COMPETING BIMETALLIC RATIOS: AMSTERDAM, LONDON AND BULLION ARBITRAGE IN THE 18TH CENTURY

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ABSTRACT
This paper analyzes the stability of bimetallism. I study the competition between legal bimetallic ratios set independently by monetary authorities in different countries. I articulate a new framework which extends previous theories to deal with the case where different countries set different ratios, a usual situation in the early modern period. I then show how this does influence outcomes. Then, using new data hand-collected from archival sources and relevant to the two main bullion markets in the 18th century; Amsterdam and London, I show how this framework can be put to work to identify the regimes that actually prevailed in London and Amsterdam during that period. Amsterdam was on effective bimetallism while London was on gold standard de facto.

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INTRODUCTION

Bimetallic standard is a commodity-money system consisted of gold and silver. Both metals are commodities as well as money. This twin function of bullion has created a wide theoretical debate on the stability of bimetallism. The debate derives from a broad arbitrage principle: the legal ratio between gold and silver as money must equal the market ratio between gold and silver as commodities, otherwise, arbitrage becomes possible.

Is bimetallism stable? The opponents of bimetallic stability claims that the legal ratio can not equal the market ratio because shocks on the market ratio lead to brutal switches from bimetallic standard to an alternation of de facto monometallic standards (Locke 1696, Say 1826, Stuart Mill 1848 Jevons 1884; Laughlin 1885, and recently Garber 1986 and Redish 1990, 1995 and 2000). The legal ratio is hence an unstable rule, a “knife-edge”, so the authorities should have abandoned the pretension of ruling the relative ratio between gold and silver.

The knife-edge approach has an important assumption: the equilibrium market ratio between gold and silver is exogenously set in the commodity market, so demand for monetary use should not affect the metals’ availability as commodities. Therefore, the legal ratio is a redundant constraint, super-imposed on a well-defined market equilibrium. But this is a wrong assumption because monetary uses had a very important role in total bullion consumption. Silver for monetary uses represented 45% of total silver stock in the 16th century, 38% in the 17th century and 24% in the 18th century; and gold for monetary uses represented 29% of total gold stock in the 16th century, 24% in the 17th century and 23% in the 18th century. So, gold and silver for monetary uses represented a very high proportion of total metal stock; and it is an error, therefore, to posit that the relative price of gold-commodity and silver-commodity is exogenous.

1 Locke (1696) began the controversy at the end of the seventeenth century. The debate was reopened at the end of the nineteenth century (Walras 1881; Laughlin 1885; Giffen 1892; Fisher 1894; Shaw 1895; Walker 1896; Darwin 1898; Willis 1901); and it has been revived at the end of the twentieth century (Chen 1972; Garber 1986; Rolnick and Weber 1986; Friedman 1990; Redish 1990, 1995, 2000; Flandreau 1995, 1996, 1997, 2002, 2004, Oppers 1996, 2000; Velde and Weber 2000).

2 I have calculated the percentage in monetary uses of total gold and silver stock using the following data: Gold and silver stocks in 1492 are taken from Velde and Weber (2000, p. 1230), and gold and silver production from 1493 to 1800 is taken from Ridgway (1929) and Merrill (1930). The amount of gold and silver money is taken from Mulhall (1903, p. 321, table C). Mulhall gives data in Sterling Pounds. I have converted Sterling Pounds to Troy Ounces using London Mint prices, available in Feavearyear (1931, pp. 346-347). The percentages of gold and silver for monetary uses are calculating without considering depreciation of the stock, so they represent the minimum percentage because the stock is maximized.
The proponents of the stability of bimetallism focus on a broader perspective of a general equilibrium. They recognize that the legal ratio was the exogenous factor that governed the market ratio between gold and silver as commodity. The main idea is that the market is incapable to price the equilibrium ratio between the two metals, so the setting of a legal ratio by the monetary authorities is a necessary condition to determine the equilibrium (Wolosky 1870, Fisher 1894, Walras 1881, Friedman 1990, Flandreau 2002, 2004). The reasoning is that the market ratio between gold and silver cannot be defined without knowledge of the monetary demand for each metal; and monetary demand depends on the purchasing power which itself depends on the price of the two metals. Reliance on the market to price the gold-silver ratio results in a circular argument. Given a legal ratio, equilibrium is achieved through the reallocation of gold and silver monetary balances, which readjust to satisfy the precious metal needs as commodity.

Recent literature has provided evidence of the stability of bimetallism. Bimetallism does not exhibit knife-edge fluctuations between de facto gold and silver monometallism because metals move between money market and commodity market to maintain the equality between legal ratio and market ratio (Velde and Weber 2000). Flandreau (1995, 2002, 2004) has proved the success met by French monetary system in their attempt to fix the market ratio during the 19th century. The reason was that gold or silver supply shocks, rather than jeopardizing the system, led to smooth arbitrage. For instance, during the Gold Rush after 1848, France imported gold and exported silver, but its circulation was large enough to buffer the shock. French bimetallism in mid 19th century is the example of the stability of bimetallism. It was a large bimetallic country able to maintain market ratio at the level of the legal ratio because shocks moved quantities and stabilized prices.

This paper extends the theoretical framework on the stability of bimetallism to the case of coexistence of different legal ratios in several large bimetallic countries. In open markets, where transactions are free, two commodities such as gold and silver can only have one relative market price. Having several legal ratios and only one market ratio, the intriguing question in this case is to know which ratio is going to prevail.

The stability of bimetallism with several bimetallic centres is tested for the cases of London and Amsterdam in mid-18th century, large countries as they were the main money centres at that period (Flandreau et al. 2009a). Market prices of gold and silver are needed for
both centres to test the stability of bimetallism. Until now, London was the only center which had series of the bullion market prices from the end of the 17th century, collected in the financial bulletin *The Course of the Exchange*. But market prices should be available also for other centres, like Amsterdam. According to Van Dillen (1926), Amsterdam was the main bullion market in the world during the 17th and 18th centuries. Despite its importance, no scholar has exploited Amsterdam bullion prices probably because they are difficult to locate. But the data for Amsterdam do exist and are available—at least for some periods. I found Amsterdam data in the commercial bulletin *Kours van Koopmanschappen tot Amsterdam* for the period 1734-1758. Using this new primary source, I can test the stability of bimetallism for several bimetallic centres which have different bimetallic legal ratios and only one bimetallic market ratio.

First section develops a general equilibrium model for a world bimetallic economy. Bimetallism is possible at a ratio compatible with the use of either metal as money. If centres cooperate in fixing the same legal ratio, bimetallism is possible in both centres. But if centres compete in fixing the bimetallic ratio, maximum the legal ratio of one centre will be the equilibrium ratio, so preserving effective bimetallic standard in that centre. The other centre thus will have monometallism *de facto*. Second section calculates bullion market integration. Only one market price for gold and only one market price for silver in both centres is a needed condition for the stability of bimetallism. This section demonstrates that international arbitrages ensure uniformity in the market price of gold and silver. And third section determines the monetary regime. When two centres have different bimetallic legal ratios and only one bimetallic market ratio, which ratio is going to prevail? Amsterdam had an effective bimetallic system because legal ratio was closed to the market ratio, but London had a gold standard *de facto* because its legal ratio was too far from the market ratio to make possible the use of silver as money.

**1. THE MODEL: BIMETALLIC STANDARD IN EQUILIBRIUM**

This section develops a general equilibrium model for a world bimetallic economy. Market prices of gold and silver can not be defined without consider the monetary demand for each metal, and the monetary demand depends on the purchasing power which itself depends on the price of the two metals. Since the market by itself is ordinarily incapable of fixing a single equilibrium bimetallic ratio, the government is obliged to fix a legal ratio. But the government
is not free to set any legal ratio because it must be one compatible with the use of either metal as money. Too high legal bimetallic ratio might induce agents to increase their demands for commodity silver to the point where this metal disappears from the circulation creating a gold standard _de facto_. And too low legal bimetallic ratio might provoke a silver standard _de facto_.

The model determines where permissible bimetallic ratios lie. It is an adaptation of the model set out by Flandreau (2004) to the case of a world economy which comprises two large bimetallic centers³. The two centers, Amsterdam and London, are on a bimetallic standard _de iure_. The bimetallic economies can be in equilibrium on an effective bimetallic standard or on a monometallic standard _de facto_, or on a combination of both, i.e., one center on bimetallism and the other on monometalism. There are, therefore, nine possible equilibriums depending on the legal ratio set by the governments.

This world open economy is composed by three tradable goods: gold, silver, and one representative consumer good which is not used for monetary purposes. Gold and silver are used for both monetary and nonmonetary purposes. The three goods are available in quantities that are exogenously given. International arbitrages ensure uniformity in the market price of gold, silver and the consumer good around the world⁴.

According to Walras’ Law, when considering any particular market, if all other markets in an economy are in equilibrium, then that specific market must also be in equilibrium. So we can drop one market (e.g., the representative good market) because the general equilibrium in this world economy is entirely described by three markets: the money market, commodity-gold market and commodity-silver market. Gold and silver are perfect substitutes for monetary purposes but imperfect substitutes for nonmonetary purposes. The clear-cut distinction between monetary and nonmonetary purposes is that the utility of the monetary market depends upon the purchasing power while the utility of the nonmonetary market depends upon the physical quantity.

The equilibrium conditions for the world economy under the bimetallic standard are described by the following equations.

³ Large bimetallic countries have a so great monetary circulation in comparison with gold-commodity and silver-commodity markets that they can resolve any discrepancy between bullion supply and demand. See Flandreau (2004), chapter 7.

⁴ The uniformity in the market price of gold and silver is demonstrated in section 2.
First, let us describe the nonmonetary demand function for gold and silver. Demand for 
commodity-gold in center \( i \) (\( G^i \)) is a function of gold market price (\( p_G \)) and demand for 
commodity-silver in center \( i \) (\( S^i \)) is a function of silver market price (\( p_S \)):

\[
G^A = \mu_G^A \frac{P}{p_G} Y^A
\]

\[
G^L = \mu_G^L \frac{P}{p_G}
\]

\[
S^A = \mu_S^A \frac{P}{p_S}
\]

\[
S^L = \mu_S^L \frac{P}{p_S}
\]

where \( \mu_G^A \) and \( \mu_S^A \) are positive constants for center \( i \) (i=Amsterdam, London), \( P \) is the general 
price level (the price of the representative consumer good), \( p_G \) is the market price of gold as commodity and \( p_S \) is the market price of silver as commodity, and \( Y^i \) is the real income in 
center \( i \) (quantity of the representative consumer good).

So as to preserve tractability, both economies, Amsterdam and London, are deemed to be 
on “balanced” growth paths; in that way, the real incomes of the two centers remain 
proportionate to one another:

\[
Y^L = \beta Y^A
\]

Merging equations (1), (2) and (5), we have the world demand for commodity-gold 
(equation 6); and merging equations (3), (4) and (5), the world demand for commodity-silver 
(equation 7):

\[
G^W = (\mu_G^A + \beta \mu_G^L) \frac{P}{p_G} Y^A = \mu_G^W \frac{P}{p_G} Y^A
\]

\[
S^W = (\mu_S^A + \beta \mu_S^L) \frac{P}{p_S} Y^A = \mu_S^W \frac{P}{p_S} Y^A
\]

Second, let us describe the monetary demand function. The nominal amount of money 
demanded in center \( i \) (i=Amsterdam, London) is the quantity of gold for monetary purpose 
(\( G^m_i \)) multiplied by gold price (\( p_G \)) plus the quantity of silver for monetary purpose (\( S^m_i \)) 
multiplied by silver price (\( p_S \)). Recall that gold currency and silver currency are perfect
substitutes for payments, and thus the money demand is expressed in purchasing power units. The money demand is defined in accordance with the Cambridge equation (being $k$ a positive constant):

$$ p_g G_m^d + p_s S_m^d = k^d \cdot P \cdot Y^d \tag{8} $$

$$ p_g G_m^l + p_s S_m^l = k^l \cdot P \cdot Y^l \tag{9} $$

Merging (8) (9) and (5), we have the world demand for money (equation 10):

$$ p_g (G_m^d + G_m^l) + p_s (S_m^d + S_m^l) = (k^d + \beta k^l)P \cdot Y^d = k^w \cdot P \cdot Y^A \tag{10} $$

The model is closed by equating world bullion supply and demand (G and S representing the total outstanding stocks of gold and silver):

$$ G^w_c + G_m^d + G_m^l = G \tag{11} $$

$$ S^w_c + S_m^d + S_m^l = S \tag{12} $$

The model is resolved in Appendix 1 which shows the equilibrium ratio between the two precious metals as a function of relative gold and silver resources. The bimetallic economies can be in equilibrium on an effective bimetallic standard or on a monometallic standard de facto, or on a combination of both, i.e., one center on bimetallism and the other on monometalism. There are, therefore, nine possible equilibriums, depending on the legal ratios defined by the English and Dutch governments ($\frac{P_G^L}{P_S^L}, \frac{P_G^d}{P_S^d}$).

Figure 1 shows the equilibrium ratio between the two precious metals as a function of relative gold and silver quantities, when both centres cooperate in fixing the legal ratio at $\frac{P_G^L}{P_S^L}$.

The line “Gold” represents the gold standard equilibrium for both London and Amsterdam ($S_m^L = S_m^d = 0$) and the line “Silver” represents the silver standard equilibrium for both economies ($G_m^L = G_m^d = 0$). For any given level of quantities ($\frac{S_0}{G_0}$), the equilibrium market
ratio between $\max \frac{p_G}{p_S}$ and $\min \frac{p_G}{p_S}$ corresponds to the continuum of bimetallic equilibria compatible with $\frac{S_0}{G_0}$.

The relation between total quantities, equilibrium price and the standard in both centres is represented in Figure 1 by the thick grey line. Suppose that the British and Dutch government have set the legal ratio at $\frac{p_G^A}{p_S^A}$. Let us imagine starting from a relative scarcity of silver ($\frac{S}{G}$ lower than $\min \frac{S_0}{G_0}$). Then, silver is too scarce for a bimetallic equilibrium corresponding to $\frac{p_G}{p_S}$ to exist, and the British and Dutch economies operates on a *de facto* Gold Standard. Symmetrically, starting from a too relative scarcity of gold resources ($\frac{S}{G}$ higher than $\max \frac{S_0}{G_0}$) for a bimetallic equilibrium corresponding to $\frac{p_G}{p_S}$ to exist, the British and Dutch economies operates on a *de facto* Silver Standard. For a level of resources between $\min \frac{S_0}{G_0}$ and $\max \frac{S_0}{G_0}$, the monetary regime is in a *de facto* bimetallic standard for the legal ratio $\frac{p_G}{p_S}$.
If both centres, London and Amsterdam have the same legal ratio which coincides with the equilibrium market ratio for a given level of resources, positives quantities of gold and silver will be in circulation in the money market. But if each economy has a different bimetallic ratio, as commodity markets are integrated and there is only one market ratio, different possibilities appears.

Suppose that each center fixes a different legal ratio, and the Dutch government has set a smaller legal ratio than the British ratio \( \frac{p_A^G}{p_S^G} < \frac{p_L^G}{p_S^G} \). The line “Gold” represents the gold standard equilibrium for both London and Amsterdam \( (S_m^L = S_m^A = 0) \), the line “Silver” represents the silver standard equilibrium for both economies \( (G_m^L = G_m^A = 0) \) and the line “London Gold & Amsterdam Silver” represents the gold standard equilibrium for London \( (S_m^L = 0) \) and the silver standard equilibrium for Amsterdam \( (G_m^A = 0) \). When the legal ratio in Amsterdam is smaller than in London \( \frac{p_A^G}{p_S^G} < \frac{p_L^G}{p_S^G} \), there are 5 possible equilibria (Figure 2):

- Possibility 1 (part 1 of the grey line): for a level of resources lower than \( \min \frac{S_0}{G_0} \left[ \frac{p_A^G}{p_S^S} \right] \), the equilibrium ratio is lower than Amsterdam and London legal ratios \( \frac{p_A^G}{p_S^G} < \frac{p_L^G}{p_S^G} \) and \( \frac{p_A^G}{p_S^G} < \frac{p_L^G}{p_S^G} \) because \( p_L^G < p_S^G \) and \( p_A^G < p_S^G \). Both London and Amsterdam are on a gold standard de facto.

- Possibility 2 (part 2 of the grey line): for a level of resources between \( \min \frac{S_0}{G_0} \left[ \frac{p_A^G}{p_S^S} \right] \) and \( \min \frac{S_0}{G_0} \left[ \frac{p_A^G}{p_S^G} \right] \), the equilibrium ratio coincides with legal ratio in Amsterdam, so lower than legal ratio in London \( \frac{p_A^G}{p_S^S} = \frac{p_A^G}{p_S^G} < \frac{p_L^G}{p_S^G} \) because \( p_S^G < p_S^L \). Amsterdam is on a bimetallic standard, but London is on a gold standard.

- Possibility 3 (part 3 of the grey line): for a level of resources between \( \min \frac{S_0}{G_0} \left[ \frac{p_A^G}{p_S^S} \right] \) and \( \max \frac{S_0}{G_0} \left[ \frac{p_A^G}{p_S^G} \right] \), the equilibrium ratio is higher than Amsterdam legal ratio and lower than

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5 The case of different legal ratio when the legal ratio in Amsterdam is higher than in London would be symmetrical, and it is explained in Appendix 1.
London legal ratio \( \left( \frac{\bar{p}_G^A}{\bar{p}_S^A} < \frac{\bar{p}_G^L}{\bar{p}_S} \right) \) because \( \bar{p}_S^L < p_S \) & \( \bar{p}_G^A < p_G \). Amsterdam is on a silver standard and London is on a gold standard.

- Possibility 4 (part 4 of the grey line): for a level of resources between \( \max \frac{S_o}{G_o} \left[ \frac{\bar{p}_G^L}{\bar{p}_S} \right] \) and \( \max \frac{S_o}{G_o} \left[ \frac{\bar{p}_G^L}{\bar{p}_S} \right] \), the equilibrium ratio coincides with legal ratio in London, so higher than legal ratio in Amsterdam \( \left( \frac{\bar{p}_G^A}{\bar{p}_S} = \frac{\bar{p}_G^L}{\bar{p}_S} \right) \) because \( \bar{p}_G^A < p_G \). London is on a bimetallic standard, but Amsterdam is on a silver standard.

- Possibility 5 (part 5 of the grey line): for a level of resources higher than \( \max \frac{S_o}{G_o} \left[ \frac{\bar{p}_G^L}{\bar{p}_S} \right] \), the equilibrium ratio is higher than Amsterdam and London legal ratios \( \left( \frac{\bar{p}_G}{\bar{p}_S} \right) \) and \( \frac{\bar{p}_G}{\bar{p}_S} \) because \( \bar{p}_G < p_S \) and \( \bar{p}_G < p_S \). Both London and Amsterdam are on a silver standard de facto.

Figure 2: The bimetallic equilibria when \( \frac{\bar{p}_G^A}{\bar{p}_S} < \frac{\bar{p}_G^L}{\bar{p}_S} \)
To sum up, bimetallism, impossible at one ratio, is possible at another (Fisher, 1894; Flandreau, 2004). Bimetallism is possible at a ratio compatible with the use of either metal as money. When several bimetallic centres cooperate to fix a legal ratio compatible with the use of either metal as money, all centres are in an effective bimetallic standard. But if several centres compete to fix the legal ratio, as there is uniformity in the market ratio, only maximum one centre will be bimetallic. The other center will be monometallic _de facto_, although bimetallic _de iure_.

The model has assumed one single market ratio for London and Amsterdam. The uniformity in the market ratio must be tested for the context of mid-18th century. Were bullion market integrated? On one hand, we know that financial markets were integrated in the 18th century (Neal, 1990). One the other hand, the also know that in the 18th century commodity markets were not integrated yet (Federico, 2010). Gold and silver were commodities and also financial instruments because gold and silver, along with bills of exchange, may be used to settle international payments. Next section tests bullion market integration to guarantee the uniformity in the market ratio.

### 2. SPECIE-POINT MECHANISM: MEASURING BULLION MARKET INTEGRATION

Gold (silver) markets in London and Amsterdam are integrated if the price of gold (silver) in London equals the price of gold (silver) in Amsterdam. In a world without transaction costs, the price of gold (silver) in London (measured in Sterling Pounds) should equal the price of gold (silver) in Amsterdam (measured in Gulden Bank) multiplied by the exchange rate (Sterling Pounds/Gulden Bank).

\[
p^G_A (gulden bank) \cdot x(\frac{sterling \ pounds}{gulden \ bank}) = p^G_L (sterling \ pounds) \tag{13}
\]
\[
p^S_A (gulden bank) \cdot x(\frac{sterling \ pounds}{gulden \ bank}) = p^S_L (sterling \ pounds) \tag{14}
\]

where \( p^G_A \) is the price of gold in Amsterdam, \( p^S_A \) is the price of silver in Amsterdam, \( p^G_L \) is the price of gold in London, \( p^S_L \) is the price of silver in London and \( x \) is the exchange rate of bills of exchange.
Equations (13) and (14) represent the Law of One Price for Gold and Silver respectively. If markets are integrated, prices equals in both centres and arbitrage is not profitable. If gold (or silver) markets were not integrated, arbitrage would move gold (or silver) from the cheapest center to the most expensive center in exchange for a bill of exchange issued in the most expensive center and payable in the cheaper center\(^6\). Arbitrage between cities was thus not only practiced between gold and silver, but mainly between bullion and bills of exchange (Hayes 1739, pp. 285-288; Quinn, 1996; Flandreau 1995, 1996, 2002, 2004). Four types of flows are possible: gold exports from Amsterdam (gold imports from London), gold imports from Amsterdam (gold exports from London), silver exports from Amsterdam (silver imports from London) and silver imports from Amsterdam (silver exports from London) So, it would be possible to find the export of one metal and the import of the other, but also only the export of one single metal (or the import of one single metal), or the export of both metals (or the import of both metals) (see Flandreau 2002).

But arbitrage was not free and it involved transaction costs. The Law of One Price for precious metal including arbitrage costs is denominated Specie-Point mechanism. The gold-point mechanism was first applied to the case of the classical gold standard (Morgenstern 1959; Clark 1984; Officer 1983, 1986, 1989, 1996; Canjels, Prakash-Canjels and Taylor 2004; Esteves, Reis and Ferramosca 2007). Flandreau (1995, 1996, 2002, 2004) develops a new method that extends the notion of gold-points for the gold standard to specie-points for a bimetallic standard.

The bimetallic specie-point recognizes that gold and silver, along with bills of exchange, may be used to settle international payments. Because shipping specie was costly, exchange rates between bimetallic centres will fluctuate within the “bimetallic point”, which is the narrow band between gold and silver points. Gold, silver and bimetallic points are defined by Flandreau (1996, pp. 421-422 and 2004, pp. 57-61):

- The gold point is defined according to the equation 15:

\[
\text{Gold points: } (1 - c^{g}_{LL}) \frac{p^g_A}{p^g_L} \leq \frac{x}{1 + c^{g}_{ML}} \frac{p^g_A}{p^g_L} \leq (1 + c^{g}_{ML}) \frac{p^g_A}{p^g_L}
\]  

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\(^6\) Bullion movements were free in London and Amsterdam in the 18\textsuperscript{th} century, although only for ingots. Exporting domestic coins were forbidden. See Munro (1992), Ricard (1732) and Vilar (1974).
where $p^g_A$ denotes the market price of gold in Amsterdam; $p^g_L$ denotes the market price of gold in London; $x$ is the spot exchange rate between Amsterdam and London; $c^g_{La}$ is the cost of trading gold from London to Amsterdam; and $c^g_{Al}$ is the cost of trading gold from Amsterdam to London.

According to gold points, for a given spot exchange rate between London and Amsterdam and the market price of gold in Amsterdam, the market price for gold in London could not rise higher than the point where it became profitable to send gold from Amsterdam to London; or fall lower than the point where it became profitable to send gold from London to Amsterdam.

- Analogously, the silver point is defined according to equation 16:

$$\text{Silver points: } (1 - c^s_{La}) \frac{p^s_A}{p^s_L} \leq x \leq (1 + c^s_{Al}) \frac{p^s_A}{p^s_L}$$

(16)

where $p^s_A$ denotes the market price of silver in Amsterdam; $p^s_L$ denotes the market price of silver in London; $x$ is the spot exchange rate between Amsterdam and London; $c^s_{La}$ is the cost of trading silver from London to Amsterdam; and $c^s_{Al}$ is the cost of trading silver from Amsterdam to London.

According to silver points, for a given spot exchange rate between London and Amsterdam and the market price of silver in Amsterdam, the market price for silver in London could not rise higher than the point where it became profitable to send silver from Amsterdam to London; or fall lower than the point where it became profitable to send silver from London to Amsterdam.

- And finally, the bimetallic point is defined in the equation 17 as the narrow band of overlap between gold-points (equation 15) and silver points (equation 16):

$$\text{Bimetallic points: Max } \left[ (1 - c^g_{La}) \frac{p^g_A}{p^g_L}; (1 - c^s_{La}) \frac{p^s_A}{p^s_L} \right] \leq x \leq \text{Min } \left[ (1 + c^g_{Al}) \frac{p^g_A}{p^g_L}; (1 + c^s_{Al}) \frac{p^s_A}{p^s_L} \right]$$

(17)

Suppose that a Dutch agent needs to settle a debt in England. Gold and silver, along with bills of exchange, may be used to settle international payments. The best way to settle the debt normally was to buy a bill of exchange in Amsterdam on London, provided enough such bills were available. But if bills were scarce, their price would rise. If the bill price increases above the level at which it became preferable to send metal than bills as payment, two transactions are possible. The Dutch debtor could buy gold or silver on the Amsterdam market and ship to
London. Symmetrically, an English debtor who needed to remit to Amsterdam had three choices. He could buy a bill of exchange in London on Amsterdam, or he could buy gold or silver in the London market to ship to Amsterdam if the exchange rate of bills was too unfavourable. To avoid metal shipments, the exchange rate must lie within the bimetallic band, which represents the range of overlap between gold and silver points.\textsuperscript{7}

Specie-Point mechanism means the Law of One Price including transaction costs, which states that different prices of bullion will tend to equalize. The violation occurs when the exchange rate goes down the lower band \( (1-c_{BA}) \frac{P_A}{P_B} > x \), and then exporting bullion from centre \( B \) to centre \( A \) is profitable (see Figure 3.). On contrary, if the exchange rate goes up the upper band \( (1 + c_{AB}) \frac{P_A}{P_B} < x \), exporting silver from centre \( A \) to centre \( B \) is profitable.

\textbf{Figure 3: the violation of the lower silver point}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure3.png}
\caption{The violation of the lower silver point}
\end{figure}

Appendix 2 explains the dataset to calculate the specie-point mechanism: arbitrated parity, spot exchange rate and costs. I show here results. Figure 4 shows the gold band, figure 5 the silver band and figure 6 the bimetallic band. We expect few and no persistent violations, because when the bullion point is violated, arbitrage will adjust bullion market prices to eliminate arbitrage profitability.

\textsuperscript{7} Contemporaries shipped bullion only when the exchange rate of bills was too unfavourable, i.e., when the bullion point was violated. For example, 25 April 1720 George Middleton (London) said to William Law (Paris): “The Exchange today is from 18 1/2 to 19 1/8 [in London on Paris], to Amsterdam ‘tis from 36 2 to 36 3 [in London on Amsterdam]. I don’t find easy to draw on Mouchard [Amsterdam] and therefore wish you could send gold also your own account and in the mean time let me know if I may draw on him”. Coutts Archive (letter book O 14). I am very grateful to Larry Neal, who showed me this material.
Figure 4: Gold band of arbitrage equation between London and Amsterdam, 1734-1758
(monthly observations), shellinge bank/sterling pound

Source: see text.

Figure 5: Silver band of arbitrage equation between London and Amsterdam, 1734-1758
(monthly observations), shellinge bank/sterling pound

Source: see text.
Figure 6: Bimetallic band of arbitrage equation between London and Amsterdam, 1734 - 1758 (monthly observations), shellinge bank/sterling pound

Figures 4 to 6 show that the specie point mechanism between London and Amsterdam works well, and only a few and no persistent breaks occurred. Concretely, results show that all breaks are located in the lower band, which means profitability in arbitrage from London to Amsterdam. There were only one break for the lower band of gold on 18 September 1741 (Figure 4), for the lower band of silver there were breaks in 1736 (23/04/1736, 13/08/1736 and 17/09/1736) and 1750 (13/04/1750, 18/05/1750 and 15/06/1750) (Figure 5); and the breaks for the bimetallic lower band are the combination of both gold and silver breaks (Figure 6). There are no breaks for the upper band and, therefore, it was never profitable to export bullion from Amsterdam to London.

Breaks mean that the exchange rate falls below or rises above the bullion point in which sending bullion from one to the other centre become profitable. Let us observe that violations were short lived because arbitrageurs will bought bullion in the center with the lowest market price and sold it in the centre with the highest market price, which quickly adjusted prices to
eliminate arbitrage profitability. So, the process of arbitrage maintained pegged the arbitrated parity to the exchange rate. We observe the different behaviour of exchange rate and bullion points in war and peace episodes. The band defined by the bullion points is narrower and the fluctuation of exchange rate is smoother during the peace periods than in episodes of war. Exchange rate fluctuated deeply during the War of the Austrian Succession (1742-1748), but the bullion points were not broken because bullion points opened due to the increase of insurance cost from an average of 1.25% in times of peace to 3.5% during the War (see Appendix 2).

Bullion flows between London and Amsterdam were not profitable in mid-18th century. These results are consistent with our knowledge of capital market integration in 18th century. Neal (1990) demonstrated that the London and Amsterdam financial markets were integrated in the 18th century. And this section has demonstrated that the London and Amsterdam bullion market were already integrated in mid-18th century. International arbitrages ensure uniformity in the market price of gold and silver. Once that we have demonstrated that there is only one market ratio, we can determine the monetary regime in the next section.

3. MELTING-MINTING POINTS: DETERMINING THE MONETARY REGIME

In an “ideal” bimetallic system without transactions costs the market bimetallic ratio equals the legal ratio when a centre is in an effective bimetallic regime, as explained in Section 1. In a “real” bimetallic system, with transactions costs, the market bimetallic ratio must remain close to the legal ratio, but not exactly the same value. The legal ratio between gold and silver as money can differ from their relative prices as commodities without an unstable bimetallic system because the costs of melting and minting prevent arbitrage. Costs are incurred under a bimetallic standard in converting the coins of the overvalued metal by the market into ingots (melting cost) and in converting the ingots of the undervalued metal by the market into coins (minting cost). These melting-minting costs define the upper and lower legal ratio points; so the market ratio can fluctuate between these points without moving the effective bimetallic system towards a de facto monometallic system (Friedman 1990; Flandreau 2004).

The difference between market ratio and legal ratio should be smaller than the transaction costs involved in arbitrage. Otherwise, arbitrage will be profitable. Suppose that the legal ratio differs from the market ratio more than costs. How did arbitrage take place? Agents will melt
down and sell in the market the metal overvalued by the market, and buy in the market the metal undervalued by the market to mint. Arbitrage process will drive down market prices of the overvalued metal by the market and drive up market prices of the undervalued metal by the market until arbitrage profits are cancelled out. As soon as appreciation in the overvalued metal is lower than melting-minting expenses, arbitrage stops being profitable. So, arbitrage will get market ratio closer to the legal ratio. The market ratio stabilizes, not exactly at the legal ratio, but within the band defined by melting-minting points that includes the legal ratio. The equilibrium market ratio cannot therefore differ from the legal ratio more than the legal ratio points (Flandreau 2004).

When the market bimetallic ratio is close to the legal ratio, there is a situation of effective bimetallism. However, if the market bimetallic ratio is far from the legal ratio and there is not convergence, there is a monometallic system *de facto*. The quantity of coins of the metal overvalued by the market is so small in the money market that it is not possible to transfer coins from money market to commodity market. Arbitrage is not possible and thus it can not stabilize the market ratio close to the legal ratio. A market ratio far above the legal ratio means a silver standard *de facto*, and a market ratio far below the legal ratio means a gold standard *de facto*. The band defined by melting-minting points indicates the maximum distance between market and legal ratios to sustain an effective bimetallic standard.

The melting-minting band follows the logic set out by Friedman (1990) and defined by Flandreau (1997 and 2004, pp. 30-31):

Commodity-money has two values, legal value as money and market value as commodity. Arbitrage occurs when transferring money from the money market to commodity market or *vice versa*. Coins of the overvalued metal by the market are converting into ingots (melting cost) to sell in the market in exchange for ingots of the undervalued metal by the market for converting into coins (minting cost). The melting-minting costs define the upper and lower legal ratio points. Therefore, market ratio can fluctuate within melting-minting points in an effective bimetallic standard. The melting-minting points are defined as follows:

- **Minting-point**: the seller of the ingot in the market wants to receive at least the same quantity of units of account per ingot that he would receive in the Mint if he minted the ingot:

  \[ p \geq \bar{p}(1 - s - b) \]  
  (units: number of units of account / standard ingot)  
  \[ p \]  
  denotes the price received in the market per a standard ingot; \( \bar{p} \) is the legal price of the ingot before discounting the minting costs; and \( \bar{p}(1 - s - b) \) is the mint price, i.e., the legal
price of the ingot after discounting the minting costs: tax of minting (s, seigniorage) and cost of minting (b, brassage).

- Melting-point: the buyer of the ingot wants to receive at least the same standard weight of ingot that he could receive melting down the equivalent coins per unit of account:

\[ p^{-1} \geq \bar{p}^{-1} \cdot (1 - m) \]  
(units: weight of standard ingot/unit of account) \hspace{1cm} (19)

where \( p^{-1} \) denotes the weight of standard ingots that you receive in the market per unit of account and \( \bar{p}^{-1} \cdot (1 - m) \) denotes the weight of standard ingots received when you melt down the number of coins equivalent to the unit of account after subtracting the cost of melting down \( m \).

Merging equations (18) and (19) gives the following inequality “enclosing” the price of gold (equation 20) and the price of silver (equation 21) as commodities:

Gold: \( \bar{p}_G \cdot (1 - s_G - b_G) \leq p_G \leq \frac{\bar{p}_G}{1 - m_G} \)  
(units of account / standard ingot) \hspace{1cm} (20)

Silver: \( \bar{p}_S \cdot (1 - s_s - b_s) \leq p_S \leq \frac{\bar{p}_S}{1 - m_S} \)  
(units of account / standard ingot) \hspace{1cm} (21)

And merging equations (20) and (21) gives the bounds within which the market ratio should lie to prevent bimetallic arbitrage:

\[ \frac{\bar{p}_G \cdot (1 - s_G - b_G) \cdot (1 - m_S)}{\bar{p}_S} \leq \frac{p_G}{p_S} \leq \frac{\bar{p}_G}{\bar{p}_S \cdot (1 - m_G) \cdot (1 - s_s - b_s)} \]  
(units of account/st. ingot) \hspace{1cm} (22)

Arbitrage occurs if the market bimetallic ratio breaks the minting-melting bounds (see figure 7). If the market ratio breaks the upper band \( \left( \frac{p_G}{p_S} \geq \frac{\bar{p}_G}{\bar{p}_S \cdot (1 - m_G) \cdot (1 - s_s - b_s)} \right) \) gold melts-down to sell in the market and silver is bought in the market to mint. Arbitrage will drive down the market price of gold and drive up the market price of silver until the market ratio comes back within the bound, so arbitrage stops being profitable. If the break persists, there is not gold enough in the money market, so it is not possible to melt it to arbitrate. There is already a silver standard *de facto*. And if the market ratio breaks the lower bound \( \frac{\bar{p}_G \cdot (1 - s_G - b_G) \cdot (1 - m_S)}{\bar{p}_S} \geq \frac{p_G}{p_S} \) silver melts-down and gold mints. Arbitrage will drive down the market price of silver and drive up the market price of gold until the market ratio introduces again into the bound, so arbitrage stops being profitable. If the break persists, there
is not silver enough in the money market, so it is not possible to melt it to arbitrate. There is a gold standard *de facto*.

Figure 7: the violation of the melting-minting points

\[
\begin{align*}
\frac{p_G}{p_S} &\geq \frac{\bar{p}_G}{\bar{p}_S (1 - m_G) (1 - s_G - b_G)} \\
\text{gold melted, silver minted} \\
\frac{p_G}{p_S} &\leq \frac{\bar{p}_S (1 - m_G) (1 - s_G - b_G)}{\bar{p}_G} \\
\text{silver melted, gold minted}
\end{align*}
\]

Appendix 3 explains legal prices for Amsterdam and London, and melting-minting costs. It also shows a comparison of market prices and mint prices for gold and silver in both centres. I show here the effective monetary regime for each centre, first for London, and then for Amsterdam.

Figure 8 shows the melting-minting bounds in London and Figure 9 shows the net profitability of arbitrage. The legal bimetallic ratio is 15.21, measured in 100% fineness for both metals\(^8\). Minting was free in Britain and melting cost has been estimated in 1.613%, so the melting-minting band is the interval [14.96, 15.46] (see Appendix 3). Figure 8 shows the market bimetallic ratio systematically below the lower bound, except for the first period, from April 1734 to March 1736. Therefore, arbitrage between gold and silver was profitable: silver is melted and gold is minted. Figure 9 shows the net profitability of arbitrage. We can consider that melting-minting costs have been underestimated because I only consider the minimum melting price (i.e. melting cost) and I do not consider other costs proposed by Friedman (1990, p. 90) and Flandreau (2004, pp. 39-44) like brokerage and assays, abrasion, insurance fees and loss of interest for delays. So, we should take account of net profit estimation in Figure 9 with caution because it is probably overestimated\(^9\). However, to push

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\(^8\) Gold Mint price was 136.568 £/pure kilogram and silver Mint price was 8.979 £/pure kilogram. See also Fay (1935), p. 114

\(^9\) Friedman (1990, p. 90) has estimated the London melting-minting points for mid-19th century as [15.3, 15.89]
the market ratio into the melting-minting bounds we would have had a maximum cost of near 8%, which seems to be too high, so we can accept the gold standard *de facto*. Arbitrage was systematically profitable: melting silver, selling it in the market in exchange for gold and sending gold to the mint. Silver was overvalued by the market (undervalued by the law) and gold was undervalued by the market (overvalued by the law). If silver had been sold in the market and gold had been bought in the market, silver price would have driven down and gold price would have driven up until arbitrage profits had cancelled out, and market ratio had got closer to legal ratio. But we observe in Figure 8 that market ratio was systematically outside the band, so arbitrage did not operate in spite of having arbitrage profit (Figure 9). This happened because there was not silver enough in the money market to transfer to commodity market by arbitrage, so London was *de facto* in a gold standard. Silver was demonetized in 1774 in recognition of the fact that only gold circulated as money in Great Britain\(^{10}\). So, Britain adopted a monometallic gold standard *de iure* in 1774, but Britain had already adopted a gold standard *de facto* in mid-18\(^{th}\) century.

*Figure 8: Melting-minting bounds in London, 1734-1758*

![Melting-minting bounds in London, 1734-1758](source: see text.)

(spread of 0.59 points) (see also Flandreau, 2004, p. 33-34). I estimate London melting-minting points for mid-18\(^{th}\) century as [14.96, 15.45] (spread of 0.49). We can expect higher costs for mid-18\(^{th}\) century than for mid-19\(^{th}\) century, so probably I underestimate melting-minting points for London in mid-18\(^{th}\) century.

\(^{10}\) Frieden (1997), p. 213
Amsterdam is analysed following the same logic of melting-minting points than for London. Figure 10 shows the melting-minting bounds in Amsterdam (Figure 11 shows the net profitability of arbitrage according to our estimated melting-minting points). The legal bank bimetallic ratio between fine gold and fine silver is 14.68 and the melting-minting band is the interval [14.22, 15.15] (see Appendix 3). Figure 10 shows the market bimetallic ratio systematically within the melting-minting points, so arbitrage was not profitable. The market ratio breaks the lower band only in a few cases 1741, 1753-1754 and 1758 and in those cases net arbitrage profitability is always negligible (around 0.5% - see Figure 11). The market ratio is not exactly equal to the legal ratio, but fluctuates within the band defined by melting-minting costs that includes the legal ratio. So the bimetallic standard was stable in Amsterdam. The spread of melting-minting points in the case of Amsterdam is greater than in London because Amsterdam had a minting cost while minting in London was free. But the stability of bimetallism in Amsterdam is not defined by the spread of the estimated costs, but by a market ratio gravitated around legal ratio.
Amsterdam had a stable bimetallic system in mid-18th century because the market ratio of silver to gold gravitated around the legal ratio. London, however, was a gold standard *de facto* because London Mint had chosen a “too high” legal bimetallic ratio, which was not compatible with the use of either metal as money. The choice of a “too high” legal ratio
triggered the apparition of the gold standard *de facto* in Great Britain\textsuperscript{11}$. The market ratio in London did not gravitate around its legal ratio. What was driving the London market ratio?

To explain what was driving the London market ratio, we come back to the model explained in the first section. The model showed the relation between relative gold and silver resources, the equilibrium price and the monetary regime. When bullion markets are integrated, so there is only one market price (as demonstrated in section 2), centres should coordinate to fix a legal ratio compatible with market ratio. But if centres compete to fix the legal ratio, as the market ratio is uniform, there will be at maximum one unique centre able to join the legal ratio and the equilibrium market ratio. We have seen in this section that London and Amsterdam competed in fixing the legal ratio. Legal ratio in London was 15.21 while legal ratio in Amsterdam was 14.68. We have also seen in this section that Amsterdam legal ratio was compatible with market ratio, so Amsterdam had an effective bimetallic standard; but London legal ratio was too high to maintain silver in circulation, so London was in a gold standard *de facto*. According to the model, this case is the second possibility explained in figure 2 (see now figure 12). The equilibrium ratio coincides with legal ratio in Amsterdam, so lower than legal ratio in London ($\frac{\bar{p}_G^A}{\bar{p}_S^A} = \frac{p_G}{p_S} < \frac{\bar{p}_G^L}{\bar{p}_S^L}$ because $\bar{p}_S^L < p_S$). London legal price of silver was “too low”, so all silver in London had been moved from money market to commodity market without adjusting London market ratio to legal ratio. The legal silver price was too low, so although arbitrage moved all silver holding from money market to commodity market, it was not enough as to adjust market ratio to legal ratio. London market ratio was not ruled by London legal ratio, but by international market ratio which gravitated around the Amsterdam legal ratio.

\textsuperscript{11} Eichengreen and Flandreau (1997)
Figure 12: The bimetallic equilibrium when $\frac{p_G^L}{p_S^L} = \frac{p_G}{p_S} < \frac{p_G^L}{p_S^L}$

Figure 13 shows the data which support the theoretical model drawn in Figure 12. This figure merges Figures 8 and 10 and represents a summary of the main ideas developed in this paper. First, we observe that market ratio is equal in London and Amsterdam. There is only one market ratio because London and Amsterdam bullion markets were integrated. It is not surprising as both cities had free bullion movements, so we can expect that both markets are integrated and prices converge. And second, we observe that London market ratio did not gravitate around London legal ratio. London market ratio and Amsterdam market ratio gravitated around the Amsterdam legal ratio. The legal ratio in London was too high to achieve bimetallic stability because London legal silver price was too low to maintain silver money circulation.
Let us finally emphasize the interdependence between legal ratio and international market price for a given level of resources. Centres had not monetary autonomy to change the legal ratio to peg to the international market ratio, because any change in legal ratio would move precious metals quantities between money market and commodity market, so generating a new equilibrium price. At this new equilibrium price, different situations are possible, as explained in section 1. The economies with bimetallic standard *de iure* can be in the new equilibrium on an effective bimetallic standard or on a monometallic standard *de facto*, or on a combination of both, i.e., one center on bimetallism and the other on monometalism. There are again nine possible equilibriums for a given level of resources, depending on the legal ratio set by the governments which will reallocate the gold and silver monetary balances and therefore, the equilibrium prices and quantities of gold and silver as commodities. When considering several bimetallic centres, fixing the legal bimetallic ratio compatible with the use of either metal as money is an interdependent game.
CONCLUSIONS

The stability of bimetallism has been the subject of a wide theoretical debate which derives from a simple arbitrage principle: the legal ratio between gold and silver as money must equal the market ratio between gold and silver as commodities. On one hand, the opponents of the stability of bimetallism consider that shocks on the market ratio will demonetize the metal overvalued by the market. The legal ratio was a fixed price defined by government while the market ratio varied constantly because it was set by supply and demand, so bimetallism will derive systematically in an alternation of de facto monometallic standards.

However, this approach has an error because it assumes that market price is exogenously defined by commodity market, so money holdings can not influence in market prices. But suppose that market price differs from legal price, so the metal overvalued by the market moves from money market to commodity market in exchange for the undervalued metal. The arbitrage process will drive down the market price of the overvalued metal and drive up the market price of the undervalued metal until market ratio joins legal ratio. If market price is endogenously determined, the stability of bimetallism is possible.

The market prices are endogenously determined because precious metal for monetary uses represented a very high proportion of total precious metal stock. Silver for monetary uses were the 45% of total silver stock (16th century), 38% (17th century) and 24% (18th century); and gold for monetary uses were the 29% of total gold stock (16th century), 24% (17th century) and 23% (18th century). To determine market prices, legal prices are needed. Legal prices define purchasing power, which define money demand. And money balances defines commodity demand and market prices for a given stock of resources.

Bimetallism is possible, but not at any ratio. Legal ratio must be one compatible with the use of either metal as money for a given stock of gold and silver, because if the legal ratio differs too much from the equilibrium ratio, bimetallism de iure will turn monometallism de facto. Recent literature has provided evidence of the stability of bimetallism (Flandreau, 2004). During the shock provoked by the Gold Rush, France imported gold and exported silver, so pegged the market ratio to the legal ratio because its circulation was large enough to moved quantities and stabilized prices. France had a well defined legal ratio at a level compatible with gold and silver circulation, so buffered shocks moving quantities.

But what happen when several countries have different legal ratios? This paper has tested the stability of bimetallism in mid-18th century for the case of two large centres which had
different legal ratios and only one international market ratio. Which ratio is going to prevail in this case? Section 1 (and Appendix 1) has develop a general equilibrium model to determine where permissible bimetallic ratios lie. It is an adaptation of the model set out by Flandreau (2004) to the case of two bimetallic centres. When considering several bimetallic centres, they should cooperate to fix a legal ratio compatible with the use of either metal as money. Then, all centres will be in an effective bimetallic standard. However, if centres do not cooperate but compete for fixing a legal ratio, only the center whose legal ratio is the equilibrium market ratio will be bimetallic. The other center will be monometallic *de facto* because its legal ratio differs from the equilibrium ratio.

This result is based in the existence of one market ratio for both centres. Bullion market integration is a need condition to distinguish instability from disintegration. If bullion market were disintegrated, two different legal ratios could be stable. For example, let us think in remote times with disintegrated markets because bullion movements were forbidden and transport costs were as high as two centres could have different market ratios. Then, these closed economies could have stable bimetallism with different legal ratios if legal ratio was equal market ratio in each centre. But when markets are integrated and there is only one market ratio, bimetallic economies should coordinate a legal ratio equal to market ratio to achieve stability.

Bullion market integration in mid-18th century must be tested. We know that commodity markets were not integrated yet (Federico 2010), but financial markets were already integrated (Neal, 1990). Gold and silver were commodities and also financial instruments because they may be used, along with bills of exchange, to settle international payments. Section 2 (and Appendix 2) calculates specie-point mechanism to demonstrate that London and Amsterdam bullion markets were already integrated in mid-18th century. Integration ensures uniformity in the market price of gold and silver.

Having only one international market ratio, legal ratios in London and Amsterdam can not differ to have stable bimetallic systems in both centres. But legal ratios differed. Amsterdam legal ratio was 14.68 while London legal ratio was 15.21. Section 3 (and Appendix 3) calculates melting-minting points to test the stability of bimetallism in both centres. When two centres have different legal ratios and only one market ratio, which ratio is going to prevail? Amsterdam had an effective bimetallic system because market ratio gravitated around legal ratio, but London had a gold standard *de facto*. London market ratio also
gravitated around Amsterdam legal ratio because bullion markets were integrated. Market ratio was too from the legal ratio defined by British government to make possible the use of silver as money.

**PRIMARY SOURCES**

- *Banco de San Carlos* (AAJG. L186), Archivo Histórico del Banco de España, Madrid.
- *Kours van Koopmanschappen tot Amsterdam*, 1734-1758 (BC 674 (6.1-6.5)), Nederlandsch Economisch-Historisch Archief, Bijzondere Collecties 674, Amsterdam.
- *Rotterdamsche Courant* (microfilm C. 46), *Amsterdamsche Courant* (microfilm C. 20), *Utrechse Courant* (microfilm C. 31) and *Oprechte Haarlemsche Courant* (microfilm C.37), Koninklijke Bibliotheek Den Haag.
- Newton, I. (1717) [1731]: *Table of the Assays, Weights and Values, of most Foreign Silver, and Gold coins, actually made at the MINT by Order of the Privy Council*, (updated table 28 March 1729), The Making of the Modern Economy (MOME), Goldsmiths’ Kress Library.
- *The Course of the Exchange*, 1734-1741 (MIC.A.788), and 1742-1758 (MIC.A.789), British Library (London).

**REFERENCES**

APPENDIX 1: THE BIMETALLIC EQUILIBRIA

The model described in section 1 (equations 1 to 12) can be reduced to a system which describes the world economy’s gold and silver monetary holdings as a function of world stocks of the two metals. The prices \( p_G \) and \( p_S \) are the equilibrium market prices, and the parameters result from the combination of the different propensities to hold bullion (as money or commodity) in the two bimetallic centres.

The system sums up formally into two equilibrium relations:

\[
\begin{align*}
\left\{ \begin{array}{l}
\left[ p_G \cdot (G^d + G^l) \right] = p_G \cdot G \cdot \left[ 1 - \left( \frac{\mu_G^w}{k^w + \mu_G^w + \mu_S^w} \right) \right] - p_S \cdot S \cdot \frac{\mu_G^w}{k^w + \mu_G^w + \mu_S^w} \\
\left[ p_S \cdot (S^d + S^l) \right] = -p_G \cdot G \cdot \frac{\mu_G^w}{k^w + \mu_G^w + \mu_S^w} + p_S \cdot S \cdot \left[ 1 - \left( \frac{\mu_S^w}{k^w + \mu_G^w + \mu_S^w} \right) \right]
\end{array} \right. \\
\end{align*}
\]

(23a) (23b)
The bimetallic economies can be in equilibrium on an effective bimetallic standard or on a monometallic standard *de facto*, or on a combination of both, i.e., one center on bimetallism and the other on monometalism. There are, therefore, nine possible equilibria, depending on the legal ratios defined by the English and Dutch governments \( \frac{\bar{p}_G}{\bar{p}_S}, \frac{\tilde{p}_G}{\tilde{p}_S} \). Let us see the different equilibria.

**Case 1**: Amsterdam and London are Gold Standard *de facto* \( (S_m^L = S_m^A = 0) \). Substituting \( S_m^L = S_m^A = 0 \) in the reduced model (equation 23), the model is resolved for the equilibrium ratio as a function of relative gold and silver resources:

\[
\frac{p_G}{p_S} = S \frac{\mu_G^W + k^W}{\mu_S^W} \quad (24)
\]

**Case 2**: Amsterdam and London are Silver Standard *de facto* \( (G_m^L = G_m^A = 0) \). Substituting \( G_m^L = G_m^A = 0 \) in the reduced model (equation 23), the model is resolved for the equilibrium ratio as a function of relative gold and silver resources:

\[
\frac{p_G}{p_S} = S \frac{\mu_G^W}{\mu_S^W + k^W} \quad (25)
\]

Figure 1 (in section 1) have shown the equilibrium ratio between the two precious metals as a function of relative gold and silver quantities, when both centres cooperate in fixing the legal ratio at \( \frac{\bar{p}_G}{\bar{p}_S} \). The line “Gold” represents the gold standard equilibrium for both London and Amsterdam (equation 24) and the line “Silver” represents the silver standard equilibrium for both economies (equation 25). The slope of “Silver” line \( \text{equation 25: } \frac{\mu_G^W}{\mu_S^W + k^W} \) is smaller than the slope of “Gold” line \( \text{equation 24: } \frac{\mu_G^W + k^W}{\mu_S^W} \), so the equilibrium ratio is higher, for a given level of resources, under the Gold Standard than under the Silver Standard.

For any given level of resources \( \left( \frac{S_0}{G_0} \right) \), the equilibrium market ratio between \( \max \frac{p_G}{p_S} \) and \( \min \frac{p_G}{p_S} \) corresponds to the continuum of bimetallic equilibria compatible with \( \frac{S_0}{G_0} \).
**Case 3:** Amsterdam is in a Silver Standard *de facto* ($A^s=0$) and London is in a Gold Standard *de facto* ($L^s=0$). Substituting $G_m^A = S_m^L = 0$ in the model (equations 1-12), it is resolved for the equilibrium ratio as a function of relative gold and silver resources:

$$\frac{p_G}{p_S} = \frac{S}{G} \frac{\mu_G^w + \beta k^L}{\mu_S^w + k^L}$$ \hspace{1cm} (26)

Figure 2 (in section 1) have shown the equilibrium ratio between the two precious metals as a function of relative gold and silver quantities, when Amsterdam fixes a smaller legal ratio than London ($\frac{P_G^A}{P_S^L} < \frac{P_G^L}{P_S^L}$). The line “London Gold and Amsterdam Silver” (equation 26) represents the gold standard equilibrium for London ($S_m^L = 0$) and the silver standard equilibrium for Amsterdam ($G_m^A = 0$). The slope of “London Gold & Amsterdam Silver” line is higher than the slope of “Silver” line and smaller than the slope of “Gold” line. Figure 2 has explained the five possible equilibria for a given level of resources depending on the relation between market ratio and legal ratios in London and Amsterdam.

**Case 4:** Amsterdam is in a Gold Standard *de facto* ($A^g=0$) and London is in a Silver Standard *de facto* ($L^g=0$). Substituting $S_m^A = G_m^L = 0$ in the model (equations 1-12), it is resolved for the equilibrium ratio as a function of relative gold and silver resources:

$$\frac{p_G}{p_S} = \frac{S}{G} \frac{\mu_G^w + k^A}{\mu_S^w + \beta k^L}$$ \hspace{1cm} (27)

Figure 14 shows the equilibrium ratio between the two precious metals as a function of relative gold and silver quantities, when Amsterdam fixes a higher legal ratio than London.
The line “Amsterdam Gold and London Silver” represents the silver standard equilibrium for London \((G^L_m = 0)\) and the gold standard equilibrium for Amsterdam \((S^A_m = 0)\).

The slope of “Amsterdam Gold & London Silver” line \(\left(\text{equation 27:} \frac{\mu_G^w + k^A}{\mu_S^w + \beta k^L}\right)\) is higher than the slope of “Silver” line \(\left(\text{equation 25:} \frac{\mu_G^w}{\mu_S^w + k^L}\right)\) and smaller than the slope of “Gold” line \(\left(\text{equation 24:} \frac{\mu_G^w + k^A + \beta k^L}{\mu_S^w}\right)\). Figure 14 explains the five possible equilibria for a given level of resources depending on the relation between market ratio and legal ratios in London and Amsterdam, when the legal ratio in Amsterdam is higher than in London:

- Possibility 1 (part 1 of the grey line): for a level of resources lower than \(\min \frac{S_o}{G_o} \left[ \frac{p_G^L}{p_S} \right]\), the equilibrium ratio is lower than London and Amsterdam legal ratios \(\left(\frac{p_G}{p_S} < \frac{p_G^L}{p_S} \text{ and } \frac{p_G}{p_S} < \frac{p_G^A}{p_S}\right)\). Both London and Amsterdam are on a gold standard \textit{de facto}.

- Possibility 2 (part 2 of the grey line): for a level of resources between \(\min \frac{S_o}{G_o} \left[ \frac{p_G^L}{p_S} \right]\) and \(\min \frac{S_o}{G_o} \left[ \frac{p_G^A}{p_S} \right]\), the equilibrium ratio coincides with legal ratio in London, so lower than legal ratio in Amsterdam \(\left(\frac{p_G^L}{p_S} = \frac{p_G}{p_S} < \frac{p_G^A}{p_S}\right)\). London is on a bimetallic standard, but Amsterdam is on a gold standard.

- Possibility 3 (part 3 of the grey line): for a level of resources between \(\min \frac{S_o}{G_o} \left[ \frac{p_G^A}{p_S} \right]\) and \(\max \frac{S_o}{G_o} \left[ \frac{p_G^A}{p_S} \right]\), the equilibrium ratio is higher than London legal ratio and lower than Amsterdam legal ratio \(\left(\frac{p_G^L}{p_S} < \frac{p_G}{p_S} < \frac{p_G^A}{p_S}\right)\). London is on a silver standard and Amsterdam is on a gold standard.

- Possibility 4 (part 4 of the grey line): for a level of resources between \(\max \frac{S_o}{G_o} \left[ \frac{p_G^L}{p_S} \right]\) and \(\max \frac{S_o}{G_o} \left[ \frac{p_G^A}{p_S} \right]\), the equilibrium ratio coincides with legal ratio in Amsterdam, so higher than
legal ratio in London \( \frac{\bar{p}_G^L}{p_S^L} < \frac{p_G}{p_S} = \frac{\bar{p}_S^L}{p_S^S} \) because \( \frac{\bar{p}_G^L}{p_S^L} < \frac{p_G}{p_S} \). Amsterdam is on a bimetallic standard, but London is on a silver standard.

- Possibility 5 (part 5 of the grey line): for a level of resources higher than \( \max \frac{S_A}{G_0} \left[ \frac{\bar{p}_G^A}{p_S^A} \right] \), the equilibrium ratio is higher than Amsterdam and London legal ratios \( \frac{p_G}{p_S} \) and \( \frac{p_G}{p_S} \) because \( \bar{p}_G^L < p_S^L \) and \( \bar{p}_G^A < p_S^A \). Both London and Amsterdam are on a silver standard de facto.

**Figure 14: The bimetallic equilibria when** \( \frac{p_G^A}{p_S^A} > \frac{p_G^L}{p_S^L} \)

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**APPENDIX 2: SPECIE-POINT MECHANISM**

This appendix explains the variables used to calculate the gold, silver and bimetallic points, i.e., the gold and silver arbitrated par of exchange between London and Amsterdam \( \frac{p_G^L}{p_S^L} \) and \( \frac{p_G^A}{p_S^A} \), the spot exchange rate between London and Amsterdam \( x_{LA} \) and \( x_{AL} \), the cost of trading gold and silver from London to Amsterdam \( c_{LA}^e \) and \( c_{LA}^t \) and from Amsterdam to London \( c_{AL}^e \) and \( c_{AL}^t \).
Arbitrated par of exchange

The arbitrated par of exchange is defined by the relative market prices \( p_A^g \) and \( p_A^s \).

The market prices for gold and silver in London are taken from the British financial bulletin *The Course of the Exchange*. The price of gold was measured in pounds (£), shillings (s) and pence (d) units of account per standard ounce Troy; and the silver price was measured in shillings (s) and pence (d) units of account per standard ounce Troy\(^{12}\). The bulletin collected price of gold in bars and foreign coins\(^{13}\), and price of silver in bars and the Spanish-American coin Piece of Eight.

I have collected monthly prices of gold and silver bars around the middle of the month from 1734 to 1758\(^{14}\). When quotations are in a range, I convert ranges to the midpoint. England used Julian calendar until 2 September 1757 -followed by 14 September in Gregorian calendar- so I have corrected the dates of the Julian calendar (Old Style) into the Gregorian calendar (New Style) in order to maintain the homogeneity of data for the whole series.

The market prices for gold and silver in Amsterdam are taken from the Dutch commercial bulletin *Kours van Koopmanschappen tot Amsterdam*. Amsterdam was the main world bullion market in the 17\(^{th}\) and 18\(^{th}\) century\(^{15}\) but, despite its importance, no scholar has exploited Amsterdam market prices yet. Amsterdam market prices for bullion are difficult to locate. Financial bulletins comprised exchange rates, sometimes also prices of stocks and very few times bullion prices\(^{16}\). But financial bulletins are scarce and it is not possible to obtain time series for bullion prices. Newspapers also collected the quotation of exchange rates.

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\(^{12}\) The equivalences among the units of account are: 1 pound sterling (£-librae)=20 shilling, 1 shilling (s-solidi)=12 pennies (d-denarii). The fineness for silver is: Sterling Standard (Old Standard) had 92.5% fineness. Fallon (1988, p. 9) and Newton (1731): “The silver Coin contains 11 Oz 2 Pennywt. Fine Silver, and 18 Pennywt. Of Alloy in the Pound”. And the fineness for gold is: 91.66% fineness, i.e. 22/24 carats. Newton (1731): “The present English Standard for Gold coin is 22 Carats of fine Gold, and two Carats or 1/12 of Allow”. One standard ounce Troy is equivalent to 31.103496 grams in the International System of Units. Lemale (1875, p. 189)

\(^{13}\) Gold in coin refers to foreign coins, because the export of domestic coins was forbidden until 1819 (Viner, 1955, p. 4). Gold in coins quotation was restricted to Portuguese gold coins in February 1798.

\(^{14}\) The exact date corresponds to the same date than Amsterdam quotations to calculate specie-point mechanism in section 2.

\(^{15}\) Van Dillen (1926).

\(^{16}\) Some copies of financial bulletins are available in Chambre de Commerce de Marseille (CCM-L.IX-1034), Nederlandsch Economisch-Historisch Archief (NEHA-BC-472-AMS.4.01), Archives Départementales de la Gironde (ADG-7B-2172 and 3026). I only found bullion prices reported in 2 financial bulletins. Sometimes some bullion prices were hand-writen in the reverse of the bulletin.
and/or prices of stocks, but never bullion prices\textsuperscript{17}. Commercial bulletins are an alternative source to collect bullion prices when financial bulletins are scarce\textsuperscript{18}. \textit{Kours van Koopmanschappen tot Amsterdam} is a commercial bulletin of Amsterdam belonging to the \textit{Vereenigde Oost-Indische Compagnie}. N.W. Posthumus, founder of the \textit{Nederlandsch Economisch-Historisch Archief}, ordered copies of the \textit{Kours van Koopmanschappen tot Amsterdam} from the \textit{Arsip Nasional Republik Indonesia} in the 1920s to write his book \textit{Inquiry into the History of Prices in Holland}. The copies of \textit{Kours van Koopmanschappen tot Amsterdam} remain nowadays in the \textit{Nederlandsch Economisch-Historisch Archief}. They are monthly frequency, but they are low quality photographs and sometimes the data are not available or the photos are illegible, so some blanks are unavoidable. But, despite blanks, \textit{Kours van Koopmanschappen tot Amsterdam} is the best source to collect bullion market prices for Amsterdam. I collected monthly prices of fine gold and silver bars around the middle of the month from 1734 to 1758. When quotations are in a range, I convert such ranges to the midpoint. Gold bars were measured as the percentage of premium over 355 gulden/Dutch mark\textsuperscript{19}. Silver bars were measured in gulden and stuiver units of account\textsuperscript{20}.

Amsterdam had two types of units of account in the 18\textsuperscript{th} century: current money and bank money. Current money and bank money fluctuated according to agio\textsuperscript{21}. Bullion market prices were expressed in current money (Hayes 1739, p. 285) while the exchange rate between London and Amsterdam was expressed in bank money (Hayes 1739, p. 278). As the aim is to compare the arbitrated parity with the exchange rate, I need to transform the units in current money of the arbitrated parity to units in bank money. I convert current money to bank money according to agio (equation 28) (Hayes 1719, pp. 12-14; Quinn and Roberds 2009, p. 60).

\begin{equation}
\text{Current Money} = (1+\text{agio}) \cdot \text{Bank Money}
\end{equation}

Agio data are taken from \textit{Kours van Koopmanschappen tot Amsterdam} (Figure 15 shows the fluctuation between bank and current money in Amsterdam):

\textsuperscript{17} Rotterdamsche Courant (microfilm C. 46), Amsterdamsche Courant (microfilm C. 20), Utrechtse Courant (microfilm C. 31) and Oprechte Haarlemsche Courant (microfilm C.37), Koninklijke Bibliotheek Den Haag.
\textsuperscript{18} See McCusker and Gravesteijn (1991) for a description of the sources.
\textsuperscript{19} 1 Dutch Mark = 0.246084 kg. Hayes (1777, p. 253), Kelly (1835, vol.1, p. 9), and Lemale (1875, p. 48). 355 gulden/mark is the Amsterdamsche Wisselbank price for fine gold before discounting minting cost. Gillard (2004), p. 154
\textsuperscript{20} 1 gulden=20 stuiver. McCusker (1978), p. 44
Source: Kours van Koopmanschappen tot Amsterdam

**Spot exchange rate**

The exchange rate defined in the specie-point mechanism is the implicit spot exchange rate of bills of exchange derived from the exchange rates at maturity compiled in the financial and commercial bulletins. I derive the spot exchange rate from the equation 29 (Flandreau, Galimard, Jobst and Nogues-Marco, 2009b)

\[ x_{AB} = a_{AB}(1 + r_{B}^d) \text{ (units of A/unit B)} \]  

(29)

Suppose that we know the price for a foreign bill bought in a given market $A$ and drawn on another market $B$ where it matures at a certain future date ($a_{AB}$). It is obvious that there is an interest rate for the maturity period for a commercial loan in center $B$ from center $A$ between today and the maturity period ($r_{B}^d$). Suppose that we also know the commercial interest rate in center $B$ according to center $A$, then we can calculate the implicit spot exchange rate ($x_{AB}$). It represents the price for a hypothetical identical bill, bought in market $A$ and payable in market $B$ and involving the same risks and returns, but maturing today.

I calculate the **spot exchange rate in London on Amsterdam** according to equation 29, using data of the exchange rate in London on Amsterdam at maturity ($a_{LA}$) from the London financial bulletin *The Course of the Exchange*, and data of the commercial interest rate in Amsterdam from London ($r_{A}^L$) from Flandreau, Galimard, Jobst and Nogues-Marco, 2009b. The exchange rate in London on Amsterdam was expressed in *schelling* and *groot* bank per
sterling pound\textsuperscript{22} at 2 usances (occasionally 2 and half usances)\textsuperscript{23}. I have collected monthly data—the precise date corresponds to the same date as the bullion prices quotations. I corrected the dates of the Julian calendar (Old Style) into the Gregorian calendar (New Style) in order to maintain the homogeneity of data. When quotations are in a range, I convert such ranges to the midpoint.

I also calculate the \textbf{spot exchange rate in Amsterdam on London} according to equation 29, using data of the exchange rate in Amsterdam on London at maturity (\(a_{AL}\)) from the Amsterdam commercial bulletin \textit{Kours van Koopmanschappen tot Amsterdam}, and data of the commercial interest rate in London from Amsterdam (\(r_{L}^{t}\)) from Flandreau, Galimard, Jobst and Nogues-Marco, 2009b. The exchange rate in Amsterdam on London was expressed in \textit{schelling} and \textit{groot} bank per sterling pound\textsuperscript{24} at 2 usances\textsuperscript{25}. I have collected monthly data for the same date as the bullion prices. When quotations are in a range, I convert such ranges to the midpoint.

The specie-point mechanism defined in section 2 (equations 15 to 17) assumes that the spot exchange rate in London on Amsterdam is the same than the spot exchange rate in Amsterdam on London (\(x_{LA} = x_{AL}\)), so I have denoted the spot exchange rate just as \(x\). Otherwise, we should consider \(x_{LA}\) in the case of transferring specie from Amsterdam to London and \textit{vice versa}.

I assume that the implicit spot exchange rate in Amsterdam on London (\(x_{AL}\)) is, by arbitrage, essentially identical to the spot exchange rate in London on Amsterdam (\(x_{LA}\)). It is a simple arbitrage condition. But in practice, since there are delays in information delivery and transaction costs, cross spot exchange rates could not necessarily be the same and assuming that the implicit exchange rates are identical is not innocuous. A priori, we may surmise that the validity of this assumption is influenced by the degree of development of money markets, the efficiency of arbitrage and information technology, and the quality of expectations of what is happening in other markets.

\textsuperscript{22} Giraudeau (1796) [1756], p. 220.
\textsuperscript{23} Two months maturity, plus 6 days of grace (one usance in London on Amsterdam is 1 month). Flandreau, Galimard, Jobst and Nogues-Marco (2009b), p. 186
\textsuperscript{24} Giraudeau (1796) [1756], p. 205.
\textsuperscript{25} Two months maturity, plus 3 days of grace (one usance in Amsterdam on London is 1 month). Flandreau \textit{et. al} (2009), p. 186
In the context of mid-19th century, Flandreau (1996) proved that the spot exchange-rate London-Paris and Paris-London can be used indifferently. The Figure 16 test the identity of cross spot exchange rates for London-Amsterdam. The spot exchange rate in London on Amsterdam and the spot exchange rate in Amsterdam on London are largely correlated (Pearson correlation coefficient is 0.99), so I accept the equality of cross exchange rates.

Figure 16: Scatter diagram spot exchange rate in Amsterdam on London – spot exchange rate in London on Amsterdam, (monthly observations) 1734-1758 (schelling banco/ pound st.)

Source: see text

Costs

Arbitrage costs between London and Amsterdam are broken down by main item in Table 1:

<table>
<thead>
<tr>
<th></th>
<th>London→Amsterdam</th>
<th>Amsterdam→London</th>
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<tbody>
<tr>
<td>Brokerage buying</td>
<td>1/8 % (a)</td>
<td>1/2 ‰ + 1/2 % (f)</td>
</tr>
<tr>
<td>Charges of loading</td>
<td>1/12 % (b)</td>
<td>1/8 % (e)</td>
</tr>
<tr>
<td>Insurance</td>
<td>see graph 12 (c)</td>
<td>see graph 12 (c)</td>
</tr>
<tr>
<td>Freight</td>
<td>1/4 %+1/12 % (d)</td>
<td>1/4 %+1/12 % (d)</td>
</tr>
<tr>
<td>Charges of uploading</td>
<td>1/8 % (e)</td>
<td>1/12 % (b)</td>
</tr>
<tr>
<td>Brokerage selling</td>
<td>1/2 ‰ + 1/2 % (f)</td>
<td>1/8 % (g)</td>
</tr>
</tbody>
</table>

27 Actually, bulletins reported sight exchange rates in the cases of London and Amsterdam. Sight between London and Amsterdam in mid-18th century was 3 days. Results of the specie-point mechanism do not change using spot or sight exchange rate. But I have preferred to use spot exchange rate instead sight exchange rate to provide a general way to calculate specie-point mechanism when sight data are not available. In mid-18th century sight exchange rate were only available for Paris, London, Hamburg and Amsterdam. The other European financial centres only quoted at long maturity. Flandreau, Galimard, Jobst and Nogues-Marco (2009a).
(a) Hayes (1739, pp. 285-286)
(b) Hayes (1739, pp. 285-286)
(c) *Kours van Koopmanschappen tot Amsterdam* reported insurance cost from London to Amsterdam and from Amsterdam to London (see Figure 17)
(d) ¼% freight for the trip London-Rotterdam and 1/12% freight for the trip Rotterdam-Amsterdam. Hayes (1739, pp. 285-286)
(e) Hayes (1739, pp. 285-286)
(f) ½ ‰ brokerage and ½ % commission. Brokerage in Amsterdam was 1‰, the one half to be paid by the buyer, and the other half by the seller. Hayes (1739, p. 276 and 285-286). The purchase and sale commission of ½ % for bullion was the same than for financial products (Neal, 2010).

(g) ABE. Banco de San Carlos. AAJG. L186, p. 127v. I have taken the value of the brokerage selling in London from a silver arbitrage operation done by the *Banco de San Carlos* in London in 1804. It is the same value than the brokerage buying in London (a). This commission of 1/8 % found in London Stock Exchange at the beginning of the 19th century was maintained from beginning 18th century. Brokerage commission of 1/8 % was applied to financial operations in the London Stock Exchange in the early 18th century, e.g., companies’ shares and lottery tickets. The commission of 1/8 % was both purchase and sale commission. London Stock Exchange finally established formal rules for minimum commissions that members could charge in 1912, and the minimum commission was set at 1/8 % of book value of government bonds. That rate had been established in practice 200 years earlier. (Neal, 2010, p. 10-12)

*Figure 17: Insurance cost between London and Amsterdam, 1734-1758 (%)*
APPENDIX 3: MELTING-MINTING POINTS

Melting-minting points in London

The market prices for gold and silver in London are taken from the British financial bulletin *The Course of the Exchange* (see Appendix 2). The Mint price is the fixed legal price in the money market in London.\(^{28}\) One pound Troy of standard silver (37-fortieths) was struck in 12 2/5 crowns or 62 shilling. One crown had a gross weight of 19 pennyweights (dw) and 8.516129 grains (gr), and one shilling had a gross weight of 3 dw and 20 9/16 gr.\(^{29}\) One pound Troy of standard gold (11-twelfths) was struck in 44 1/2 guineas. One guinea had a gross weight of 5 dwts 9 grains 0.4382 parts and a value of 21 shilling. Mint charges were stopped in 1666 in England, so the mint price of silver was equal to 5s 2d per standard ounce and the mint price of gold was equal to 3£ 17s 10 ½d per standard ounce. Melting down or exporting English coins was forbidden in England in the 18th century.\(^{30}\) According to Locke (1696), melting-down cost for silver was 1 penny per standard ounce. I accept melting cost as melting price; that is, I do not consider any cost for the risk of the illegal melting-down. I do not know melting-down cost for gold, so I consider it was proportional to the cost for silver (1.613% of weight) to calculate the melting-minting bounds.\(^{32}\) Figures 18 and 19 show Market Prices and Mint Prices for gold and silver respectively.

\(^{28}\) Mint price has been obtained in Newton (1729), Hayes (1739, pp.195-199), Carey (1821, pp. 95-97), Feavearyear (1931, pp. 142-143, pp. 346-347).

\(^{29}\) The units of mass are according to Newton (1731); “That the English Pound Troy contains 12 Ounces; 1 Ounce, 20 Pennyweights; 1 Pennywt, 24 Grains; and 1 Grain, 20 Mites”

\(^{30}\) Feavearyear (1931, p.112) and Viner (1955, p. 4)

\(^{31}\) Locke (1696): “The complaint made of melting down our weighty Money, answers this reason evidently. For can it be suppos’d, that a Goldsmith will give one Ounce and a quarter of Coin’d Silver, for one Ounce of Bullion; when by putting it into his Melting-pot, he can for less than a Penny charge make it Bullion? (For ’tis always to be remembred, what I think is made clear, that the value of Silver, considered as it is Money, and the measure of Commerce, is nothing but its quantity)”

\(^{32}\) As we have seen in Figure 8, the market ratio never broke the upper bound, i.e., when the way to arbitrate is melting gold and minting silver. So, melting cost of gold is not relevant because market ratio is not going to break the upper bound. Probably for this reason, there is not contemporary evidence of the cost of melting gold.
Figure 18: Price of Standard Gold Bars in London Stock Exchange, 1734-1758
(monthly observations) pounds sterling/std. ounce Troy


Figure 19: Price of Standard Silver Bars in London Stock Exchange, 1734-1758
(monthly observations) shilling/std. ounce Troy

**Melting-minting points in Amsterdam**

The market prices for gold and silver in Amsterdam are taken from the Dutch commercial bulletin *Kours van Koopmanschappen tot Amsterdam* (see Appendix 2). The Bank of Amsterdam was the intermediary between Dutch agents and Mints. The Bank price represents the legal price in the money market for Amsterdam\textsuperscript{33}. The legal price of Dutch coins was not exactly proportional to their net weight, but different types of coins had different legal prices. In our period of study, Gold Ducat had a Bank price of 354.89 gulden bank /Dutch fine mark, and Gold Lyon (Minted from 1/August/1749) had a Bank price of 354.025 gulden bank /Dutch fine mark. I consider the average Bank price of 354.4575 gulden bank /Dutch fine mark. The Dutch monetary system had four types of silver coins in our period: Silver Ducat (Bank price: 24.225 gulden bank /Dutch fine mark), Silver Rijder (Bank price: 24.08 gulden bank /Dutch fine mark), Gulden (Bank price: 24.2 gulden bank /Dutch fine mark) and Dreigulden (Bank price: 24.085 gulden bank /Dutch fine mark). I consider the average Bank price of 24.1475 gulden bank /Dutch fine mark. Mint charges at the Bank of Amsterdam were from 1% to 2% for converting bullion into Dutch coins\textsuperscript{34}, so Mint Price (equivalent to Bank Price after deducting costs) is 354.4575 gulden bank /Dutch fine mark minus mint charges for gold and 24.1475 gulden bank /Dutch fine mark minus mint charges for silver\textsuperscript{35}. I consider the average minting cost of 1.5%, and the same melting cost as in London, 1.613%. Figures 20 and 21 show Market Prices and Bank Prices for Gold and Silver respectively.

\textsuperscript{33} Bank price has been obtained from Guillard (2004), p. 145  
\textsuperscript{34} Guillard (2004), p. 146  
\textsuperscript{35} Bank prices are expressed in bank units of account. And market prices are expressed in current units of account. I use the expression: current money = (1+agio) \cdot bank money (equation 28, in Appendix 2) to convert bank units of account to current units of account in Figures 20 and 21.
**Figure 20: Price of fine Gold Bars in Amsterdam Stock Exchange, 1734-1758**

(monthly observations) gulden/Dutch mark

![Graph of gold bar prices]

Source: *Kours van Koopmanschappen tot Amsterdam* for market prices and Gillard (2004, p. 145) for Wisselbank price

**Figure 21: Price of fine Silver Bars in Amsterdam Stock Exchange, 1734-1758**

(monthly observations) gulden/Dutch mark

![Graph of silver bar prices]

Source: *Kours van Koopmanschappen tot Amsterdam* for market prices and Gillard (2004, p. 145) for Wisselbank price