Journal of Modern Applied Statistical Methods

Volume 8 | Issue 1 Article 27

5-1-2009

Industrialization in Animal Agriculture: A Kalman Filter Analysis

Oya S. Erdogdu
Ankara University, Turkey, oerdogdu@politics.ankara.edu.tr

Levent Ozbek
Ankara University, Turkey, ozbek@science.ankara.edu.tr

Journal of Modern Applied Statistical Methods
May, 2009, Vol. 8, No. 1, 289-298

1538 – 9472/09/$95.00

Industrialization in Animal Agriculture: A Kalman Filter Analysis

Oya S. Erdogdu Levent Ozbek
Ankara Unıversıty, Turkey

Studies discussing the effects of technological developments on (animal) agricultural production argue that the effective usage of chemicals and genetic engineering increase control over production processes, which in turn decreases seasonality (one significant factor defining agricultural production) significantly and brings standardization to production. Studies on broilery also show that production is not limited by nature determined seasons. Supply side changes accompanied by changes in demand have led to more healthier, standardized products. Using tools of economics and statistics, this study documents this transformation in animal agricultural production of beef, pork and milk. Results indicate decreasing seasonality, thus the industralization of animal agriculture.

Key words: Animal agriculture,seasonality, Kalman Filter.

Introduction

Agricultural production today is far different than it was 50 years ago. The social conditions and living standarts in the 21st century has led consumer preferences to support more standardized, health concerned, and user friendly agricultural products. This change from the demand side opened the door to big corporations who are are capable of producing different, standardized products to satisfy demand. As opposed to small family producers, these big corporations easily deal with economies of scope, economies of scale, market power and risk management problems, by using techonolgy intensive, manufacturing-type production techniques. These demand and supply side changes have replaced small family production with large corporations and have led to the industralization of agricultural production. This process is called industralization due to the intensive usage of high technology which increases control over nature and nurture, and standardization which increases size and quality of production.

Oya S. Erdogdu is an Associate Professor at Ankara University, and is a faculty member in Political Sciences, Department of Economics, Email: oerdogdu@politics.ankara.edu.tr. Levent Ozbek, is in the Deparment of Statistics, Email: ozbek@science.ankara.edu.tr.

Although it is important to analyze the demand and supply side factors that have caused significant changes in the sector, this article only attempts to document the decreasing seasonality in pork, beef and milk production that is the result of increased control achieved by using intensivehigh technology production techniques.

Control over nature and nurture

Allen and Lueck (2000) argued that nature is “the main feature that distinguishes farm organization from ‘industrial’ organization” (p. 14). Due to its very core of existence, agricultural production is defined and restricted by the forces of nature. Nature determines the properties, types, sequence, and timing of the stages of production, creating a certain amount of stability and predictability in the process. Nature determines the time to plant, harvest, breed, and furrow, and so creates a type of certainty in production. For example, in Iowa, USA, April-June is the time to sow, whereas September-November is the time to harvest, and spring has traditionally been the time to furrow for pigs. These are subject to weather conditions and so, contrary to standardization in manufacturing process, it can be different for different parts of the world and for different products.

Nature not only governs certainty but also uncertainty in agricultural production. The random forces of nature – unexpected changes in weather conditions, blizzards, and storms – create unpredictable and unpreventable shocks to the system.

The forces of nature and the concept of seasonality it creates, is significant to understand in the agricultural production process. For a producer of an agricultural product, a *season* is the specific period of the year during which a given activity takes place. Hence, shaped by the forces of nature, seasonality determines the stages, timing and time length of a specific process. As can be expected, this creates cycles in the production over a given period of time. As opposed to analyzing the properties or its effects of (decreasing) seasonality on production or managerial decisions, this article documents the decreasing seasonality in agricultural production over the last 50 years.

Mobility of livestock during growing stages allow it to be reared in controlled environments. Though seasonality is an issue for all types of agricultural production, compared to crop production, mobility of livestock allows a producer to exercise greater control over nature by using high-tech factory style production techniques. This article focuses on the effect of increased control over nature and nurture on animal production, specifically, beef, pork and milk.

Technological advancements are the primary factor in decreasing seasonality; they have facilitated human control on biological processes and the production environment by the effective use of veterinary medicine and by the use of genetically improved products. Thus, intensive use of technolgy has increased control over the production environment and biological development processes and allows producers to implement modern manufacturing principles to create less risky, more elastic production environments to produce more consistent, feed efficient, special nutrution enriched products. In other words, with the ability to control nature, producers have gained higher flexibility to respond to changes in consumer demand and have had an increased ability to set and sustain a certain quality level and have given the ability to reduce risks concerning food safety and contamination.

In general terms, the ability to control nature, and thus the genetic input, allows a producer to change the order in the system through mixture or separation. The method of mixture/separation can be used at the farm level, which leads to herd heterogeneity, or at the processing level, which leads to heterogeneous raw produce. The profit maximizing producer performs a cost/benefit analysis to decide on separating (at cost) or working with the mixed types they purchased to satisfy the strong demand for consistent, preparation-friendly products.

On the cost side, the use of genetic engineering is subject to patent costs and costs associated with information and uncertainty. Patent costs being a large asset, are specific costs to achieve a genetic improvement of a given species. But more importantly, the biological improvement creates information costs due to uncertainty about the composition of the mixture or the uncertainty about the reaction of each type to stimulation. Moreover, these uncertainties create inefficiency in volume production, low quality and inconsistency in raw production, leading to unsatisfactory completion of the transformation process. However, besides these negative significant impacts on commercial gains, extensive use of controlled genetic inputs is expected to decrease costs and improve commercial gains.

Given incentives, variations in inputs lead to variations in the performance of the product brought to market at the same time (intra-temporal inconsistency) and at different times. Therefore, inconsistency in production due to variations in input, like nutrition and environment, is decreased by greater control of the production environment.

Confined production systems with increased control over the production environment such as improvements in nutrition, housing, handling equipment, and management have encouraged higher and more uniform supply. Factory–style corporate livestock farming, using veterinary medicines, healthier diets and indoor environmentally controlled sheds has satisfied the needs and improved the health and production conditions of the animals. The result is a healthier, uniform, larger supply (Hurt, 1994).

Thus, the ability to control nature and nurture leads to structural changes in animal production and decreasing seasonality with more uniform and standard products. The remainder of this article aims to document this transformation using different analytical and statistical tools.

Data analysis

The data on the monthly production of pork, beef, and milk were obtained from the United States Department of Agriculture (USDA) website. Monthly milk production data was obtained for the period 1930-2000 (except 1960-1963), and monthly beef and hog production data are for the period 1944-1999 (except 1982).

The data series are monthly calculations from the first to the last day of the month. Monthly data was first normalized to 30 days per month to decrease noise in the system, in order to detect decreasing seasonality in production, the Herfindahl-Hirshman Index (HHI) was calculated, model stability/structural change tests were conducted and lastly the Kalman filter analysis was performed.

Figure 1 shows the normalized monthly production shares, calculated for 12–year averages for each month for different time periods. The shares getting closer to each other indicate increasing smoothness, which is clearly observed in the production of pork and milk. However, for beef production the variability continues; this may be due to the definition of the beef data group. Data on beef production includes data on all kinds of meat production, such as cattle and sheep. Since every production has its own timing of structural transformation, it is difficult to capture structural change from that data group, which is also expected to be a very slow process.

Figure 1 shows that the most dramatic change has occurred in milk production. The significant importance of summertime production in the 1930's is replaced with rather constant shares in 2000, indicating relatively stable production.

Methodology

In order to verify the industrialization process of animal agricultural production statistically, the Herfindahl-Hirshman (HHI) index was calculated and, to analyze the structural change in the system, Chow, CUSUMSQ and ARCH LM statistics were calculated.

Herfindahl-Hirshman Index (HHI)

HHI, is a market structure analysis tool that measures the degree of concentration in an industry. It has an advantage over other concentration measures since it works with all firms in the market and takes into account the relative distributional shares of the market held by all firms.

Based on the Jensen Inequality, the HHI is calculated using the sum of squares of the market shares of all firms. The HHI index is

$$HHI = 10{,}000 \sum_{i=1}^{K} w_i^2 \text{ , i = 1, …, K,}$$

where, w_i is the market share of the firm *i*.

In this study HHI was used to measure the degree of spread of production over 12 months for beef, pork, and milk production. HHI was calculated for each year by summing up the square of each month's share in total production; the 12-year averages of that sum were also calculated. Thus, for the time period 1945-1956 the HHI index was calculated as:

$$HHI = \frac{1}{12} \sum_{j=1945}^{1956} \sum_{i=1}^{12} s_{i,j}^2 \text{ ,}$$

where s^2_{ij} is the i[th] monthly production share in the j[th] year: the calculation is slightly different from its original form. Since decimals were not a concern, the summation result was not multiplied by 10,000, but it was preferred to take the averages to minimize the noise in the system.

Table 1 summarizes the calculation of the HHI for beef and pork averaged over the time periods: 1945-1956, 1958-1969, 1970-1981, 1983-1994, and 1988-1999. The HHI for milk production was averaged over the time

Figure 1: Monthly U.S. Production Averages for Beef, Pork and Milk

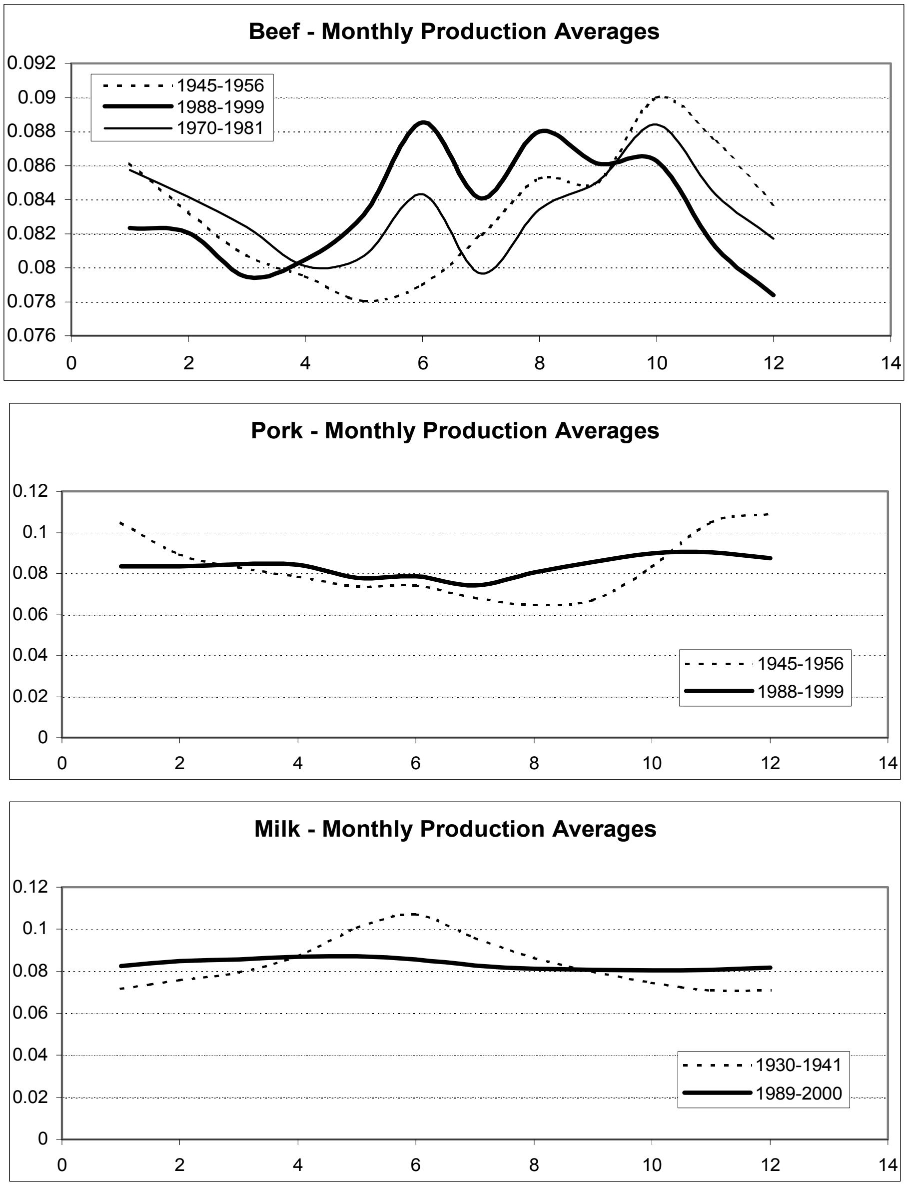


Table 1: HHI Index Values

HHI Beef		HHI Pork		HHI Milk	
1945-1956	0.084035	1945-1956	0.086944	1930-1941	0.085029
1958-1969	0.083530	1958-1969	0.084153	1941-1952	0.085543
1970-1981	0.083536	1970-1981	0.083995	1948-1959	0.084893
1983-1994	0.083542	1983-1994	0.083977	1963-1974	0.083811
1988-1999	0.083534	1988-1999	0.082635	1971-1982	0.083591
				1981-1992	0.083453
				1989-2000	0.083416

periods 1930-1941, 1941-1952, 1948-1959, 1963-1974, 1971-1982, 1981-1992, and 1989-2000.

If each month of each year had equal shares of production, 1/12, the index takes the value: $HHI = \frac{1}{12}\sum_{j=1945}^{1956}\sum_{i=1}^{12}(0.08333)^2 = 0.0833$. At the other extreme, if production was composed in only one month at each year – $s_{i,j} = 1$ and $s_{k,j} = 0$ for all $k \neq i$, the index takes the value: $HHI = \frac{1}{12}\sum_{j=1945}^{1956} 1 = 1$.

As shown in Table 1, all indexes decrease over the time periods and move towards the value of 0.083. This indicates a change in the production process such that the production is spreading over the whole year equally.

Model stability tests

The decline in seasonality implies an underlying structural change in the production process and changing parameter values, which can be detected using the Chow, CUSUMSQ and ARCH LM statistics. The OLS regression analysis implicitly assumes that the coefficients do not change over time, however, Chow, CUSUMSQ and ARCH LM tests can detect the existence of time dependency in the model, if any are present.

To test for structural change in our problem, the monthly production shares were regressed on a constant term and the monthly dummy variables:

$$y_t = \beta_0 + \sum_{i=1}^{11}\beta_i M_i + \varepsilon_t \quad (*)$$

In order to prevent the dummy trap, 11dummies were used instead of 12. The dummy for the month with less production share is excluded from the regression. Thus, for beef production the dummy for November was excluded, for pork production the dummy for October was excluded, and for milk production the dummy for March was excluded.

The monthly production shares getting closer to each other is a satisfactory indicator of decreasing seasonality. Therefore, it was expected that a structural change had occurred and the coefficients of the model have changed over time.

To document these changes, structural change statistics including Chow, CUSUMSQ and ARCHLM were calculated. To calculate the Chow test statistics, the time of structural change must be defined. However, the graphical analysis indicates a very slow change; no specific shock is given, thus the statistics for different time periods were calculated. For beef and pork production the statistics are calculated to determine if the coefficients of the regressions are different for the periods 1944-1961, 1962-1998, 1944-1974, and 1975-1998. For milk production Chow statistics are calculated for the periods 1930-1961 and 1962-2000. These results are summarized in Table 2.

Each Chow statistic for pork and milk production was greater than the critical value 1.75 at the 5% significance level. Therefore, the null hypothesis of same coefficients was rejected, and it was concluded that the coefficients obtained on regression for the given two time periods were significantly different from each other. That is, a structural change has occurred in pork and milk production in the last 50 years.

As for beef production, similar to the case in Figure 1, the Chow test results are the image of the definition of the beef data group. The test statistics for beef production indicate a structural change between 1944-1981 and 1983-1999. The same result was achieved when the sample is divided into three different time periods, but a more detailed analysis indicated that no structural change has occurred. The Chow calculation did not result in rejecting the null of no structural change for the time periods, 1944-1961 and 1962-1981, and similarly for the periods 1983-1992 and 1993-1999. This reflects a significant, but slow, transformation in beef production.

The Chow test statistics search for structural changes in the specified markets for specified periods of time. In this study the CUSUMSQ statistics were also calculated without restricting the cut off time periods in the data when searching for the existence of stability. In addition, the CUSUMSQ test has a lower power than the Chow test; results are shown in Figure 2.

The CUSUMSQ statistics for beef and pork production move outside the confidence bounds until the 1980's, indicating a structural change in the production process. However, the statistic moves inside the confidence bounds in the 1990's. This same confusing result was observed in milk production. Although the lack of milk production data may provide the explanation regarding the generality of the null hypothesis, the CUSUMSQ statistics are not very helpful in determining a structural change. This is surprising given that previous results indicated a very slow transformation process, which may be ongoing even now.

Besides searching for structural changes in the model using the Chow and CUSUMSQ statistics, ARCH LM statistics were also calculated to test whether the coefficients of the model were time varying. The results shown in Table 3 reject the null hypothesis of constant variance and thus certifies that beef, pork and milk production coefficients are time varying.

Based on these analyses the models for beef, pork and milk production were estimated again under the assumption that parameters were time varying: the Kalman filter was used for that purpose.

Kalman filter analysis

Because the model stability/structural change test results indicated that the parameters of the equation (*) are not constant due to the ongoing industrialization process of animal agricultural production, the equation is modified to allow for parameters varying over time.

$$y_t = \beta_{0t} + \sum_{i=1}^{11} \beta_{it} M_i + \varepsilon_t \qquad (2)$$

The Kalman filter estimation results from equation (**) reported in Figures 3, 4 and 5 show convergent monthly shares and thus decreasing seasonality in production. The beef production estimation results are not as clear in defining structural change, but pork and milk production estimation results show that monthly production shares are getting closer to each other. Figures show that the constant term converges to 0.1 and the dummy variable coefficient values converge to zero. As in Figure 1, the most significant change is observed in milk production. The increase in summer production and relatively low winter production is replaced by production spreading equally across all year. This change occurring in the late 1990's indicates the effect of greater control over nature and nurture in animal agricultural production.

Discussion

This study focused on decreasing seasonality to document the structural change in animal agricultural production. To satisfy consumers' preferences for healthier, user-friendly products, high technology is used intensively in production, thus increasing control over nature and nurture. The demand and supply side factors leading to decreasing seasonality have caused a significant transformation in the sector, creating factory style large manufacturing firms instead of small family farms. That process is named the *industrialization* of animal agricultural production.

In this study analytical (HHI) and statistical (Chow, CUSUMSQ and ARCH LM) tools were used with Kalman Filter methodology to document the industrialization process of animal agricultural production. However, many questions remain that must be answered by economists.

First, it is important to document how effective existent policies have been on the structural changes in animal agriculture. To document the impact of these policies on innovation, the implementation of scientific knowledge, and the role of policies to encourage/discourage vertical integration is crucial to decide on the direction of future actions.

Second, it is important to analyze the impacts of this new production structure on technological developments, bio-security, national and international market structure, prices, and the environment.

It is argued that the use of technological developments in animal agriculture have created uniformity in production. Is this a two-way road? Does uniformity encourage or discourage technological developments and innovative attempts? If so, what would the effect on market

Table 2: Chow Test Results

Beef Production

Hypothesis	Chow Statistics
$H_0 : \beta_{1944-1981} = \beta_{1983-1999}$	Chow Test: 4.19
$H_0 : \beta_{1944-1961} = \beta_{1962-1981}$	Chow Test: 1.19
$H_0 : \beta_{1983-1992} = \beta_{1993-1999}$	Chow Test: 0.53
$H_0 : \beta_{1944-1981} = \beta_{1983-1991} = \beta_{1992-1999}$	Chow Test: 46.65
$H_0 = \beta_{1944-1971} = \beta_{1972-1981} = \beta_{1983-1999}$	Chow Test: 5.23

Pork Production

Hypothesis	Chow Statistics
$H_0 : \beta_{1944-1981} = \beta_{1983-1999}$	Chow Test: 5.85
$H_0 : \beta_{1944-1961} = \beta_{1962-1981}$	Chow Test: 27.55
$H_0 : \beta_{1944-1981} = \beta_{1983-1991} = \beta_{1992-1999}$	Chow Test: 4452.44
$H_0 = \beta_{1944-1971} = \beta_{1972-1981} = \beta_{1983-1999}$	Chow Test: 622.41

Milk Production

Hypothesis	Chow Statistics
$H_0 : \beta_{1930-1959} = \beta_{1963-2000}$	Chow Test: 228.45
$H_0 : \beta_{1930-1945} = \beta_{1946-1959}$	Chow Test: 5.37
$H_0 : \beta_{1963-1982} = \beta_{1983-2000}$	Chow Test: 43.92
$H_0 : \beta_{1930-1959} = \beta_{1963-1981} = \beta_{1982-2000}$	Chow Test: 315.65
$H_0 : \beta_{1930-1945} = \beta_{1946-1959} = \beta_{1963-2000}$	Chow Test: 259.04

Figure 2: CUSUMSQ Results

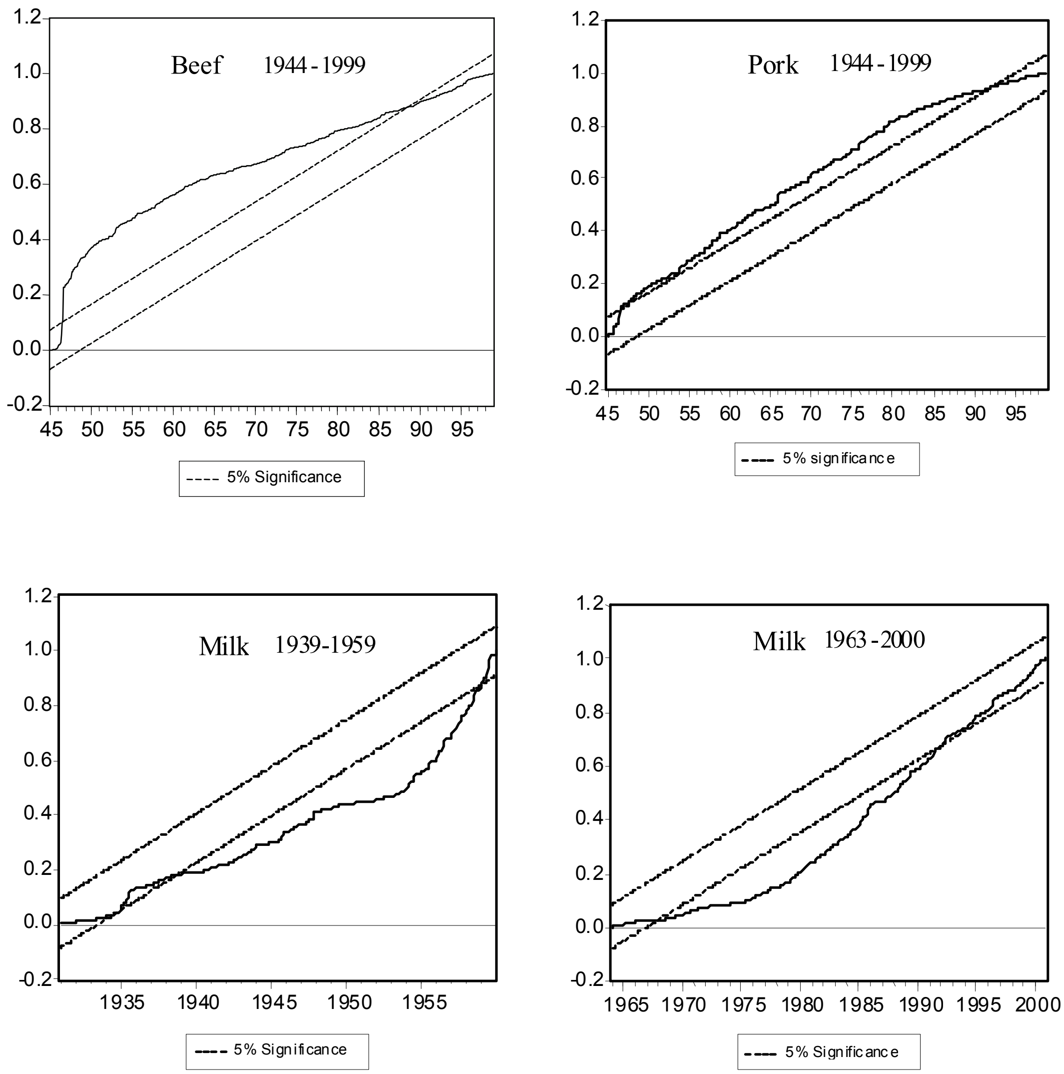


Table 3: Arch LM Test Results

	Milk 1930-1959	Milk 1963-2000	Beef 1944-1999	Pork 1944-1999
ARCH LM	93.68 (0.00)	70.23 (0.00)	24.49 (0.00)	15.16 (0.00)

Figure 4: Milk Production Estimation Results

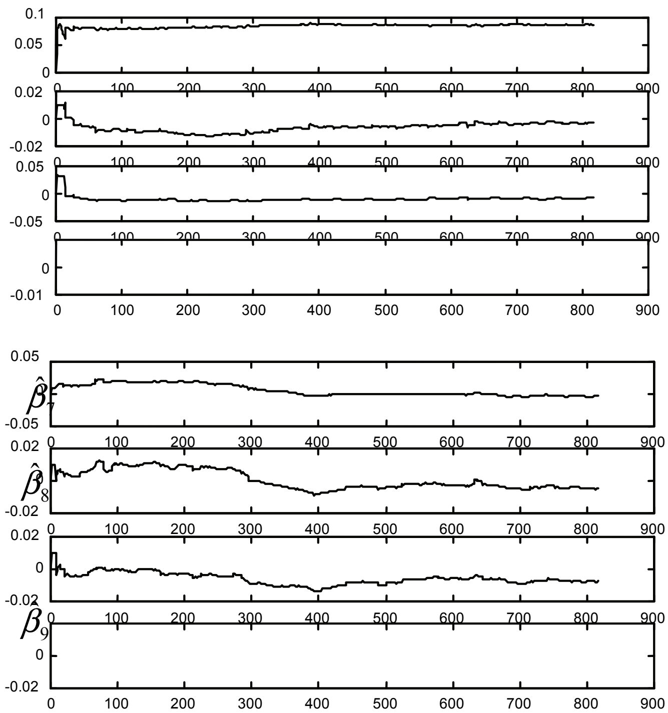


Figure 5: Pork Production Estimation Results

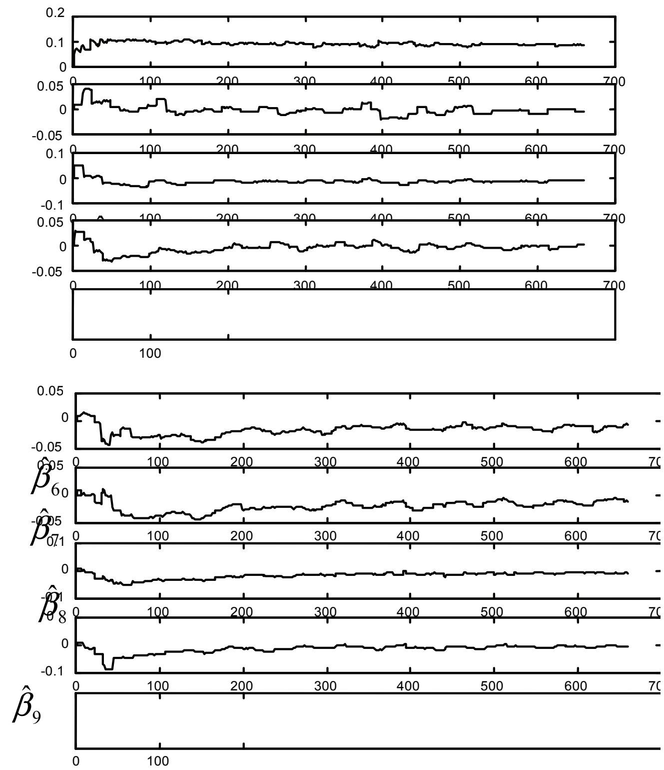


Figure 6: Beef Production Estimation Results

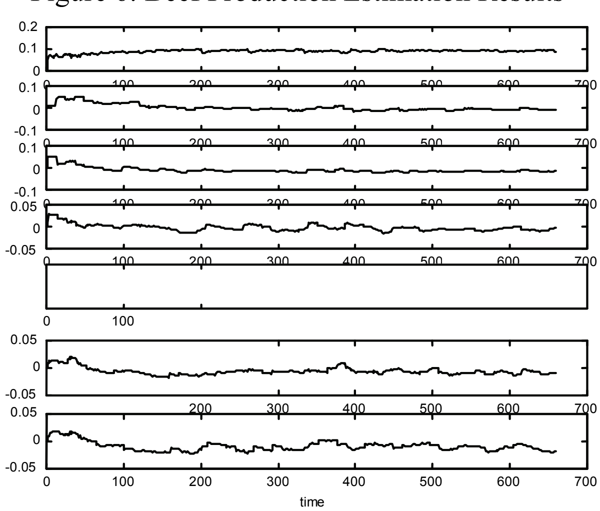
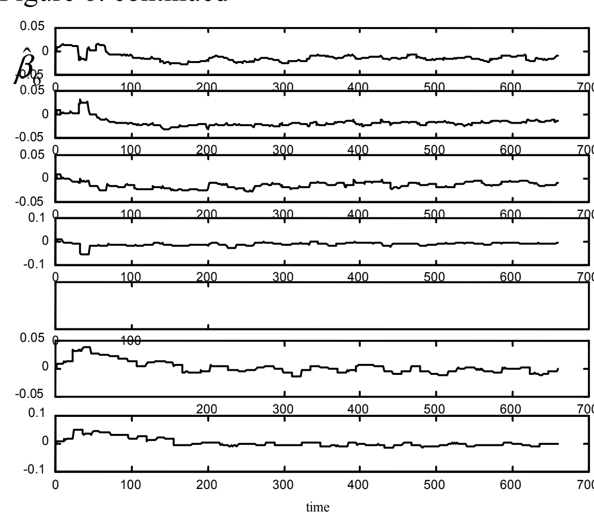


Figure 6: continued



structure, quality, quantity, prices, and the role of government? How and how much regulation should be there? As the Dioxin case in Belgium and Starlink case in Iowa pointed out, there exist important bio-security issues regarding the usage of veterinary medicines and genetic improvement techniques in large corporations with high division of labor. What would be the regulations on the usage of veterinary medicines, genetic inputs, and patent rights? Do these regulations affect the pattern of seasonality in animal agriculture?

With globalization, the international effects of decreasing seasonality in domestic markets have also become an important issue. The effects of seasonality on the price, quantity, and quality in the international markets should be analyzed as well as the consequences of policies on the usage of biological improvement techniques and medicines.

Finally, similar to arguments regarding the use of genetics in human development processes, arguments on the effect of high control of nature and nurture on animal welfare exist. Animal rights activists question if it is fair to genetically and environmentally restrict the natural development process, as in the case of factory style animal production. All of these present areas for further research.

References

Allen, D. & Dean, L. (2000). Family farm, inc. *Choices,1*, 13 –17.

Boehlje, M. (1999). Structural changes in the agricultural industries: How do we measure, analyze and understand them? *American Journal of Agricultural Economics, 81(5)*, 1028-1041.

Brewer, C. (1999). The trend of concentration in the pork industry: A brief explanation of why it's happening. *Unpublished Notes*.

Brown, R., Durbin, J. & Evans, J. (1975). Techniques for testing the constancy of regression relationships over time. *Journal of the Royal Statistical Society, Series B, 37*, 149-172.

Bugos, G. (1992). Intellectual property protection in the American chicken-breeding industry. *Business History Review, 66*, 127-168.

Drabenstott, M. (1994). Industrialization: Steady, Current or Tidal Wave. *Choices, 4*, 4-8.

Greene, W. (1997). *Econometric Analysis.* Prentice Hall Int.

Hall R, & Lieberman, M. (2001). *Microeconomics: Principles and Applications.* Southwestern College Publishing.

Hennessy, D. & Roosen, J. (2001). A Model of Seasonal Production, with Application to EU Milk Policy. *Tartışma Metini*.

Hurt, C. (1994). Industrialization in the Pork Industry. *Choices, 4*, 9-13.

United States Department of Agriculture Economic Research Service: http://www.ers.usda.gov.