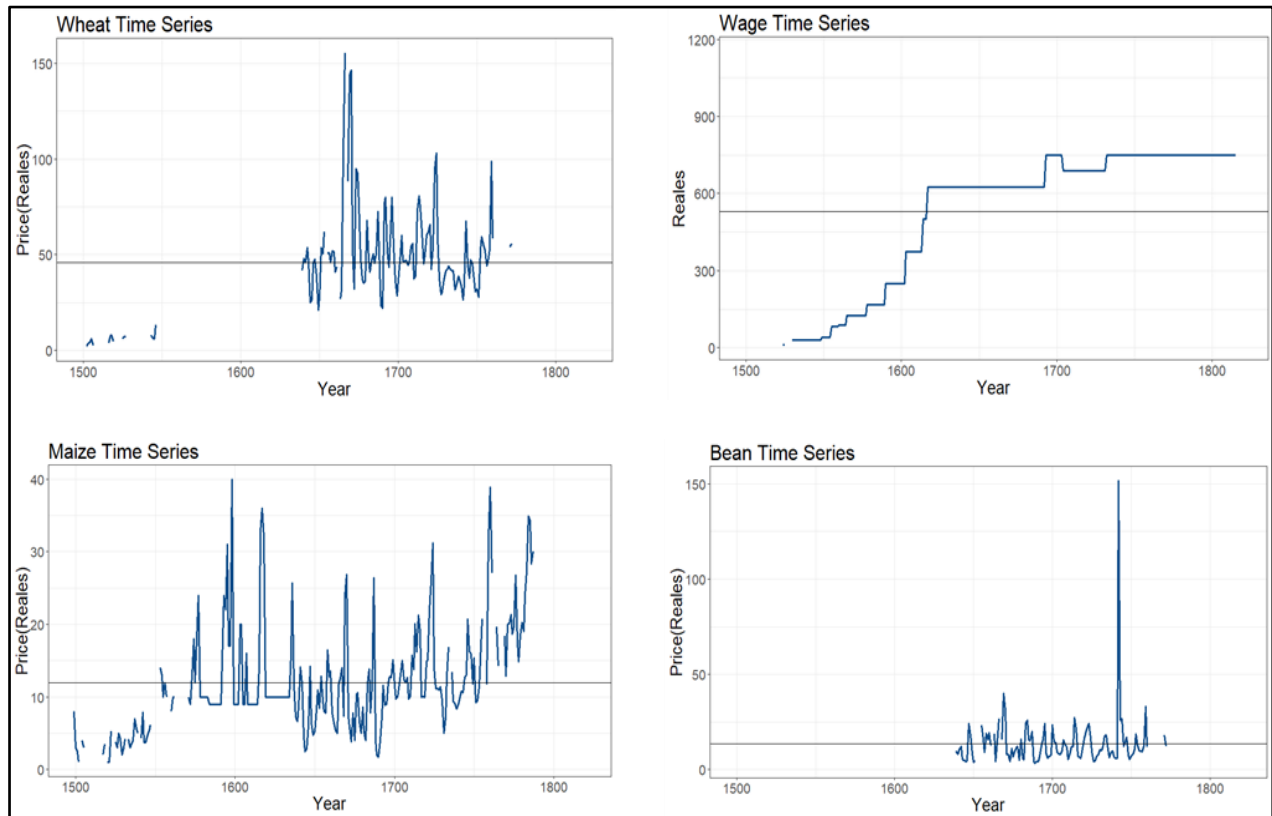
Source:Author's Elaboration

RESULTS

CLIMATIC CONDITIONS ESTIMATION

I estimate the climatic conditions proxy from equation [10] by pooling each kind of wood growth (LW, EW) of every tree. Then, I run a fixed effects model given that the over-identification test rejects the random effects model (pvalue: 0.000). This means that there exists time invariant characteristics for every tree which are not related with the climactic signal.

From this estimation I take the year dummies coefficients as the climatic signal, which are defined as the growth compared to the year 1474. The Figures 3 and 4 are a comparison between the observed average growth per year and the estimated growth per year. For this, I took the average growth of every tree that was alive in every year, then subtracted the average growth of the year 1474. In principle, the coefficients are a good estimate of the average growth.

Although, in the Earlywood estimation there is a kink in the first half of the XVIII century that deviates the path of both series. This deviation can be due to the extraction of the age component or external shocks which translates to a lower growth due to the climatic environment. In the case of the Latewood, it is even better fitted to the observed growth than the Earlywood, this could be a sign that the Latewood is better at collecting the climatic conditions of the environment for every year.

CONSUMPTION, PRODUCTION AND LABOR ESTIMATION

Once extracted the climatic signal, it is time to fulfill one of the goals of the paper: asses the effect of the climatic conditions on the production. Although, I lack of two essential variables: labor and production. The former helps to determine the production and the later determines the consumption. Then, this investigation requires the estimation of these two variables. For this I use the approximation around the steady state for the equilibrium condition in [4]; taking as the SS, the global average of the variables. The labor supply is estimated using non-linear Generalized Method of Moments. In this estimation I use the deviations from the steady state for the estimated climatic conditions, the price of the crops and the yearly wage. At some points in the time, as can be seen in Figure 2, the prices soar. Given that we are using the deviations from the steady state, I drop the outliers that exceed more than 3 times over the SS from the estimation. With this, the number of observations reduces to 89 for the three crops. These range along the years 1644-1771. The producers make their decision based on the expected climatic conditions and prices for the next period; so, we instrumentalize these variables with two lags from the climatic conditions proxy and the second and third lags for the prices. The results for this estimation are shown in *Table 4*.

Figure 2. Earlywood: Average Growth vs Estimated Growth
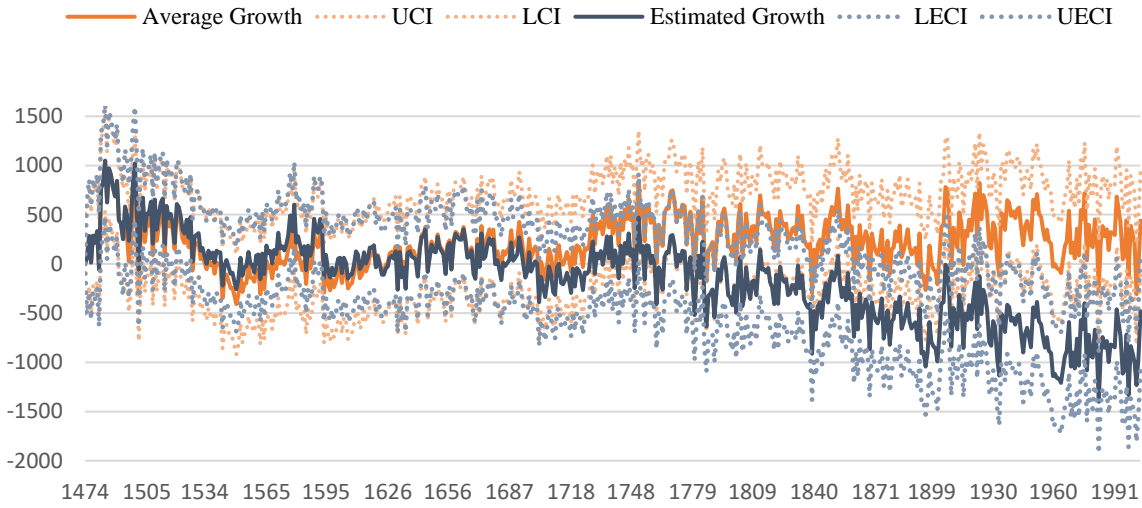
Source:Author's Elaboration

Figure 3. Latewood: Average Growth vs Estimated Growth
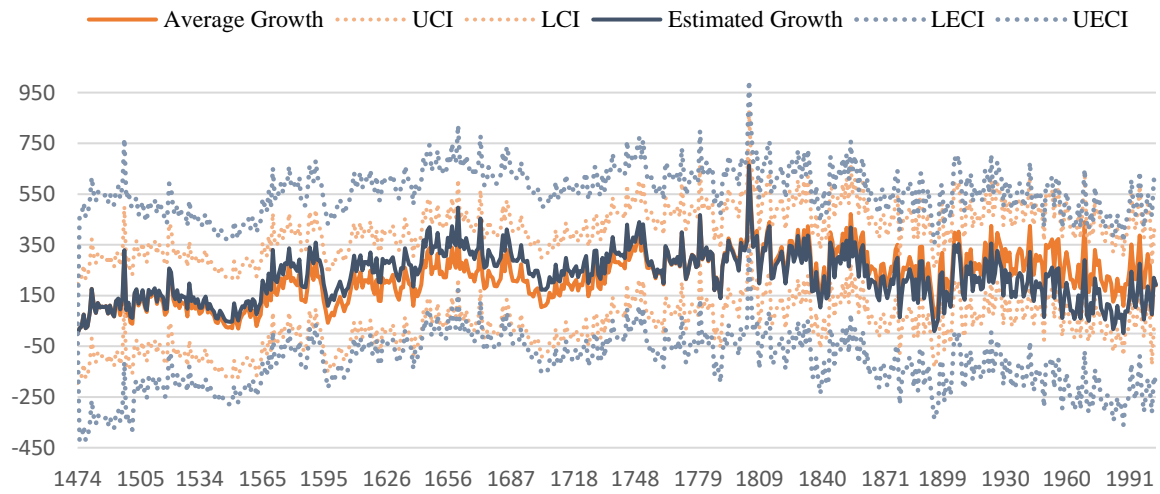
Source:Author's Elaboration

Table 4. Labor Estimation Results

Crop	Coefficients			J's p-value	SSE
	1-γ-α	α	γ		
wheat	0.017	0.169	0.814***	0.963	13.57
	[0.225]	[0.169]	[0.066]		
maize	0.093	0.206	0.701***	0.175	14.68
	[0.198]	[0.145]	[0.063]		
bean	0.399*	0.081	0.52***	0.162	17.91
	[0.241]	[0.178]	[0.074]		

Source:Author's Elaboration

The estimated shares of the supplies have diminishing returns. Labor is used with more intensity than the climatic conditions. This is consistent with the labor being highly required in the agricultural production during colonial Mexico. The climatic conditions coefficient is smaller than the labor one and is non-significant. It could be expected that the climatic conditions coefficient could be higher, given that this is a main factor in the development of the crops. This result could be due to climate differences between the growing areas and the forests. Although statistical significance is the usual method of coefficient evaluation, the coefficients are consistent along other sets of instruments. Also, its standard deviation is not very high which points to some precision in the estimation. Moreover, to test the endogeneity of the instruments used, I use the J's test which is based on the null hypothesis: the model is correctly specified; so, the optimal outcome would be to not reject the null hypothesis. This test tells that the model is properly specified, this is consistent along different sets of instruments for most of the crops.

For the production estimation I plug the coefficients obtained from the labor estimation (γ and α), together with the estimated labor supply deviations and the estimated climatic conditions deviations, into the approximation around the steady state realized in equation [5]. At last, it is not possible to assess the exact quantities of neither the labor supply or the production. The labor and production output of these estimations are defined as deviations of the steady state.

Finally, I take the production estimated in the prior step as the consumption of the individuals. With equation [9] I estimate the elasticity of substitution for every good by pooling all the data. Again, this estimation uses the deviations from the SS of prices and consumption.

Given the range of years in the observations, this estimation is valid only for the years 1644-1771. The results are shown in Table 5.

Table 5. Consumption Share Estimation

Share	Value
σ	0.7307272***
	[0.130123]

Source:Author's Elaboration. Estimated via OLS

The hypothesis of this text is that the crops are substitutes given that the subsistence conditions lead the individuals to consume respect to their necessity instead of their preferences. That implies that the elasticity of substitution goes to infinity. The consumption share allows to test if σ is equal to one as null hypothesis. Running this test gives for outcome that σ is different from one (pvalue: 0.000). Thus, wheat, maize and bean are complements. Then, consumption is defined by the preferences and not by the caloric necessities of the individuals. This result may be derived from the fact that these three goods are basic in the diets of the whole population of colonial Mexico. There is no doubt about the significance of the maize in the Mesoamerican cultures, it is one of the most basic elements for the development of these cultures along thousands of years. Even, this result could derive from their Milpa cultivation method; the Mesoamericans used to cultivate maize and bean together.

The wheat is a product of Spanish consumption; though its consumption could have generalized along all the population. This could be true because of the production model carried on by the haciendas. The owners of the hacienda determined the goods to produce for the market and given that the indigenous populations were contingent to the decisions of the owner, it is possible wheat could be part of the consumption of this population too. Although, given the existence of the Ranchos, it is possible for the indigenous populations to grow their own crops. This gives way to a consumption based on preferences instead of necessity.

This result differs from the effect that extractive institutions had on the reversal of fortune during colonialism in Latin America (AJR, 2002). Though, these are consistent to the

findings of Dobado and García (2010) or Albouy (2008). These results do not support the idea that the colonial societies were especially unequal. As the results state, the populations had preferences for the consumption of certain goods, crops in this case. This implies that the individuals had the option to choose what to consume despite of the inequality conditions that haciendas generated. As DG state: "Those views on the viceroyal period and its economic long-term legacy based on assumptions about extractive, unequal or bad institutions that appeared shortly after 1500 should offer more convincing empirical evidence." Though, all these kinds of analyses are limited by the data available.

CONCLUSION

This investigation assesses the elasticity of consumption for the maize, wheat and bean in colonial Mexico. The findings state that agriculture indeed was labor intensive and based most of production in it; also, the climatic conditions seem to be not that important in the production of the crops analyzed despite the contextual conditions of the era. Finally, this investigation finds that the consumption of the individuals is based on preferences instead of their necessity. This is not consistent with the inequality characteristics that extractive institutions as haciendas are supposed to generate in this context. The principal limitations for this text are based on the data availability which is inherent to the historical reports. Given the prior, it is possible that the elasticity of substitution result is not properly evaluated. Looking ahead of this investigation, it seems to be necessary to assess if this effect changes through the time or in different periods. Besides, the use of other tree rings series from Mexico could function as a support for these results; even the use of other methods to extract the climatic signal from the tree rings seem to be plausible for the confirmation of the results obtained. However, all these results are still limited by the lack of essential information for the analysis.
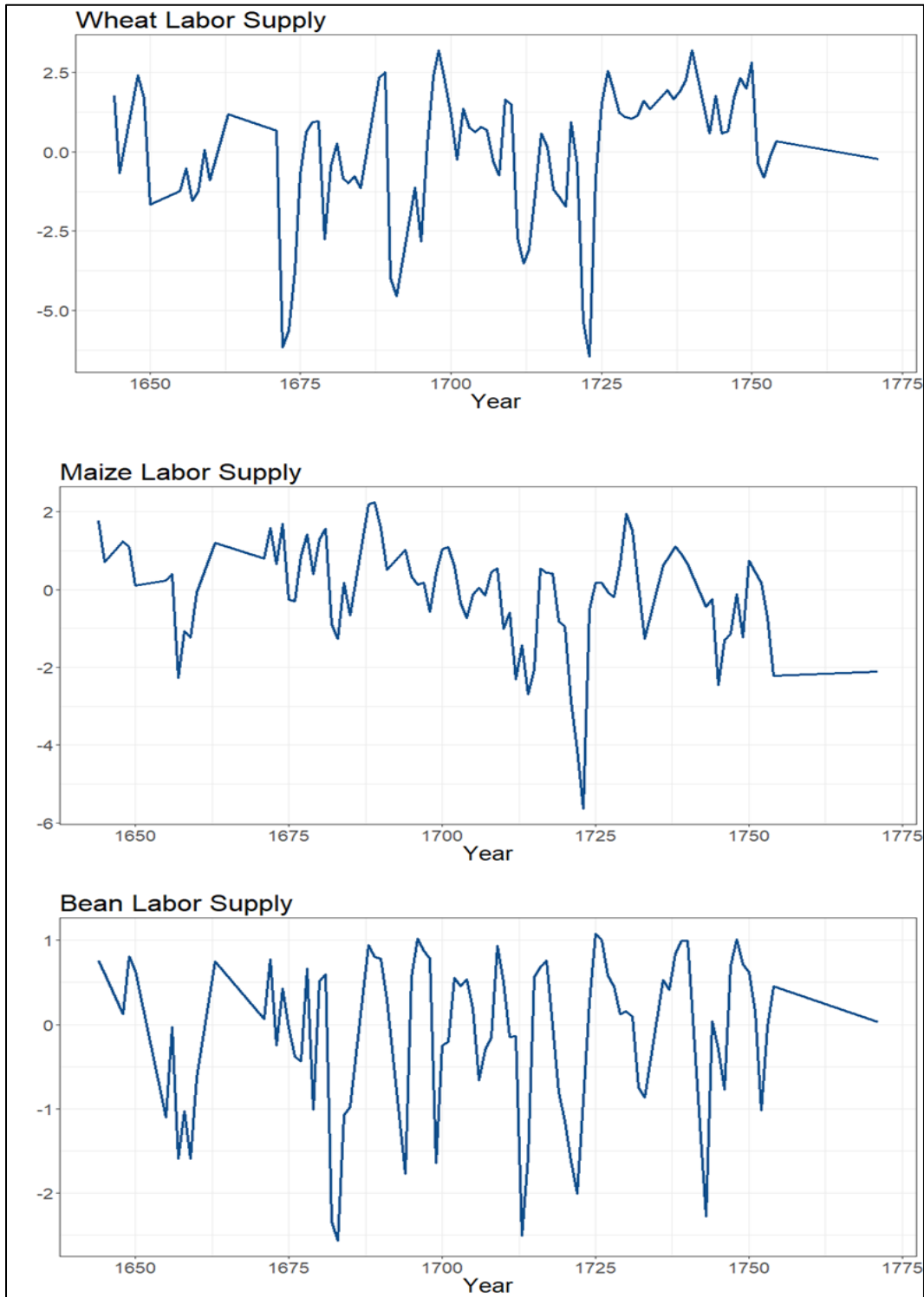
Appendix 1. Labor, Production Estimation and Deviations Time Series
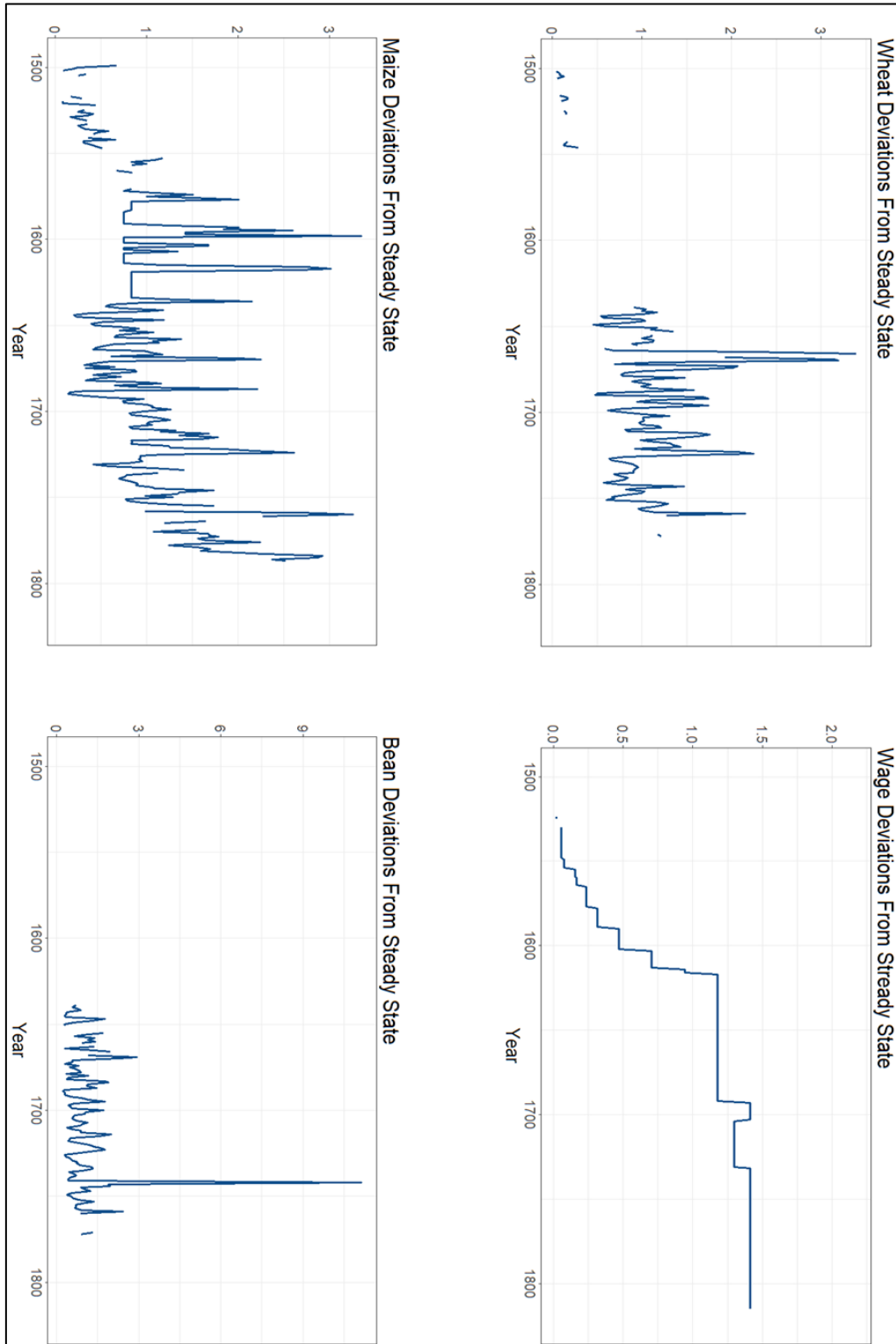
Figure. Production Estimation
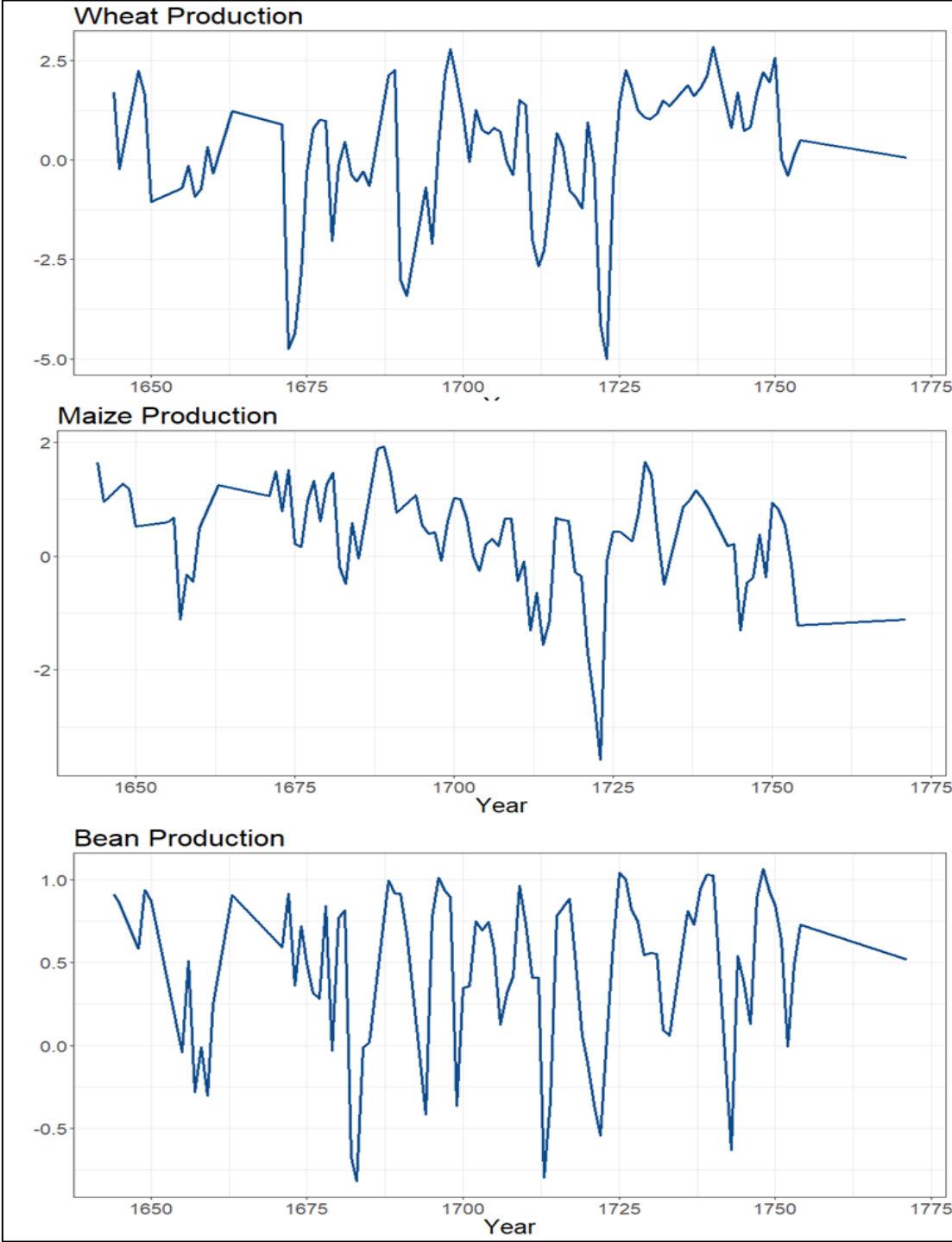
Source: Author's Elaboration

Figure. Labor Supply Estimation

Source: Author's Elaboration

Figure. Prices and Wages Deviations from Steady State

Source: Author's Elaboration

Appendix 2. Equations Development

Haciendas' Problem

$$\max V(y_{it}) = y_{it}p_{it} + [-L_t w_+ \beta E[V(y_{it+1})]]$$

FOC's:

$$\frac{\delta V}{\delta y_{it}} = p_{it} = 0$$

$$\frac{\delta V}{\delta L_{it}} = -w_t + \beta E[\frac{\delta V}{\delta y_{it+1}}\gamma_i A_i C_t^{\alpha_i} L_t^{\gamma_i-1}] = 0$$

$$\frac{w_t}{\beta\gamma_i A_i L_t^{\gamma_i-1}} = E[C_{t+1}^{\alpha_i}p_{it+1}]$$

Taylor's approximation along steady state:

LHS:

$$w_t L_t^{\gamma_i-1} \approx \overline{w}\overline{L}^{1-\gamma_i} + \overline{w}\overline{L}^{-\gamma}(1-\gamma_i)(L_t - \overline{L}) + \overline{L}^{1-\gamma_i}(w_t - \overline{w})$$

$$\Rightarrow \frac{\overline{w}\overline{L}^{1-\gamma_i}}{\beta\gamma_i A_i L_t^{\gamma_i-1}}[(1-\gamma_i)(\tilde{L}_t - 1) + \tilde{w}_t]$$

RHS:

$$F_t^{\alpha_i}p_i' \approx \overline{C}^{\alpha_i}\overline{p}_i + \alpha_i\overline{C}^{\alpha_i-1}\overline{p}_i(C_t - \overline{C}) + \overline{C}^{\alpha_i}(p_{it} - \overline{p}_i)$$

$$\Rightarrow E[\overline{C}^{\alpha_i}\overline{p}_i[\alpha_i(\tilde{C}_t - 1) + \tilde{p}_{it}]]$$

Joining LHS and RHS :

$$(1-\gamma_i)(\tilde{L}_t - 1) + \tilde{w}_t = E[\alpha_i(\tilde{C}_t - 1) + \tilde{p}_{it}]$$

$$\Rightarrow \epsilon = \tilde{L}_t(1-\gamma_i) = 1 - \gamma_i - \alpha_i + E[\alpha_i\tilde{C}_t + \tilde{p}_{it}] - \tilde{w}_t$$

Individuals' problem:

$$\max U = (\delta_w c_{wt}^\sigma + \delta_m c_{mt}^\sigma + \delta_b c_{bt}^\sigma)$$

$$st : \sum_i c_{it} p_{it} = w_t$$

$$\forall i = w, m, b$$

FOC (c_{jt}) :

$$\delta_j c_{jt}^{\sigma-1} U^{1-\sigma} = \lambda p_{jt}$$

$$\forall j = w, m, b$$

$$i \neq j$$

Combining any two FOC's we get:

$$c_{jt} = c_{it} \left(\frac{p_{jt}\delta_i}{p_{it}\delta_j}\right)^{\frac{1}{1-\sigma}} = c_{it}\left(\frac{p_{jt}\delta_i}{p_{it}\delta_j}\right)^{-\epsilon}$$

In the steady state the optimal consumption:

$$\overline{c_{jt}} = \bar{c}_i \left(\frac{\bar{p}_j \delta_i}{\bar{p}_i \delta_j}\right)^{-\epsilon}$$

Taylor approximation around steady state:

$$c_{jt} \approx \bar{c}_j + \frac{1}{\bar{c}_i}\bar{c}_j(c_{it} - \bar{c}_i)$$

$$-\epsilon \frac{\delta_i}{\bar{p}_i \delta_j}\bar{c}_i\left(\frac{\bar{p}_j \delta_i}{\bar{p}_i \delta_j}\right)^{-\epsilon-1}(p_{jt} - \bar{p}_j)$$

$$+\epsilon \frac{\bar{p}_j \delta_i}{\bar{p}_i^2 \delta_j}\bar{c}_i\left(\frac{\bar{p}_j \delta_i}{\bar{p}_i \delta_j}\right)^{-\epsilon-1}(p_{it} - \bar{p}_i)$$

Rearranging:

$$c_{jt} \approx \bar{c}_j(\tilde{c}_{it} - \epsilon \tilde{p}_{jt} + \epsilon \tilde{p}_{it})$$

$$\tilde{c}_{jt} = \frac{c_{jt}}{\bar{c}_j} \approx \tilde{c}_{it} - \epsilon \tilde{p}_{jt} + \epsilon \tilde{p}_{it}$$

$$\Delta_{ji}^c = \tilde{c}_{jt} - \tilde{c}_{it} = \epsilon(\tilde{p}_{it} - \tilde{p}_{jt})$$

$$\Delta_{ji}^c = \frac{1}{1-\sigma}\Delta_{ij}^p$$

$$\Rightarrow \Delta_{ji}^c - \Delta_{ij}^p = \sigma \Delta_{ji}^c$$

REFERENCES

Acemoglu, D., S. Johnson, and J. A. Robinson. 2002. "Reversal Of Fortune: Geography And Institutions In The Making Of The Modern World Income Distribution". *The Quarterly Journal Of Economics* 117 (4): 1231-1294. doi:10.1162/003355302320935025.

Albouy, David Y. 2012. "The Colonial Origins Of Comparative Development: An Empirical Investigation: Comment". American Economic Review 102 (6): 3059-3076. doi:10.1257/aer.102.6.3059.

Andreyeva, Tatiana, Michael W. Long, and Kelly D. Brownell. 2010. "The Impact Of Food Prices On Consumption: A Systematic Review Of Research On The Price Elasticity Of Demand For Food". American Journal Of Public Health 100 (2): 216-222. doi:10.2105/ajph.2008.151415.

Arias, Luz Marina, and Desha M. Dirod. 2014. "Indigenous Origins Of Colonial Institutions". Quarterly Journal Of Political Science 9 (3): 371-406. doi:10.1561/100.00013135.

Arroyo Abad, Leticia, Elwyn Davies, and Jan Luiten van Zanden. 2012. "Between Conquest And Independence: Real Wages And Demographic Change In Spanish America, 1530–1820". *Explorations In Economic History* 49 (2): 149-166. doi:10.1016/j.eeh.2011.12.001.

Barrales, José S. 2016. "La Asociación Maíz-Frijol Como Alternativa Para Agricultura Con Problemas De Heladas.". *Agronomía Mesoamericana* 8 (2): 121. doi:10.15517/am.v8i2.24674.

Carrillo Trueba, César. 2009. "El Origen Del Maíz. Naturaleza Y Cultura En Mesoamérica – Revista Ciencias". *Revistaciencias.Unam.Mx*. https://www.revistaciencias.unam.mx/en/41-revistas/revista-ciencias-92-93/148-92-93-articulo-01.html.

Cook, E. R, and L. A Kairiukstis. 2013. *Methods Of Dendrochronology*. Dordrecht: Springer Netherlands.

Dobado González, Rafael, and Héctor García Montero. 2010. "Colonial Origins Of Inequality In Hispanic America? Some Reflections Based On New Empirical Evidence". *Revista De Historia Económica / Journal Of Iberian And Latin American Economic History* 28 (2): 253-277. doi:10.1017/s0212610910000108.

Ertan, Arhan, Louis G. Putterman, and Martin Fiszbein. 2012. "Determinants And Economic Consequences Of Colonization: A Global Analysis". SSRN Electronic Journal. doi:10.2139/ssrn.2129786.

Fageria, N. K, V. C Baligar, and C. Allan Jones. 2011. *Growth And Mineral Nutrition Of Field Crops*. Boca Raton: CRC Press.

Fernández Suárez, Rocío, Luis A. Morales Chávez, and Amanda Gálvez Mariscal. 2019. "Importancia De Los Maíces Nativos De México En La Dieta Nacional: Una Revisión Indispensable". *Scielo.Org.Mx*.

http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S0187-73802013000500004&lng=es&nrm=iso.

Florescano, Enrique. 1979. *Haciendas, Latifundios Y Plantaciones En América Latina*. México: Siglo XXI.

French, Simone A. 2003. "Pricing Effects On Food Choices". The Journal Of Nutrition 133 (3): 841S-843S. doi:10.1093/jn/133.3.841s.

Huang, Kuo S. and Lin, Biing-Hwan, 2000. "Estimation Of Food Demand And Nutrient Elasticities From Household Survey Data," *Technical Bulletins 33579*, United States Department of Agriculture, Economic Research Service.

Larson, Philip R. 1969. *Wood Formation And The Concept Of Wood Quality*. New Haven: Yale University.

Mörner, Magnus. 1977. "La Hacienda Hispanoamericana : Examen De Las Investigaciones Y Debates Recientes". In *Haciendas, Latifundios Y Plantaciones En América Latina*, 1st ed. Mexico City: Siglo XXI.

Navarro García, Luis. 1983. *América En El Siglo XVIII*. Madrid: Rialp.

Nickel, Herbert J. 1996. *Morfología Social De La Hacienda Mexicana*. México, D.F.: Fondo de Cultura Económica.

Riley, Micheal. 1977. "El Prototipo De La Hacienda En El Centro De México: Un Caso Del Siglo XVI". In *Haciendas, Latifundios Y Plantaciones En América Latina*, 1st ed. Mexico City: Siglo XXI.

Schiff, Warren. *The Hispanic American Historical Review* 60, no. 3 (1980): 481-82. doi:10.2307/2513275.

Schweingruber, Fritz H. 2012. *Trees And Wood In Dendrochronology*. Birmensdorf, Switzerland: Springer.

Sokoloff, Kenneth L, and Stanley L Engerman. 2000. "History Lessons: Institutions, Factor Endowments, And Paths Of Development In The New World". Journal Of Economic Perspectives 14 (3): 217-232. doi:10.1257/jep.14.3.217.

Spanoghe, Sander. 1997. "Los Salarios Dentro Del Sistema Del Repartimiento Forzoso En El Valle De México, 1549-1632". *Anuario De Estudios Americanos* 54 (1): 43-64. doi:10.3989/aeamer.1997.v54.i1.398.

Therrell, Matthew D., David W. Stahle, Jose Villanueva Diaz, Eladio H. Cornejo Oviedo, and Malcolm K. Cleaveland. 2006. "Tree-Ring Reconstructed Maize Yield In Central Mexico: 1474–2001". *Climatic Change* 74 (4): 493-504. doi:10.1007/s10584-006-6865-z.

Wobeser, Gisela von. 1989. *La Formación De La Hacienda En La Época Colonial*. México: Universidad Nacional Autónoma de México, Instituto de Investigaciones Científicas.

Data bases

Prices and Wages Data: www.iisg.nl/hpw/data.php#southamerica

Tree Ring Data:

https://www.ncdc.noaa.gov/paleo-search/study/8547