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THE HISTORY OF PORTUGUESE AND SPANISH COLONIES GOLD YIELD'S TREND FROM 1492-1810

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Abstract: In the world economic history, gold has been acting as a fundamental character as a universally expensive useful commodity. Gold has possessed a unique social rank of the human race for millennia which has a long history as a costly metal and its history is far from over. Its natural beauty, luster, brilliance, resistance to tarnish and high malleability make it enjoyable to work and play. So, the production of gold has been started long years ago by the human race. The history of gold production data was not consistent, as they were reported in many books or diaries. Note that any historical data set is not accurate as a scientific experiment, or measurement data. It is highly important to study history with unbiased historical data which can only be obtained by using some scientific modeling method from the raw available data. The current article aims to study the history of Spanish and Portuguese colonies' gold production trends from 1492 to 1810 statistically. The report not only develops the efficient estimates of gold production during this period, but also examines the depression status in the gold mining industry, and many historical events such as the early industrial advancement, industrial revolution that were related with this industry. All the events are located from the developed parametric and non-parametric models, while the non-parametric model gives better estimates.

Keywords: Ancient history of gold; Cubic spline; Gold production trend; Joint generalized linear models; Spanish and Portuguese colonies.

Introduction

Gold is closely related to the history of human civilization. Gold has been inextricably associated with human civilizations approximately from 6000 BC. Absolutely, there is no way of looking at world history except encountering gold history. During ancient times, the primary gold-producing

country was Egypt (Habashi, 2014). Silver and gold production in ancient history is clearly mentioned in the article by Das *et al.* (2021). In the present article, very briefly, the gold production ancient history is reproduced herein.

In the book by Professor John TePaske (2010), it was noted that the Spanish nation was completely followed by three primary words such as glory, God and gold. They thought that their prestige and power could be improved by controlling the supply of silver and gold throughout the world. Based on these views, they began to search for gold and silver all over the world, and tried to play the leadership role all over the world. Due to the shortage of gold in Europe in the fifteenth century, the emerging nations such as Portugal and Spain were compelled to motivate the quest for new sources of gold & silver all over the world. Economic Historian Pierre Vilar noted in his diary that Columbus mentioned gold was increased approximately sixty-five times between October 12, 1492, and January 30, 1493 when the Genoan Born sailor started his return to Castile (Vilar, 1991). Columbus came back home from the first voyage with nearly 33,100 silver *pesos,* where each *peso* was of eight *reales,* and gold nuggets worth 20,000 *escudos*, approximately 9,000,000 *maravedís.* Note that *Maravedís* were small coins, primarily of copper, that were used in Castile. More importantly, the maravedi became a standard Spanish unit of account. One silver peso or piece consisted of eight *reales*. Each real was worth 34 maravedis, and thus the peso had a value of 272 maravedis. The main purpose of Columbus' second voyage was to search for gold & silver along with the discovery & victory. Columbus returned home from his second voyage with nearly 30,000 ducats in gold amounting nearly to 11,250,000 maravedis, along with more than 41,000 silver pesos. His claims were supported by the new riches sources for the Catholic Kings given by Indies (Jaime Vicens Vives, ed. 1961).

The settlers, conquistadores Portugal & Spain and mobsters, who followed them obtained a plentitude of silver and gold in the New World. Consequently, silver was dominated in Spanish America. In addition, from the very early colonial period, gold was discovered by Europeans in the Caribbean, and later on in Chile, New Granada (present-day Colombia), Ecuador as well, which were the major gold & silvers producers areas in Spanish America. At last, the Portuguese obtained plenty of gold in Luso-America (Brazil) during the eighteenth century. During the European three centuries domination periods, they made valiant efforts to estimate New World gold and silver output, as huge amounts of precious metals were extracted, refined, and minted in the Indies during that period.

For nearly three and half centuries in consequence of Brazil's discovery in 1500, the court of Portuguese was run over with imaginary gold strikes reports in Brazil (Russell-Wood, 1984). These reports mostly lacked basis, which were some misguided trusts mixture of native American stories (or legends). These stories were over-optimistic accounts by explorers, and they had the apparently right logic that a continent which had remunerated the Spaniards with emeralds, silver and gold must also possess costly metals located to the Portuguese by the Treaty of Tordesillas (1494). Not all these records had been totally free from truth. Gold had actually been obtained in Sao Vicente in

the 1560s, and by the 1570s Paulistas had discovered alluvial gold in Paranagua. There had been records of gold strikes in the interior of the captaincy of Bahia by Joao Coelho de Sousa; his brother Gabriel Soares de Sousa had received official authorization (1584) to launch an expedition to confirm these findings (Russell-Wood, 1984).

The distinguished German scientist (or educationist) Alexander von Humboldt (1769 - 1859) traveled extensively throughout Spanish America at the end of the eighteenth century and beginning of the nineteenth. Due to the blessing of Charles IV, the scientist obtained the Spanish royal fiscal records, and published his details in the book entitled- *Political Essay on the Kingdom of New Spain.* In this book, the scientist not only mentioned his own calculations of New World gold and silver output, but he also deposited those before him who had made aware calculations of New World bullion production, and had given benchmarks for his own estimates (Humboldt, 1972). Juan Solorzano Pereira (1575 - 1655), a Spanish jurist published his book — *De indiarium jure* between 1629 and 1637, later on published in five volumes as *Política Indiana,* where he estimated New World bullion output between 1492 and 1628 was 1,500,000,000 silver pesos of 272 maravedis (Juan de Solorzano Pereira, 1648). In the eighteenth century two French investigators, Abbe Raynal or Guillaume Francois Thomas Raynal (1713 - 1796), and Jacques Necker (1732 - 1804) gave their predictions of New World gold and silver production. Between 1492 and 1770, Raynal estimated that New World bullion output was 5,154,000,000 pesos that was mentioned in the book *Histoire philosophique et politique des établissements et du commerce dans les deux Indes*, which was first published in six volumes in 1770 and in many later editions were published (Raynal et al, 2010). Jacques Necker, Minister of Finance under Louis XVI restricted his observations between the period 1763 and 1777, he believed New World mines yielded 304,000,000 pesos. Another French observer Francisque Michel (Francisque Michel, 2018) predicted that New World bullion output was 5,072,000,000 pesos between 1492 and 1775, which was very close to Raynal's estimate (Raynal *et al,* 2010).

In the early eighteenth-century, politician & economist Geronimo de Uztariz (1670 - 1732) estimated Spanish American bullion production from 1492 to 1724 was 3,536,000,000 pesos, which was mentioned in his book - *Theorica and practice of commerce and marine in different speeches* (or in Spanish- *Teórica y práctica de comercio, y de la marina, en diferentes discursos*) (Geronimo de Uztariz, 1724). Scottish historian William Robertson (1721 - 1793) estimated the Indies bullion production from 1492 to 1775 was 8,800,000,000 pesos, which was too high according to Humboldt (Humboldt, 1972), as the author examined the government provided data, and long-range picture of mining and minting activity. Following very nearly the entire period of Portuguese and Spanish domination in the New World from 1492 to 1803, Humboldt estimated the amount of gold and silver produced in the Indies at 5,706,700,000 pesos, colonial Spanish output at 4,851,156,000 pesos, and Luso-American output at 855,544,000 pesos. Humboldt also tried to estimate for unregistered and untaxed output. The author predicted that of the totals for each region, 816,000,000 pesos were unregistered in Spanish America, and 171,000,000 pesos in Luso-America. One German scholar Adolf Soetbeer (1814 - 1892) estimated the world gold and silver output between 1493 and

1810 (Adolf Soetbeer, 1892). His estimations appeared in marks and kilograms of fine silver and gold which were displayed in Table 1-1, page 19 (TePaske 2010). He interpreted that between 1493 and 1810 Spanish and Portuguese America obtained 3,743,770 kilograms of gold and 126,657,400 kilograms of silver.

In 1976, TePaske published the treasury account summaries for the Mexico City Caja (TePaske, 1976). In the 1980s the team — TePaske, Klein and Jara, published similar information for Chile, Peru, Upper Peru, and the other Mexican treasury offices, followed by accounts for Ecuador in 1990 (TePaske and Klein, 1982, 1986; TePaske and Jara, 1990). This team also analyzed the data and concluded that the Mexican mining industry had not suffered a long depression during the seventeenth century (TePaske and Klein, 1981). TePaske (1983) also estimated the issue of bullion flows from Spanish America to Asia and Europe during the seventeenth and eighteenth centuries. Klein (1998) published a book searching trends in taxation and expenditure in colonial Bolivia, Peru, and Mexico during the long eighteenth century. Prof. TePaske and his team examined and cleaned the data for long times, and finally published in 2007 in the website - *http://www.insidemydesk.com/hdd.html* and also in the book by TePaske (2010).

It is observed from the above that the reported New World gold production quantities between 1492 and 1810 were different, and there were many discrepancies and also unrecorded data. Prof. TePaske and his team cleaned the data based on only the records and their personal calculations and intuitions. Best of our knowledge, no study has been made to clean the data based on probabilistic modeling. The current report attempts to present robust & unbiased predictions of New World gold production quantities between 1492 and 1810 based on probabilistic modeling, using the cleaned data presented by Prof TePaske (2010). The fitted trend curves of the New World gold production quantities between 1492 and 1810 have been derived in the report. Fitting of the curve has been examined based on graphical analysis. Based on the fitted trend curves, the robust estimates of the New World gold production quantities between 1492 and 1810 have been provided.

The manuscript is organized as follows. The next section describes very shortly the historical trends, and the remaining sections describe respectively gold production materials and statistical analysis methods, results, and discussion and conclusion. The report has developed the parametric linear polynomial mean trend curve of degree five, while the variance non-linear trend curve of degree three of transformed time t. In addition, a non-parametric cubic spline gold production model has been developed which gives better estimates than parametric models. Both the derived gold production models can be used for forecasting the mean gold production quantity at any time during the period from 1892-1810, which are more efficient, consistent and robust than the recorded data.

Historical Trend Detection Methods

The trends related to historical data are clearly described in a recent article by Das *et al.* (2021). This is not restated herein. Historical trends are completely descriptive (Schlesinger, 1926, p. viii), which were tried to express by the probabilistic models in the early days that were clearly described

in the articles by Mills (1932) and Frickey (1934). The descriptive historical trends are primarily reduced in some data sets. There may be a trend component is a time series data, which is illustrated in the books by Montgomery, Jennings and Kulachi, (2016); Shumway and Stoffer, (2017).

Historical, or any social science trends are always reduced by some statistical models, which are known as trend equations. Therefore, trends for any area are statistical problems. Generally, for deriving trend equations, it is assumed that the variance is constant, which may not be true for social science, or historical data sets. Assuming equal variance for a time series data set, mean trend equations are derived using linear polynomials, Gompertz equations, simple logistic, logarithmic parabola etc. (Montgomery, Jennings and Kulachi, 2016; Shumway and Stoffer, 2017). For unequal variance time series data sets, it is important to consider both the mean and dispersion trends simultaneously, which are not illustrated in the time series books (Montgomery, Jennings and Kulachi, 2016; Shumway and Stoffer, 2017). Note that variance of a historical data set has its own conclusions, which are connected with many historical situations during the considered period. For such an unequal variance data set, one should prefer the mean trend along with dispersion trend jointly (Lee, Nelder, Pawitan, 2017).

Material & Statistical Methods

Materials

The manuscript has derived the gold production trend equation of Portuguese and Spanish colonies for the period 1492 to 1810 adopting the gold yields data provided by John TePaske. The author obtained gold yields recorded Portuguese & Spanish colonies data primarily based on the treasury records. These data sets began to be expressed more than 33 years ago. After expressing these data sets, Prof. TePaske worked on these data sets to make them free from errors. The data set is available on the web link- *http://www.insidemydesk.com/hdd.html*. Similar silver production data is described in the article by Das *et al.* (2021). For ready reference it is given in Table 1.

Parametric Statistical Method (Joint Mean & Variance Modeling)

The present study considers the gold production trend of Spanish and Portuguese colonies from 1492 to 1810 using the registered data set as given in the above link. It is noted that the response gold production quantity over the time is continuous, positive and heterogeneous. So, the mean and variance can be modeled jointly using joint generalized linear models (JGLMs) (Lee, Nelder, Pawitan, 2017; Das and Lee, 2009; Lesperance and Park 2003). It is clearly described in many books and research articles (Lee, Nelder, Pawitan, 2017; Lesperance and Park, 2003). For ready reference, it is very shortly given herein.

For a positive gold production quantity continuous random variable y_i over time (t) with $E(y_i) = \mu_i$ and $Var(y_i) = \sigma_i^2$, where μ_i's and σ_i^2's are mean & variance parameters, respectively. We may use parametric polynomial trend functions for the mean and variance, which are

Table 1: New World Gold Registrations Decennial in Pesos and Mean estimated Gold

Decade	*Gold Pesos (GP)*	*Mid period*	*GP (in thousands) x3*	*t= (Mid period - 1635.5)/10*	*Polynom. estimated GP (in thousands)*	*Spline estimated GP (in thousands)*
1492-1500	700,000	1,495.5	700	-14	9,160.773	7,011.866
1501-1510	8,200,000	1,505.5	8,200	-13	5,396.505	7,239.051
1511-1520	7,210,000	1,515.5	7,210	-12	4,545.092	7,466.235
1521-1530	3,920,000	1,525.5	3,920	-11	5,470.913	7,816.581
1531-1540	11,120,000	1,535.5	11,120	-10	7,277.995	8,325.915
1541-1550	8,730,000	1,545.5	8,730	-9	9,288.819	8,997.262
1551-1560	10,640,000	1,555.5	10,640	-8	11,023.124	9,681.855
1561-1570	8,850,000	1,565.5	8,850	-7	12,176.719	10,292.746
1571-1580	13,000,000	1,575.5	13,000	-6	12,600.290	10,824.024
1581-1590	10,180,000	1,585.5	10,180	-5	12,278.208	11,077.135
1591-1600	11,910,000	1,595.5	11,910	-4	11,307.336	10,990.408
1601-1610	12,750,000	1,605.5	12,750	-3	9,875.837	10,610.645
1611-1620	10,430,000	1,615.5	10,430	-2	8,241.987	9,910.800
1621-1630	9,910,000	1,625.5	9,910	-1	6,712.973	8,913.600
1631-1640	5,240,000	1,635.5	5,240	0	5,623.710	7,825.200
1641-1650	6,720,000	1,645.5	6,720	1	5,315.647	6,958.800
1651-1660	6,730,000	1,655.5	6,730	2	6,115.571	6,360.800
1661-1670	4,740,000	1,665.5	4,740	3	8,314.419	7,064.000
1671-1680	4,540,000	1,675.5	4,540	4	12,146.085	9,287.200
1681-1690	5,850,000	1,685.5	5,850	5	17,766.228	14,513.600
1691-1700	8,240,000	1,695.5	8,240	6	25,231.078	23,446.400
1701-1710	33,240,000	1,705.5	33,240	7	34,476.249	36,338.000
1711-1720	37,050,000	1,715.5	37,050	8	45,295.541	50,456.000
1721-1730	74,250,000	1,725.5	74,250	9	57,319.753	65,430.416
1731-1740	99,120,000	1,735.5	99,120	10	69,995.485	78,831.829
1741-1750	108,730,000	1,745.5	108,730	11	82,563.955	88,828.367
1751-1760	90,410,000	1,755.5	90,410	12	94,039.798	94,426.098
1761-1770	95,410,000	1,765.5	95,410	13	103,189.879	97,346.685
1771-1780	104,650,000	1,775.5	104,650	14	108,512.100	97,721.897
1781-1790	102,270,000	1,785.5	102,270	15	108,214.208	97,098.255
1791-1800	102,590,000	1,795.5	102,590	16	100,192.601	95,755.235
1800-1810	82,060,000	1,805.5	82,060	17	82,011.141	94,412.215

$$\mu_i = \beta_0 + \beta_1 t + \beta_2 t^2 + \cdots + \beta_p t^p \text{ and } \log\left(\sigma_i^2\right) = \gamma_0 + \gamma_1 t + \gamma_2 t^2 + \cdots + \gamma_q t^q.$$

These models are JGLMs, which can be fitted using the R-package given in Lee, Roonnegaard and Noh (2017).

Non-parametric Statistical Method (Cubic Splines)

Non-parametric function estimation has been well described in statistical research (Ruppert, Wand, Carrol, 2003; Green and Silverman, 1994; Wahba, 1990). For fitting trends, generally we use a known functional form called parametric model. However, we prefer the smooth function even its form is unknown, which is known as non-parametric function. In this paper, we use a cubic spline as a non-parametric trend estimation method, and its fitting can be done using R-package given in (Lee, Roonnegaard and Noh, 2017).

Statistical Analysis

The response decennial production of gold quantity is modeled using Gaussian distribution. Here decennial production of gold quantity is treated as the dependent variable, and time t is considered as the independent variable. Final model has been derived based on examining the highest degree of time t is significant separately for the mean and variance model. In mean model t, t^2, t^3, t^4 and t^5 are included, while in the variance model, t, t^2 and t^3 are included. For mean and variance of gold production trend, fifth and third degree polynomials are fitted respectively. Polynomial fitted final results are shown in Table 2, and the fitted values are shown in Table 1. In addition, cubic spline fitted values are also given in Table 1.

Results

Table 2 shows the summarized results of decennial production of gold quantity under Gaussian JGLMs. The fitted mean model shows that the mean response of decennial production of gold quantity is fifth degree function of time "t". Note that time "t" is the transformed time, where t = (Mid period – 1635.5) /10 (shown in Table 1). In the mean model, t (P=0.1120) is insignificant, while t^2 (P<0.0001), t^3 (P<0.0001), t^4 (P=0.0104) and t^5 (P<0.0001) are significant. Note that, even if t is insignificant, it is included in the model due to functional marginality rule (i.e., if higher degree term is significant, then all its lower degree should be included) (McCullagh and Nelder, 1989). On the hand in the variance model, t (P<0.0001), t^2 (P=0.0236), and t^3 (P=0.0236) are all significant.

Gaussian fitted gold production mean ($\hat{\mu}$) model (Table 1) is

$$\hat{\mu} = 5623.7103 - 755.0555\, t + 391.2103\, t^2 + 56.5693 t^3 - 0.6108 t^4 - 0.1766 t^5$$

and the fitted gold production variance $\left(\hat{\sigma}^2\right)$ model is

$$\hat{\sigma}^2 = \exp.(16.554517 + 0.421224t + 0.009588t^2 - 0.002289t^3).$$

Table 2: Gold Production Trend Fit for Gaussian Joint Models between 1492 and 1810

Model	*Covariate*	*Estimate*	*Standard error*	*t-value*	*P-value*
Mean	Intercept	5623.7103	1590.0	3.536	0.0004
	t	-755.0555	475.2	-1.589	0.1120
	t^2	391.2103	47.19	8.290	<0.0001
	t^3	56.5693	7.371	7.675	<0.0001
	t^4	-0.6108	0.2383	-2.563	0.0104
	t^5	-0.1766	0.0267	-6.623	<0.0001
Dispersion	Intercept	16.5545	0.4210	39.320	<0.0001
	t	0.4212	0.0754	5.588	<0.0001
	t^2	0.0096	0.0045	2.153	0.0236
	t^3	-0.0023	0.0005	-4.581	<0.0001

Discussions & Conclusions

The report has focused on the gold production trend of Spanish and Portuguese colonies from 1492 to 1810 using polynomials and cubic spline. It has been mentioned in the Introduction Section that the information regarding New World gold production quantities are controversial, miss recorded and unrecorded. It is well known that history study is always based on information. In addition, this information gives many social, economic and political status of the society, which are the main study subjects in history research. Earlier historians, and historical economists have tried to study history with some statistical graphs, figures and maps etc (TePaske, 2010). Best of our knowledge, there is very little study of history using advanced probabilistic modeling. So, the present results are not compared with the previous similar studies, while the present findings are compared with the previous historical recorded results in Table 1 and Figure 1.

Figure 1 shows that scattered plots of the original recorded data, and both the mean fitted polynomial and spline, against the time. Cubic spline fit is closer to original points than the polynomial fit. At the boundary points (i.e., at initial and the end positions), the fitted polynomial trend curve is fluctuating unsteadily, while the smooth fitted cubic spline curve is not so (Figure 1). Within the interval period, both the fitted trend curves give very similar estimates, while at the boundaries, the cubic spline gives better estimates. In addition, the cubic spline gives better estimates in the future and also in the past than the fitted polynomial. From both the fitted mean curves (Figure 1), it is observed that at the beginning from 1492 to end of seventeenth century, gold productions were almost stable, but there is a big jump of gold production amount around the year 1700, and it was increasing up to year 1750, and after that it was almost stable. Figure 2 presents

the variance plots for both cubic spline and polynomial fit, while both the figures show that gold production variance was stable at the beginning from 1492 up to the end of seventeenth century, and after that there was a big variation up to the mid of eighteenth century, and after that it was stable. This fact is also reflected in the both fitted mean plots. This shows that some advanced mining techniques were introduced around the end of the seventeenth century, which were highly applied in mining.

Industrial advancement had started at the end of the seventeenth century in Europe and America. The invention of the steam pump by Thomas Savery in 1698 and the Newcomen steam engine in 1712 highly facilitated the extraction of water & mud, and enabled holes to be made deeper, enabling more gold and silver to be extracted. These pumps were greatly used in gold, or silver, or coal mining. These developments had begun before the Industrial Revolution, nowadays it was also known as the *First Industrial Revolution*, which was the transition to new manufacturing processes in the United States and Europe, in the mid eighteenth century. Historically it is well known that at the end of the seventeenth century there was a great advancement in industrial revolution in America

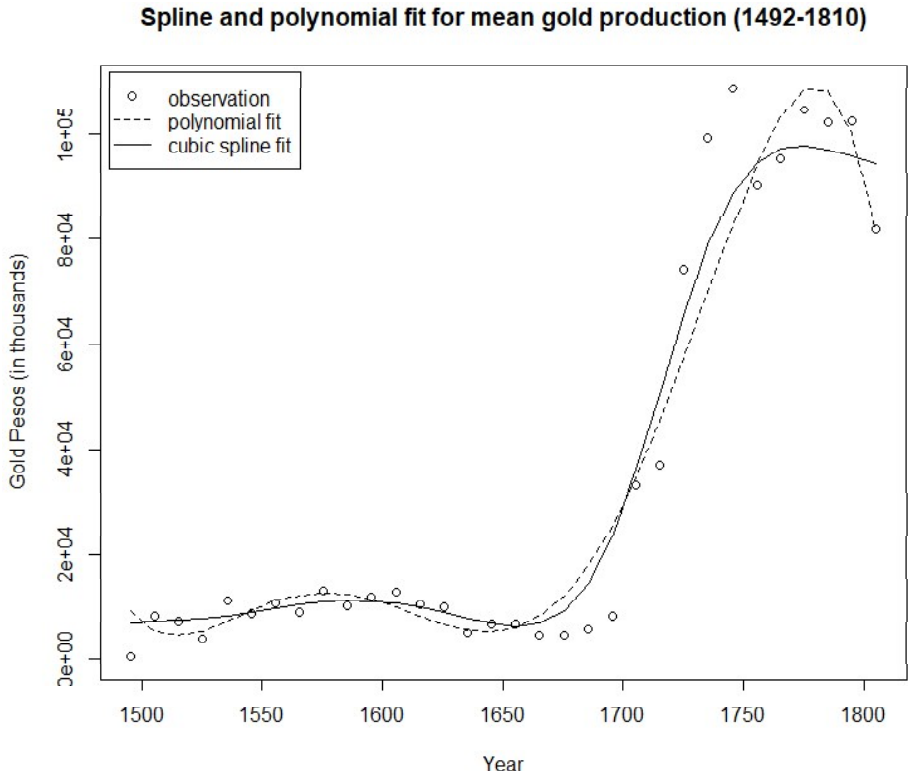

Figure 1: Scattered plot of the original observations and the smooth fitted mean trend curves for polynomial and cubic spline

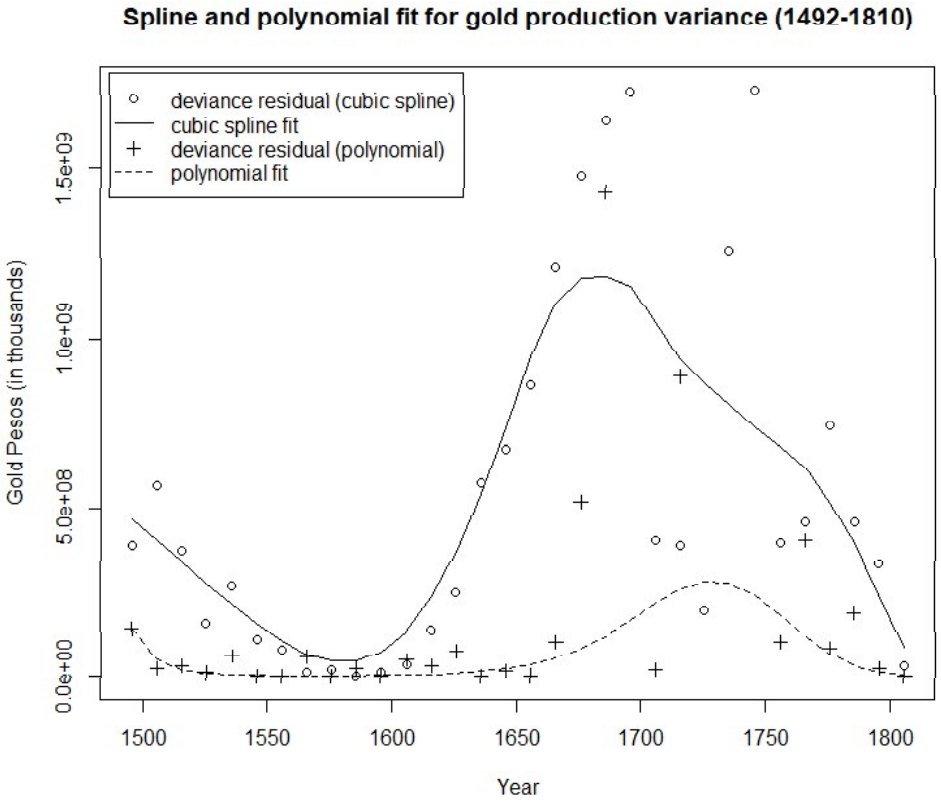

Figure 2: Variance plots for smooth fitted cubic spline and polynomial

and Europe. This is also reflected in the present analysis. In addition, present analysis does not reflect any depression in gold mining during the period, which is also supported by (TePaske and Klein, 1981). Thus, the present statistical analysis not only predicts the gold production quantity, but also reflects many historical facts of society such as depression, industrial revolution etc. In order to reduce the controversy and miss records of the historical data, statistical modeling can be more effective.

Conflict of Interest

The authors confirm that this article content has no conflict of interest.

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