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Session of the European Business History Association and Business History Society of Japan,
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Musée de Sète: inv. 891.14.1, Robert Mols, "Port de Cette", 1891,
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Silver production in 17th- century Spanish America: A preliminary analysis of its volatility, trajectory and possible effects on the Castilian monetary system

Claudia de Lozanne Jefferies¹

This paper presents a preliminary analysis of volatility in Peruvian and Mexican silver production series throughout the 17th-century, based on ARCH/GARCH models. Through a comparison of volatility patterns in the two viceroyalties, hypotheses on investor behaviour will be put forward and compared to theories on the relationship between risk and the development of merchant networks. Trends of silver production will be compared to trends of exchange rate series registered in Seville, exploring the possibility of a link between exchange rates in Seville and metal production in either viceroyalties.

Introduction

Within the historical literature on early Spain and Spanish America of the last four decades, numerous have been the discussions centred on volumes and destiny of Spanish American precious metals. Those discussions have certainly resulted in a much clearer picture of the subject matter, not only in terms of estimations related to volumes and the places where metals were transported, but of the underlying elements determining those volumes and destinations. The question about the provenance of Spanish American metals has attracted less interest than the one about their destiny, probably due to the intrinsic difficulty in determining their exact trajectory within merchant circuits. The following paper introduces the use of time series econometrics as an attempt to overcome some difficulties related to determining the origin of metals feeding different trade circuits. Centrepiece of this approach will be the analysis of volatility in the production of Mexican and Peruvian silver throughout the 17th- century with the help of ARCH/GARCH models. By comparing volatility patterns in the two areas, an attempt to hypothesise on possible capital flows will be undertaken. To complement this approach, Spanish exchange rate series will be compared against trends in silver production in both viceroyalties. This is work in progress and a great deal of further results are on their way. At a preliminary level, this paper is attempting to disclose the possibility of eventually finding a relationship between exchange rates in Spain and the provenance of the silver reaching Seville, which may shed some further light on elements determining the problems of silver scarcity and *vellón* monetary crisis in 17th-century Castile.

Silver: Its origin, destiny and volatility within the historiography of mining and trade in Spanish America

Following the publication of Hamilton's series² on precious metals reaching Europe in the early modern period, the 17th-century had been associated with an overall decline in the production of silver in Spanish America. It was only after the works by Brading³ and

¹ City University London.

² Hamilton, Earl, *American Treasure and the Price Revolution in Spain, 1501-1650*. Cambridge MA, Harvard University Press, 1934.

³ Brading, D. A., and Harry E. Cross. "Colonial Silver Mining: Mexico and Peru", *Hispanic American Historical Review* 52 (1972): 545-579; Brading, D.A. and Cross, Harry E., *Colonial Silver Mining: Mexico and Peru*, *The Hispanic American Historical Review*, 52:4 (1972), (34 pages); Brading, D.A., *Miners and Merchants in Bourbon Mexico: 1763-1810*, New York, Cambridge University Press, 1971, "Mexican

Backewell⁴ on colonial mining production and later by scholars studying the Pacific⁵ trade that such theory has given way to new perspectives. The thesis of the diversion of trade routes towards the Pacific challenges older views on the development of mining activities in Spanish America during that time, as well as the overall level of economic activity during a century which had been described as characterised by a situation of general crisis.

Although the quantities of precious metals reaching Seville did decline throughout the century, in line with what can be drawn from Earl Hamilton's series,⁶ it is still uncertain how much silver was produced throughout the colonial period and how deep was the recession caused by the decline of indigenous population during the last half of the 16th century. The development of trade, both Atlantic and Pacific points towards the possibility that such depression was not as deep as described in the pre- Brading literature.

When addressing the issue of silver production in Spanish America, a great deal of effort has been placed on calculating quantities of metals mined throughout the colonial period. The question about the origin of the metals reaching Seville has barely been addressed. The relevance of such provenance has not yet been studied fully. Richard Garner's work has focused on the trends in silver production in this comparative study of Mexico and Peru. Garner⁷ carries out an analysis of trends using time series statistics and explains the different trends in silver production in the two viceroyalties by placing those trends within the context of the different ways silver was produced in Peru and Mexico. He places special attention on the differences in the nature of labour, as well as in the physical, geographical and social characteristics of the two areas. Drawing on the works of Backewell and Brading, Garner offers insightful explanations about the productivity differentials, which are of interest when attempting to explain the dynamics of trade circuits. Using OLS- based time series statistics, he has calculated trends of windows composing the series. This was an ingenious way of avoiding potentially spurious results. Garner has reached the conclusion that the trend in Peruvian silver production was declining after the turn of the 16th into the 17th century. In contrast to Peru, Mexico shows an overall upward trend throughout the colonial period, with the exception of the first eight decades of the 17th century. As already suggested by Brading, the declining trend in silver production both, in Mexico and Peru during the 17th- century can be put down to the decline in indigenous population during the last two decade of the previous century.⁸ Being labour a factor of production, the effects of a population crisis on the levels of productivity are evident. It should also be taken into account that mining activities relied on a number of complementary services, whose industries were equally affected by the decline in population. Despite the fact that, as suggested by Backewell, incentives were the main element that attracted labour into areas where labour shortages prevailed, during times of depopulation, a decline in mining activities cannot be avoided.

Potosi remained as the "superstar mining camp" even when Mexico's mining production overtook that of Peru. During the 16th and 17th centuries, Peru contributed in a much greater proportion than Mexico towards the total quantities of silver that were produced. Maximum yearly production in Peru could reach 12 million pesos, whereas in Mexico, yearly

Silver Mining in the Eighteenth Century: The Revival of Zacatecas", *Hispanic American Historical Review*, 50:4 (1970): 665-681; "La minería de la plata en el siglo XVIII: El caso Bolaños", *Historia Mexicana*, 18:3 (1969): 317-333.

⁴ Bakewell, Peter J, ed. *Mines of Silver and Gold in the Americas*. Aldershot, UK, Variorum, 1997; "Mining" in: *Colonial Spanish America*. Edited by Leslie Bethell, 203-249. Cambridge, UK: Cambridge University Press, 1987.

⁵ Dennis O. Flynn and Arturo Giráldez Born with a "Silver Spoon": The Origin of World Trade in 1571, *Journal of World History* 6: 2 (1995): 201-221 ; "Arbitrage, China, and World Trade in the Early Modern Period", *Journal of the Economic and Social History of the Orient*. 38: 4 (1995): 429-448.

⁶ Hamilton, 1934.

⁷ Garner, 1988: 889-914.

⁸ Borah, Woodrow, *Colonial Trade and Navigation Between Mexico and Peru*, Berkeley and Los Angeles, University of California Press, 1954; *New Spain's Century of Depression*. Berkeley, University of California Press, 1951.

maxima would lie at around 6 million pesos. The total volumes of silver produced are deceiving, as there was a higher degree of efficiency in Mexican mines than in their Peruvian counterpart. This efficiency became evident towards the end of the 17th century, when the volumes of Peruvian silver production were outsized by Mexico.

The opposing trends in mining production throughout most of the colonial period in Mexico and Peru have been explained in part through the different governance that the Spanish authorities exercised on each one of the two viceroyalties. One of the most important differences is the one manifested in the range of different terms of employment prevailing in the two viceroyalties, which went from tribute systems such as the *mita* in Peru or the *naborias* in Mexico, to salaried work. The *mita* played a very important role in drafting and retaining workforce in the remote Potosi region. The general trend was for salaried labour to replace coerced labour throughout time, however, the *mita* tribute system was retained as the only solution to cover the high demand for labour in the Potosi camp, given population in the area was scarce and scattered. Bakewell suggests that the reliance of Peru on the *mita* as a means of workforce retention hid real labour costs. Labour also needed to be drafted to certain northern areas in Mexico, hence the existence of *naborias* and the *encomienda* (which could also be found in Peru) as a means of addressing the labour demand in the growing mining industry, however, these forms of tribute labour were less widespread than the *mita*, which unlike the *encomienda*, survived the introduction of the New Laws of the Indies in 1542, which granted the indigenous population the right to salaried work. The *mita* was preserved through the Inca aristocracy, who, in alliance with the Spanish rule, ensured a continuity of the pre-hispanic tribute system prevailing in Peru.

As highlighted by Brading and Bakewell, population patterns in Mexico were different from those in Peru, which had consequences for the development of mining activities. Areas surrounding most Mexican mining camps were relatively densely populated and the overall indigenous population was larger. This made it possible for miners to recruit workforce more easily than in Peru. Bakewell believes that the existence of mostly salaried labour translated itself into a higher level of productivity, reflected in production cost differentials, which could be clearly observed in the 18th-century.⁹ The upward trend in silver production in Mexico throughout the colonial period can also be explained by other factors, as done by Chaunu,¹⁰ Bakewell and Brading: The supply of mercury played a crucial role in the development of silver mining activities in Spanish America. The supply of mercury used for silver production in Peru came from Huancavelica. The Fugger bankers had been granted the right by the Spanish Crown to exploit the mercury mines. Such privilege expired at the beginning of the 17th-century, when the production of mercury in the area started declining dramatically. As a determining factor of the Peruvian silver production, mercury production in Huancavelica showed an overall declining trend from about 1600 onwards.¹¹ In addition to the declining trend, mercury production reflected a high level of volatility, which was spilled over to the Peruvian silver industry.

Mexico received its supply of mercury from the Spanish mines of Almaden, which were Crown monopoly. this supply was deviated to Peru during the second and third decades of the 17th century, which reflected a desperate attempt from the part of the Crown to reinstate the former higher levels of production. It is to be noted that the Crown derived a higher tax revenue from Peruvian silver, as Mexican miners had received in the previous century a reduction of the mining tax *quinto real* from 20% to 10%.

With reference to mercury production, volatility spillovers to the mining industry can be observed both, in Mexico and Peru, however to a higher degree in Peru. In addition to volatility spillovers, exploitation was stochastic by nature, which added to the uncertainty of

⁹ Bakewell, 1987: 203–249.

¹⁰ Chaunu, Pierre and Huguette, *Séville et l'Atlantique (1504–1650)*, Paris, SEVPEN, 12 volumes, 1955–1960. (Prix de Loubat, 1962).

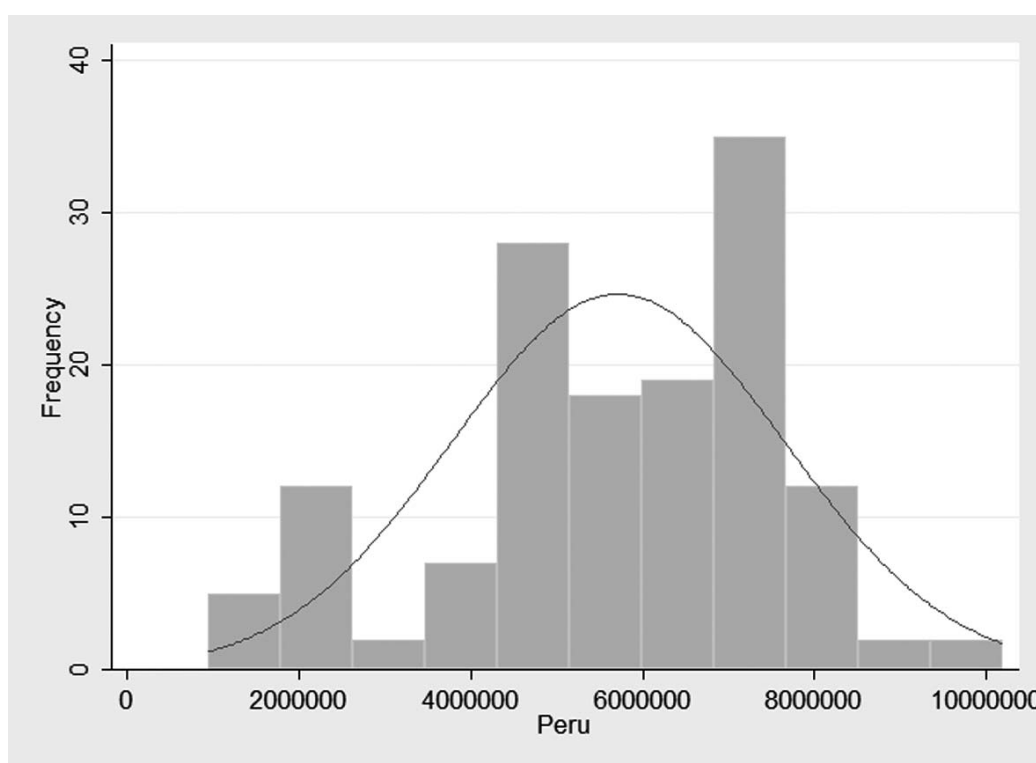
¹¹ Garner, 1988.

expected industry revenues. Scholars studying the mining industry in Spanish America are aware of the importance of volatility in explaining the way in which mining activities developed in both viceroyalties, however a close analytical comparison of volatility in the mining industries of colonial Mexico and Peru has not yet been carried out. In the following paragraphs, a preliminary comparative analysis of such volatilities will be carried out with the ultimate intent of shedding light on the linking factors between silver production in Spanish America and silver/ copper exchange rate determination in Castile.

Preliminary volatility analysis in mining industries of Mexico and Peru during the 17th-century¹²

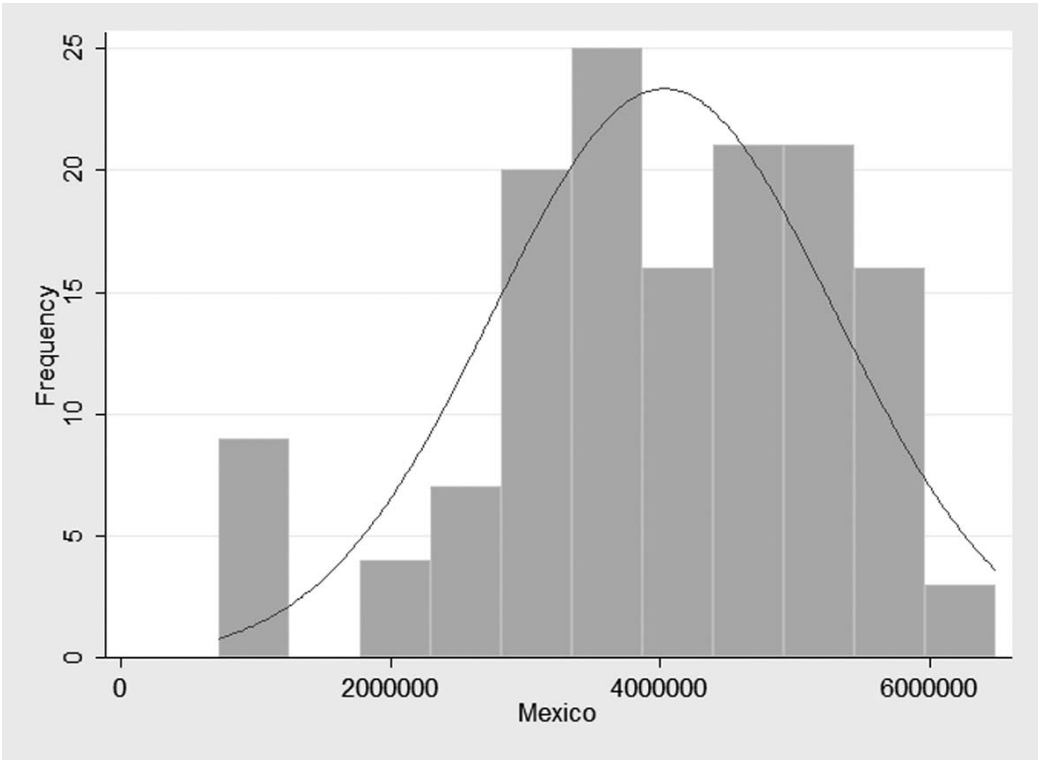
Volatility, the measure of spread of returns, can be first elicited by plotting frequency distributions.

Fig 1: Frequency distribution of silver production Peru 1600-1700 (pesos)



¹² Silver production data were obtained from: Te Paske/Garner: Gold and Silver Registration (full reference in bibliography).

Fig 2: Frequency distribution of silver production Mexico 1600-1700 (pesos)



The first histogram (fig.1) depicts the frequency distribution of silver production in Peru. It can be seen that the distribution resembles up to some degree a quasi- bimodal distribution with a relatively large spread of observations, whereas the histogram corresponding to Mexico shows more of an even, Gaussian- like spread with a more narrow range of observations.

A Lagrange Multiplier ARCH (autoregressive conditional heteroskedasticity) has been carried out for each one of the series and the following results have been obtained:

Mexico

```
. estat archlm
LM test for autoregressive conditional heteroskedasticity (ARCH)
```

lags(<i>p</i>)	chi2	df	Prob > chi2
1	118.447	1	0.0000

H0: no ARCH effects vs. H1: ARCH(*p*) disturbance

Peru

```
. estat archlm
LM test for autoregressive conditional heteroskedasticity (ARCH)
```

lags(<i>p</i>)	chi2	df	Prob > chi2
1	104.647	1	0.0000

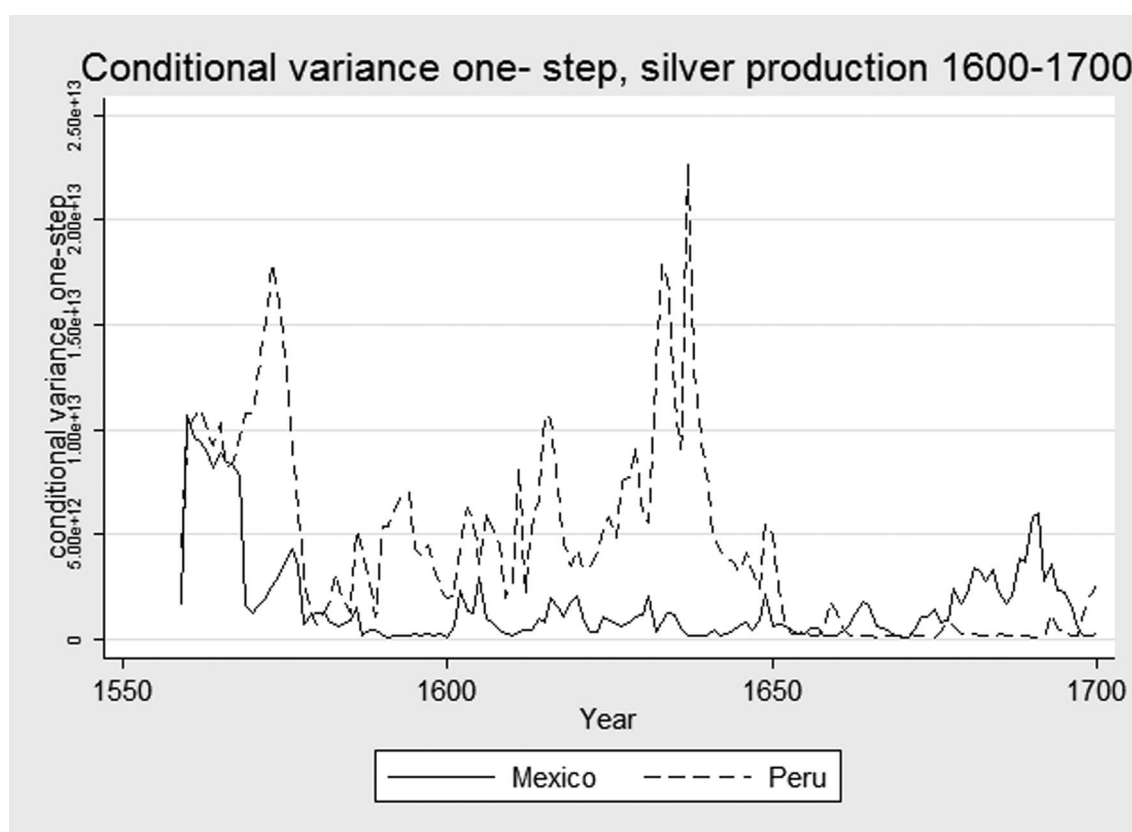
H0: no ARCH effects vs. H1: ARCH(*p*) disturbance

So far, the preliminary results point towards the presence of serial autoregressive conditional heteroskedasticity, as for both series, the null hypothesis of no heteroskedasticity could be rejected.

In order to compare the different degrees of variability throughout time in the residuals of each one of the series, ARCH- family models have been estimated.

Error variance series have been generated with the help of the models described above, with which the varying variance of the lagged error terms can be appreciated for each one of the series:

Fig. 3: Conditional Variance, one step (billions of pesos)



As it can be drawn from comparing the error variance series, Peru's series present a higher and more frequently changing variance than Mexico's series. It could be argued that higher levels of production in Peru compared to Mexico could be responsible for such larger levels of variance in the error terms, however, as it can be elicited from comparing the histograms and considering the variation coefficient for each viceroyalty, a larger number of observations are moulded around the mean in the case of Mexico. From the point of view of a potential, moderately risk- averse investor, the Mexican scenario would come across as more attractive than that of Peru. There is a stochastic element in Peru's curve which would appeal only to more risk- friendly investors. In Garner's words: "Mexico's silver productivity curve make risk taking more tolerable".¹³

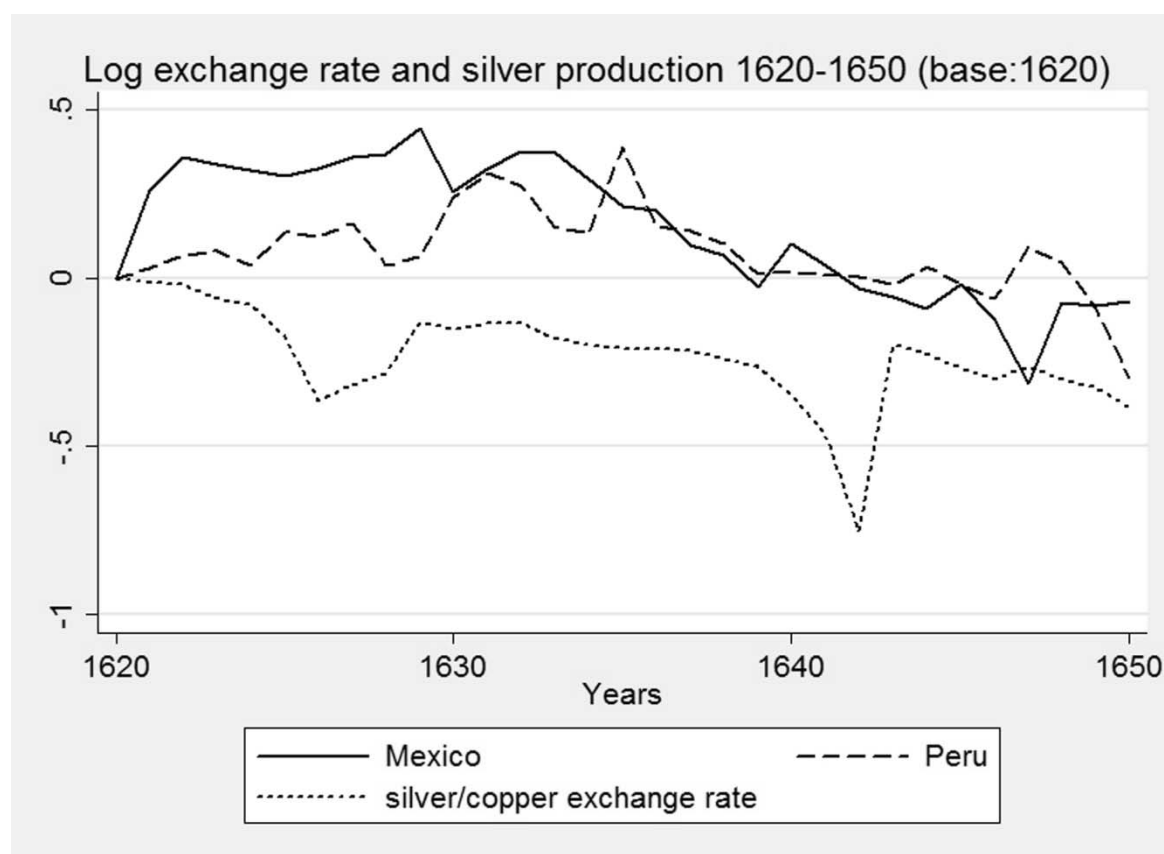
It ought to be added that mining camps in Mexico were spread out throughout the viceroyalty, which made it easier for the prospective investor to diversify his risk portfolio.

¹³ Garner, 1988: 933.

The development of better established commercial links than in Peru and the existence of credit networks headed by the *Consulado de Mercaderes* in Mexico had been a product, at least in part, of the relatively reliable levels of return in the mining sector, which enhanced the confidence of venture capitalists of the merchant classes. Merchant networks linked Spanish America with Europe and Asia, for which the fairs of Veracruz and Acapulco played a key role.

Trade survived political instability in 17th- century Mexico and centralist fiscal policies in Spain, which manifested themselves amongst other in precious metal confiscations inflicted to merchants in Seville. It also survived economic downturns in either sides of the Atlantic. The high profitability of luxury goods trade ensured its prevalence. The downward trend of the overall silver production in 17th- century Mexico did not preclude the existence of clusters of prosperity in certain areas,¹⁴ given the large spread of mining camps throughout the viceroyalty. Prosperity in mining camps tended to be spilled over to other industries, providers of complementary services, which sustained the demand for luxury goods both, from Asia and from Europe. Trade between Mexico and Spain may have experienced a reduction in the 17th- century due to economic downturns on either sides of the Atlantic, but it remained active.

Fig. 4: Silver/vellón Exchange rate vs silver production in Mexico and Peru 1600-1650 (log)¹⁵



Addressing the question about the relevance in understanding the origin of the American silver circulating in Spain, an answer cannot yet be offered, given the preliminary

¹⁴ Bakewell, 1987: 203–249.

¹⁵ Silver series: Te Paske/Garner: Gold and Silver Registration; Exchange rate series: Hamilton, 1634.

stage that this line of enquiry is at. Further work is on its way, which will hopefully offer some more conclusive results. So far, it will just be attempted to compare the rate of growth of exchange rate silver/*vellón* in Seville to the rates of growth in silver production¹⁶ in Mexico and Peru during the first half of the 17th- century (fig. 4), as a first step into this line of enquiry:

Peru's rate of growth during the period shows at times an upward tendency whereas Mexico's is mostly steadily downward, as is the trend of the exchange rate silver/ *vellón*. From the point of view of the shape of the series, the exchange rate bears more resemblance to Mexican silver production than to that of its Peruvian counterpart.

All three series were tested for stationarity with the Dickey- Fuller test, and the null hypothesis of the presence of a unit root could not be rejected, which means that the three series are non-stationary.

Some preliminary conclusions

As stated previously, this is work in progress and stronger evidence is needed in order to present more significant conclusions, however, the results obtained through the GARCH model help point towards the presence of different volatility patterns in the Mexican and Peruvian silver production series in the 17th-century. It is still yet to be analysed the relevance of volumes of production on volatility, as it can be noted from fig. 3 that higher levels of volatility can be observed when production trends are increasing than when they are declining. As only a sub- sample of data are presented in this paper, no conclusions concerning this point can be drawn.

As far as the question of attitudes towards risk is concerned, further statistical analysis is required, complemented by qualitative material, in order to shed further light on patterns of investor behaviour and risk aversion. So far, the analysis of volatility confirm the already existing hypothesis that the relative stability of the Mexican series is in line with the attraction Mexico excreted towards merchant capital, which helped develop the infrastructure of networks that supported the mining boom in the following centuries. Merchant networks were the channel through which silver circulated between continents, which had consequences such as the price revolution in the 16th- century.

The decline in population, ore exhaustion and policies detrimental to trade may have affected the levels of demand and supply of luxury goods, but trade continued. The fairs of Veracruz were still important as the centre of the axis linking the route of merchandises from Asia to Europe, as well as the trajectory of silver flowing from America into Europe's merchant networks. The resemblance between exchange rate series and Mexican silver series may be pointing towards the possibility of developing of a model of exchange rate determination drawing variables from both sides of the Atlantic.

¹⁶ Expressed in Fischer volume indices, base 1620. The natural logarithm of the Fischer volume indices reflects a continuously compounding growth rate.

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The specific interaction between the local and the global, but also between the national and the private, demonstrating the globalisation's mechanisms during the last decades of the 19th century, was the central questions examined in the Session "Business with money: monetary politics and capital flows in the era of the first globalisation" organised by C. Brégianni in the framework of the XVI EBHA Conference, Paris, EHESS, 29 August - 1 September 2012. In this Session we tried to apply a comparative approach concerning monetary systems and numismatic activity; we attended to investigate the past experiences of monetary cooperation but also the cultural transfer and the economic asymmetry that coin's fabrication often represents.

The round table "Small change: bronze or copper coins from Antiquity to 19th c.," was organized by Georges Depeyrot in Paris at the École Normale Supérieure in 2013 (13 - 14 May) in the framework of the ANR DAMIN program and of the LabEx TransferS. During this meeting, the participants tried to understand the role of the small coins (copper, bronze, brass, etc.) in the economy, in the monetarisation of societies and the relation between small change and gold and silver coins.

The last round table "Transfers of precious metals and their consequences, 16th – 19th" took place in Madrid at the Casa de Velázquez on 16 - 17 May 2013. It was organized by Georges Depeyrot and Marina Kovalchuk in the framework of the ANR DAMIN program and of the LabEx TransferS with the support of the Casa de Velázquez. The aim was to compare the consequences of the two main arrivals of precious metals in history, during the 16th century and during the 19th century. The choice of Madrid was linked to the role of Spain and Portugal in relation with the first arrival of gold and silver.



M O N E T A

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