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Keywords: bimetallism, bimetallic stability, bullion markets, arbitrage, specie-point mechanism, melting-minting points

JEL Classification: E42, N13, F15, N23

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This article analyses the stability of bimetallism in the mid-18th century for the case of two large centres that had different legal ratios and only one international market ratio. A new theoretical framework is articulated for the situation of international independence to set legal bimetallic ratios by monetary authorities in different countries. Then, using new data hand-collected from archival sources and relevant to the two main bullion markets in the 18th century, Amsterdam and London, this theoretical framework is utilised to identify the regimes that actually prevailed during that period, in which Amsterdam was effectively on the bimetallic standard while London was on the gold standard *de facto*.

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INTRODUCTION

The bimetallic standard is a commodity-money system consisting 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.¹ 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 claim that the legal ratio cannot equal the market ratio because shocks on the market lead to brutal switches from the bimetallic standard to *de facto* monometallic standards (Locke 1696, Say 1826, Stuart Mill 1848; Jevons 1884; Laughlin 1885, Garber 1986, and Redish 1990, 1995 and 2000). Since the market ratio varies over time, although the monetary authorities choose the same legal ratio as market ratio at the date the coins are valued, the market ratio will invariably deviate from the legal ratio over time. The legal ratio is hence an unstable rule, a “knife-edge”, such that 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. This assumption is incorrect because monetary uses have had a very important role in total bullion consumption. The monetary use of silver represented 45% of the total silver stock in the 16th century, 38% in the 17th century and 24% in the 18th century; and the monetary use of gold represented 29% of the total gold stock in the 16th century, 24% in the 17th century and 23% in the 18th century.² Therefore, the monetary usage of gold and silver represented a very high proportion

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 was 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 The percentages of monetary uses relative to the total stocks of gold and silver were calculated 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 ounces Troy using London mint prices obtained from Feavearyear (1931, pp. 346-347). The percentages of gold and silver used for monetary purposes are calculated without considering depreciation of the stocks; thus, they represent the minimum percentages because the stocks are maximized.

of the total metal stock, making it an error to posit that the relative prices of gold and silver commodities are exogenous.

Proponents of the stability of bimetallism focus on a broader perspective of a general equilibrium. They recognise the legal ratio as the exogenous factor that governed the market ratio between gold and silver as commodities. The main idea is that the market is incapable of pricing the equilibrium ratio between the two metals, requiring that the monetary authorities set a legal ratio to determine the equilibrium (Wolosky 1870, Fisher 1894, Walras 1881, Friedman 1990, Flandreau 2002, 2004). They reason that the market ratio between gold and silver cannot be defined without knowledge of the monetary demand for each metal; and the monetary demand depends on the purchasing power, which itself depends on the price of each metal. Relying 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 needs for the precious metal as commodities.

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 the money market and the commodity market to maintain equality between the legal ratio and the market ratio (Velde and Weber 2000). Flandreau (1995, 2002, 2004) has proved that the French monetary system's attempt to fix the market ratio during the 19th century was successful because, rather than jeopardising the system, shocks to gold or silver supplies led to smooth arbitrage. For instance, during the Gold Rush after 1848, France imported gold and exported silver, but French circulation was large enough to buffer the shock. French bimetallism in the mid-19th century is, thus, an example of the stability of bimetallism, in that the country was able to maintain the market ratio at the level of the legal ratio because shocks moved quantities and stabilised prices.

This paper extends the theoretical framework regarding the stability of bimetallism to the case where different legal ratios coexisted in several large bimetallic countries. In open markets, where transactions are free, a commodity like gold or silver can only have one relative market price. Given several legal ratios and only one market ratio, the intriguing question in this case is which ratio is going to prevail.

The stability of bimetallism in the case of several large bimetallic centres is tested for London and Amsterdam in the mid-18th century, as they were the main money centres during

that period (Flandreau *et al.* 2009a). Gold and silver market prices for both centres are required to test the stability of bimetallism. Until now, London has been the only centre for which a series of bullion market prices since the end of the 17th century exists (reported in the financial bulletin entitled *The Course of the Exchange*). Nonetheless, market prices should also be available for other centres, such as 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 examined Amsterdam bullion prices, most likely because they are difficult to locate. However, the data for Amsterdam, at least for some time periods, do exist and are available. The best source for data from 1734-1758 is the commercial bulletin titled *Kours van Koopmanschappen tot Amsterdam*. Using this new primary source, the stability of bimetallism can be tested for several bimetallic centres that have different bimetallic legal ratios and only one bimetallic market ratio.

In the first section of this paper, a general equilibrium model is developed for a world bimetallic economy. Bimetallism is possible at a ratio compatible with the use of either metal as money. If both centres coordinate and fix the same legal ratio, bimetallism is possible in both centres. However, if the centres do not coordinate to fix the bimetallic ratio, the legal ratio of one centre at the most will be the equilibrium ratio so that the bimetallic standard is effectively preserved in that centre and the other centre will have monometallism *de facto*. The second section calculates bullion market integration. Bullion market integration is required to distinguish instability from disintegration. In order for the stability of bimetallism to be tested, both centres must have the same market prices for gold and silver. This section demonstrates that international arbitrages ensure uniformity in gold and silver market prices. Finally, the 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 its legal ratio was closed to the market ratio, but London had a gold standard *de facto* because its legal ratio was too far removed 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 cannot be defined without considering the monetary demand for each

metal, and the monetary demand depends on the purchasing power, which itself depends on the price of each metal. Because the market by itself is ordinarily incapable of fixing a single equilibrium bimetallic ratio, the government is obliged to fix a legal ratio. However, the government is not free to set any legal ratio it chooses because the legal ratio must be compatible with the monetary use of either metal. A legal bimetallic ratio that is too high might induce agents to increase their demands for commodity silver to the point where this metal disappears from circulation, thereby creating a gold standard *de facto*. On the other hand, a legal bimetallic ratio that is too low might provoke a silver standard *de facto*.

The model herein, an adaptation of the model developed by Flandreau (2004), determines where permissible bimetallic ratios lie for the case of a world economy comprised of two large bimetallic centres.³ These two centres, Amsterdam and London, are on a bimetallic standard *de iure*. The two individual bimetallic economies can be in equilibrium on an effective bimetallic standard, a monometallic standard *de facto*, or a combination of the two, in which case one centre is on bimetallicism and the other is on monometalism. There are, therefore, nine possible equilibria depending on the legal ratio set by the governments.

This world open economy is composed of three tradable goods: gold and silver, which are used for both monetary and nonmonetary purposes, and one representative consumer good that is not used for monetary purposes. These three goods are available in quantities that are exogenously determined. International arbitrages ensure world-wide uniformity in the market price of gold, silver and the consumer good.⁴

According to Walras' Law, when considering any particular market, if all other markets in an economy are in equilibrium, then that particular 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

³ Large bimetallic countries have a 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.

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.

First, let us describe the nonmonetary demand function for gold and silver. Demand for commodity-gold in centre i (G_c^i) is a function of the gold market price (p_G), and the demand for commodity-silver in centre i (S_c^i) is a function of the silver market price (p_S):

$$G_c^A = \mu_G^A \frac{P}{p_G} Y^A \quad (1)$$

$$G_c^L = \mu_G^L \frac{P}{p_G} Y^L \quad (2)$$

$$S_c^A = \mu_S^A \frac{P}{p_S} Y^A \quad (3)$$

$$S_c^L = \mu_S^L \frac{P}{p_S} Y^L \quad (4)$$

where μ_G^i and μ_S^i are positive constants for centre 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 a commodity, p_S is the market price of silver as a commodity, and Y^i is the real income in centre i (quantity of the representative consumer good).

To preserve tractability, both Amsterdam and London economies are deemed to be on “balanced” growth paths, such that the real incomes of the two centres remain proportionate to one another:

$$Y^L = \beta Y^A \quad (5)$$

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

$$G_c^W = (\mu_G^A + \beta \mu_G^L) \frac{P}{p_G} Y^A = \mu_G^W \frac{P}{p_G} Y^A \quad (6)$$

$$S_c^W = (\mu_S^A + \beta \mu_S^L) \frac{P}{p_S} Y^A = \mu_S^W \frac{P}{p_S} Y^A \quad (7)$$

Second, let us describe the monetary demand function. The nominal amount of money demanded in centre i (i =Amsterdam, London) is the quantity of gold used for monetary purposes (G_m^i) multiplied by the gold price (p_G) plus the quantity of silver used for monetary purposes (S_m^i) multiplied by the 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 (in which k is a positive constant):

$$p_G G_m^A + p_S S_m^A = k^A \cdot P \cdot Y^A \quad (8)$$

$$p_G G_m^L + p_S S_m^L = k^L \cdot P \cdot Y^L \quad (9)$$

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

$$p_G (G_m^A + G_m^L) + p_S (S_m^A + S_m^L) = (k^A + \beta k^L) P \cdot Y^A = k^W \cdot P \cdot Y^A \quad (10)$$

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

$$G_c^W + G_m^A + G_m^L = G \quad (11)$$

$$S_c^W + S_m^A + S_m^L = S \quad (12)$$

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, a monometallic standard *de facto*, or a combination of both whereby one centre is on bimetallism and the other is on monometalism. There are, therefore, nine possible equilibria, depending on the legal ratios defined by the English and Dutch governments ($\frac{\bar{p}_G^L}{\bar{p}_S^L}, \frac{\bar{p}_G^A}{\bar{p}_S^A}$).

Figure 1 shows the equilibrium ratio between the two precious metals as a function of relative gold and silver quantities when both centres coordinate in fixing the legal ratio at $\frac{\bar{p}_G}{\bar{p}_S}$.

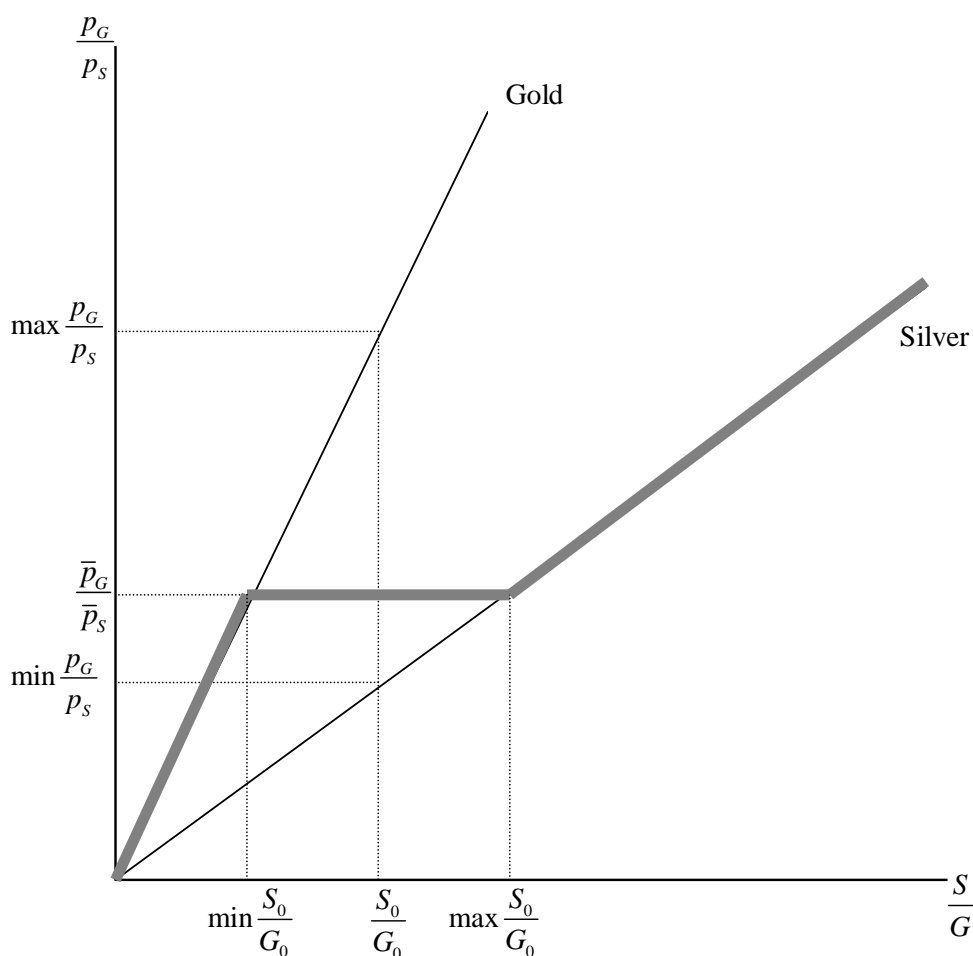
The line ‘‘Gold’’ represents the gold standard equilibrium for both London and Amsterdam ($S_m^L = S_m^A = 0$), and the line ‘‘Silver’’ represents the silver standard equilibrium for both

economies ($G_m^L = G_m^A = 0$). For any given quantity ($\frac{S_0}{G_0}$), 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

$\frac{S_0}{G_0}$.

Figure 1: The bimetallic equilibria when $\frac{\bar{P}_G^A}{\bar{P}_S^A} = \frac{\bar{P}_G^L}{\bar{P}_S^L}$



The relationship between total quantities, equilibrium price and the standards in both centres is represented in Figure 1 by the thick grey line. Suppose that the British and Dutch governments have set the legal ratio at $\frac{\bar{P}_G}{\bar{P}_S}$, and imagine starting from a relative scarcity of silver ($\frac{S}{G}$ lower than $\min \frac{S_0}{G_0}$). In this case, silver is too scarce for a bimetallic equilibrium

corresponding to $\frac{\bar{P}_G}{\bar{P}_S}$ to exist, and the British and Dutch economies operate on a *de facto* gold

standard. With regard to symmetry, starting from a quantity of gold resources that is too scarce for a bimetallic equilibrium corresponding to $\frac{\bar{p}_G}{\bar{p}_S}$ to exist (where $\frac{S}{G}$ is higher than $\max \frac{S_0}{G_0}$), the British and Dutch economies operate on a *de facto* silver standard. When the level of resources is 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 $\frac{\bar{p}_G}{\bar{p}_S}$.

If both the London and Amsterdam centres have the same legal ratio that coincides with the equilibrium market ratio for a given level of resources, positive quantities of gold and silver will be in circulation in the money market. But if each economy has a different bimetallic ratio, different possibilities appear because the commodity markets are integrated and there is only one market ratio.

Suppose that each centre fixes a different legal ratio, and the Dutch government has set a legal ratio that is smaller than the British ratio ($\frac{\bar{p}_G^A}{\bar{p}_S^A} < \frac{\bar{p}_G^L}{\bar{p}_S^L}$).⁵ 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 Amsterdam’s legal ratio is smaller than London’s ($\frac{\bar{p}_G^A}{\bar{p}_S^A} < \frac{\bar{p}_G^L}{\bar{p}_S^L}$), there are 5 possible equilibria (Figure 2):

- Possibility 1 (part 1 of the grey line): when the level of resources is lower than $\min \frac{S_0}{G_0} \left[\frac{\bar{p}_G^A}{\bar{p}_S^A} \right]$, the equilibrium ratio is lower than the Amsterdam and London legal ratios

($\frac{p_G}{p_S} < \frac{\bar{p}_G^L}{\bar{p}_S^L}$ and $\frac{p_G}{p_S} < \frac{\bar{p}_G^A}{\bar{p}_S^A}$ because $\bar{p}_S^L < p_S$ and $\bar{p}_S^A < p_S$), and both London and Amsterdam are

on a gold standard *de facto*.

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.

- Possibility 2 (part 2 of the grey line): when the level of resources is between $\min \frac{S_0}{G_0} \left[\frac{\bar{p}_G^A}{\bar{p}_S^A} \right]$

and $\min \frac{S_0}{G_0} \left[\frac{\bar{p}_G^L}{\bar{p}_S^A} \right]$, the equilibrium ratio coincides with Amsterdam's legal ratio and is lower

than London's legal ratio ($\frac{\bar{p}_G^A}{\bar{p}_S^A} = \frac{p_G}{p_S} < \frac{\bar{p}_G^L}{\bar{p}_S^L}$ because $\bar{p}_S^L < p_S$). In this case, Amsterdam is on a

bimetallic standard, but London is on a gold standard.

- Possibility 3 (part 3 of the grey line): when the level of resources is between $\min \frac{S_0}{G_0} \left[\frac{\bar{p}_G^L}{\bar{p}_S^A} \right]$

and $\max \frac{S_0}{G_0} \left[\frac{\bar{p}_G^L}{\bar{p}_S^A} \right]$, the equilibrium ratio is higher than Amsterdam's legal ratio and lower

than London's legal ratio ($\frac{\bar{p}_G^A}{\bar{p}_S^A} < \frac{p_G}{p_S} < \frac{\bar{p}_G^L}{\bar{p}_S^L}$ because $\bar{p}_S^L < p_S$ & $\bar{p}_G^A < p_G$). In this case,

Amsterdam is on a silver standard and London is on a gold standard.

- Possibility 4 (part 4 of the grey line): when the level of resources is between $\max \frac{S_0}{G_0} \left[\frac{\bar{p}_G^L}{\bar{p}_S^A} \right]$

and $\max \frac{S_0}{G_0} \left[\frac{\bar{p}_G^L}{\bar{p}_S^L} \right]$, the equilibrium ratio coincides with London's legal ratio and is higher

than Amsterdam's legal ratio ($\frac{\bar{p}_G^A}{\bar{p}_S^A} < \frac{p_G}{p_S} = \frac{\bar{p}_G^L}{\bar{p}_S^L}$ because $\bar{p}_G^A < p_G$). In this case, London is on a

bimetallic standard, but Amsterdam is on a silver standard.

- Possibility 5 (part 5 of the grey line): when the level of resources is higher than

$\max \frac{S_0}{G_0} \left[\frac{\bar{p}_G^L}{\bar{p}_S^L} \right]$, the equilibrium ratio is higher than both Amsterdam's and London's legal

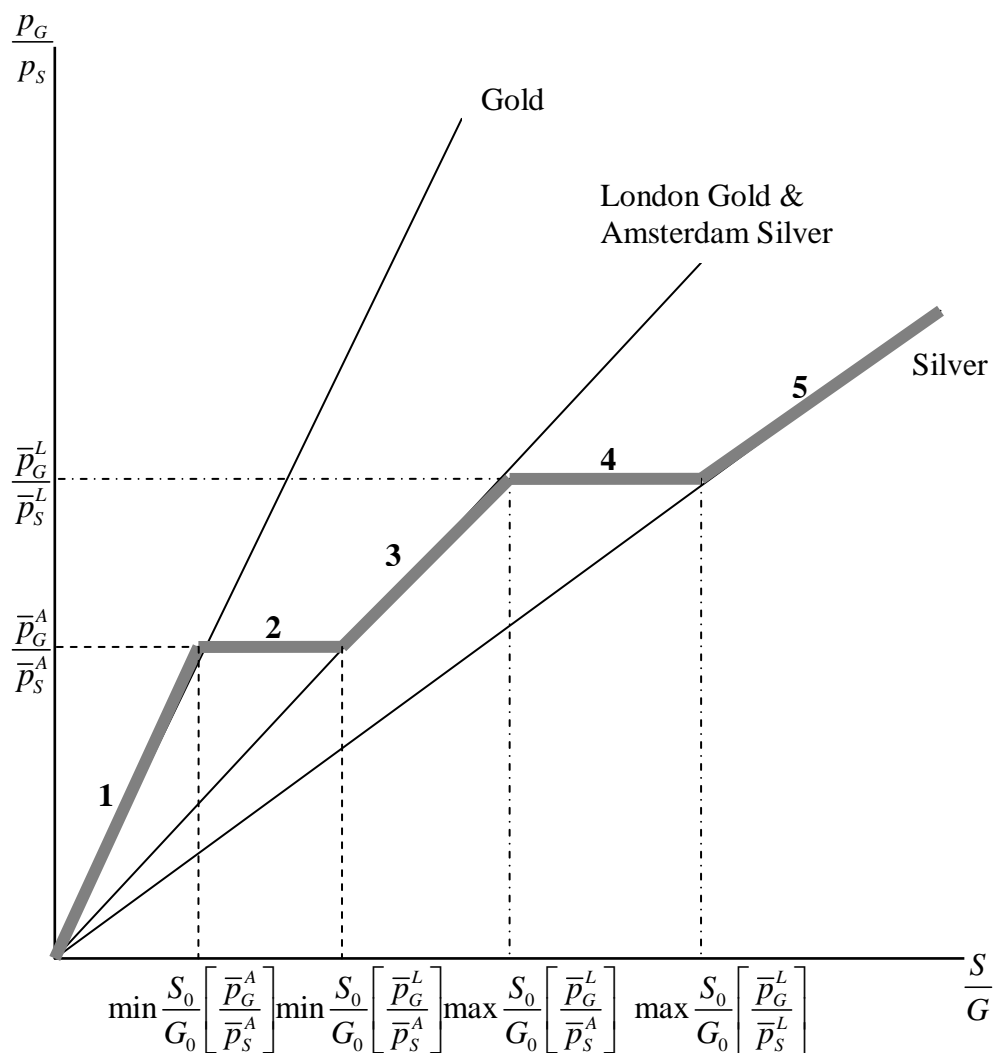
ratios ($\frac{p_G}{p_S} > \frac{\bar{p}_G^L}{\bar{p}_S^L}$ and $\frac{p_G}{p_S} > \frac{\bar{p}_G^A}{\bar{p}_S^A}$ because $\bar{p}_G^L < p_S$ and $\bar{p}_G^A < p_S$), and both London and

Amsterdam are on a silver standard *de facto*.

In summary, bimetallism can be impossible at one ratio, yet possible at another (Fisher, 1894; Flandreau, 2004). Bimetallism will be possible only at a legal ratio compatible with the use of either metal as money. When several bimetallic centres coordinate 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 do not coordinate to fix the legal ratio because there is uniformity in the market ratio, only one centre at the most will be bimetallic. The other centre will be bimetallic *de iure* but monometallic *de facto*.

Figure 2: The bimetallic equilibria when $\frac{\bar{P}_G^A}{\bar{P}_S^A} < \frac{\bar{P}_G^L}{\bar{P}_S^L}$



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

$$p_A^G(\text{gulden bank}) \cdot x \left(\frac{\text{sterling pounds}}{\text{gulden bank}} \right) = p_L^G(\text{sterling pounds}) \quad (13)$$

$$p_A^S(\text{gulden bank}) \cdot x \left(\frac{\text{sterling pounds}}{\text{gulden bank}} \right) = p_L^S(\text{sterling pounds}) \quad (14)$$

where p_A^G is the price of gold in Amsterdam, p_A^S is the price of silver in Amsterdam, p_L^G is the price of gold in London, p_L^S is the price of silver in London and x is the exchange rate for bills of exchange.

Equations (13) and (14) represent the Law of One Price for gold and silver, respectively. If the markets are integrated, the prices are equal in both centres, and arbitrage is not profitable. If the gold (or silver) markets are not integrated, arbitrage moves gold (or silver) from the cheapest centre to the most expensive centre in exchange for a bill of exchange issued in the most expensive centre and payable in the cheaper centre.⁶ Intercity arbitrage is thus not only practised 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). It is, therefore, possible to find the export of one metal and the import of the other, 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).

However, arbitrage was not free. It involved transaction costs. The Law of One Price for a given precious metal, including arbitrage costs, is denominated the specie-point mechanism. The gold-point mechanism was first applied to the case of the classical gold standard

⁶ Bullion movements were free in London and Amsterdam in the 18th century, although only for ingots. Exporting domestic coins was forbidden. See Munro (1992), Ricard (1732) and Vilar (1974).

(Morgenstern 1959; Clark 1984; Officer 1983, 1986, 1989, 1996; Canjels, Prakash-Canjels and Taylor 2004; Esteves, Reis and Ferramosca 2007). Later Flandreau (1995, 1996, 2002, 2004) developed a new method extending the notion of gold-points for the gold standard to specie-points for a bimetallic standard.

The bimetallic specie-point recognises 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 are shown to 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 equation 15:

$$\text{Gold points: } (1 - c_{LA}^g) \frac{p_A^g}{p_L^g} \leq x \leq (1 + c_{AL}^g) \frac{p_A^g}{p_L^g} \quad (15)$$

where p_A^g denotes the market price of gold in Amsterdam; p_L^g denotes the market price of gold in London; x is the spot exchange rate between Amsterdam and London; c_{LA}^g is the cost of trading gold from London to Amsterdam; and c_{AL}^g 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 nor could it 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:

$$\text{Silver points: } (1 - c_{LA}^s) \frac{p_A^s}{p_L^s} \leq x \leq (1 + c_{AL}^s) \frac{p_A^s}{p_L^s} \quad (16)$$

where p_A^s denotes the market price of silver in Amsterdam; p_L^s denotes the market price of silver in London; x is the spot exchange rate between Amsterdam and London; c_{LA}^s is the cost of trading silver from London to Amsterdam; and c_{AL}^s 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 nor could it fall lower than the point where it became profitable to send silver from London to Amsterdam.

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

$$\text{Bimetallic points: } \text{Max} \left[(1 - c_{LA}^g) \frac{P_A^g}{P_L^g}; (1 - c_{LA}^s) \frac{P_A^s}{P_L^s} \right] \leq x \leq \text{Min} \left[(1 + c_{AL}^g) \frac{P_A^g}{P_L^g}; (1 + c_{AL}^s) \frac{P_A^s}{P_L^s} \right] \quad (17)$$

Suppose that a Dutch agent needed to settle a debt in England. Gold and silver, along with bills of exchange, may have been used to settle international payments. The best way to settle the debt was typically to buy a bill of exchange in Amsterdam for London, provided that enough of such bills were available. However, if bills were scarce, their price would rise. If the bill price were to increase above the level at which it became preferable to send metal rather than bills as payment, two transactions were possible. The Dutch debtor could buy gold or silver on the Amsterdam market and ship it to London. Symmetrically speaking, 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 for bills was too unfavourable. To avoid metal shipments, the exchange rate must lie within the bimetallic band that represents the range of overlap between the gold and silver points.⁷

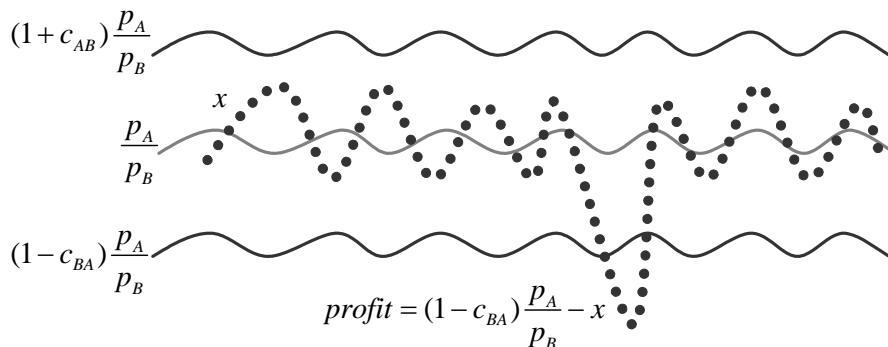
The specie-point mechanism refers to the Law of One Price, including transaction costs, which states that different prices of bullion will tend to equalise. The violation occurs when the exchange rate decreases below the lower band $\left((1 - c_{BA}) \frac{P_A}{P_B} > x \right)$ such that exporting bullion from centre *B* to centre *A* becomes profitable (see Figure 3.). On the contrary, if the

⁷ Contemporaries shipped bullion only when the exchange rate for bills was too unfavourable, i.e., when the bullion point was violated. For example, on 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.

exchange rate increases above the upper band $\left((1 + c_{AB}) \frac{p_A}{p_B} < x \right)$, exporting silver from centre

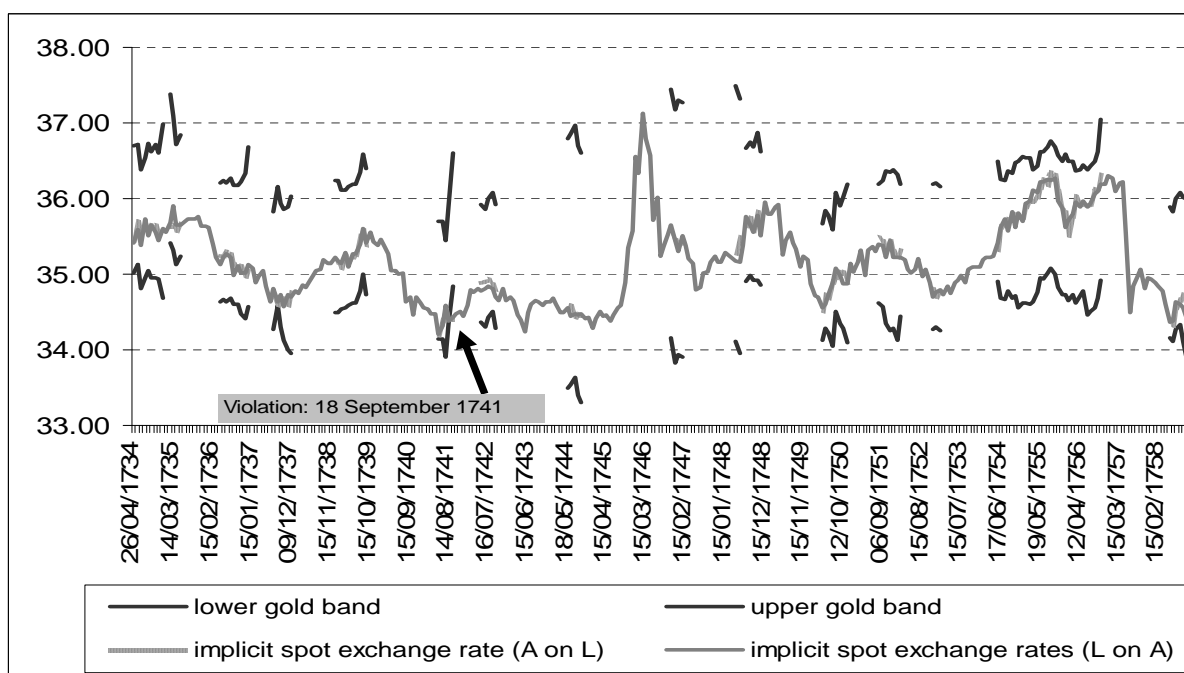
A to centre B is profitable.

Figure 3: the violation of the lower silver point



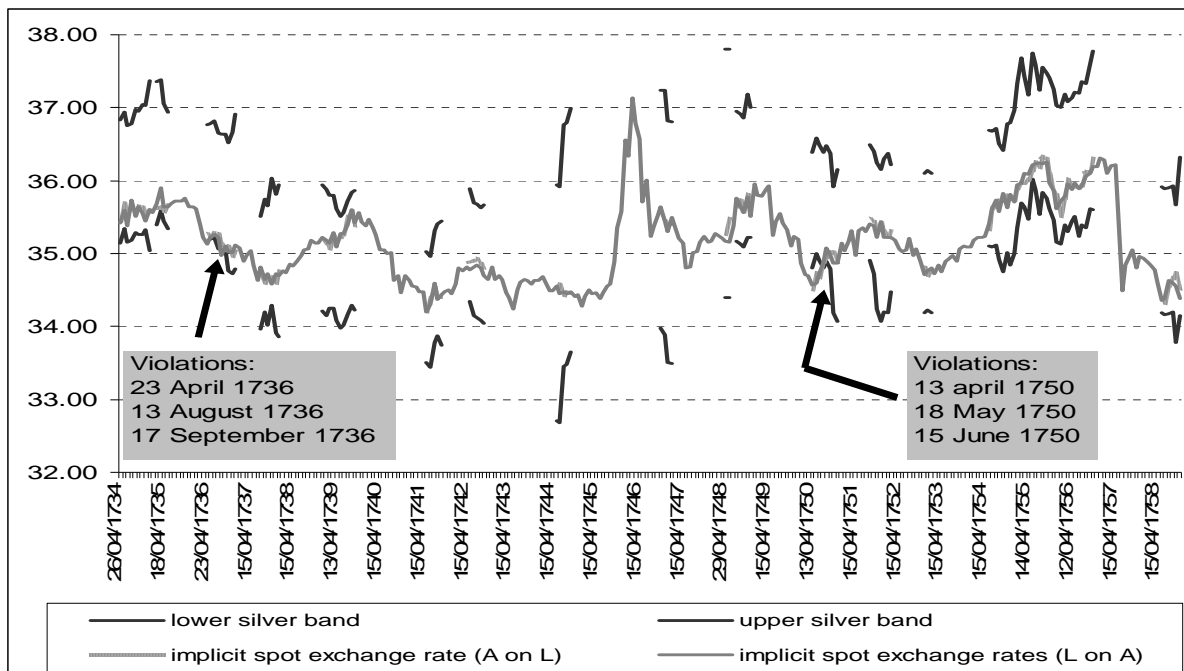
Appendix 2 explains the dataset used to calculate the specie-point mechanism, including arbitrated parity, spot exchange rate and costs. Figure 4 shows the gold band, Figure 5 the silver band and Figure 6 the bimetallic band. We expect few and no persistent violations because arbitrage will adjust the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

Figure 4: Gold band of arbitrage equation between London and Amsterdam, 1734 -1758 (monthly observations), shelling bank/sterling pound



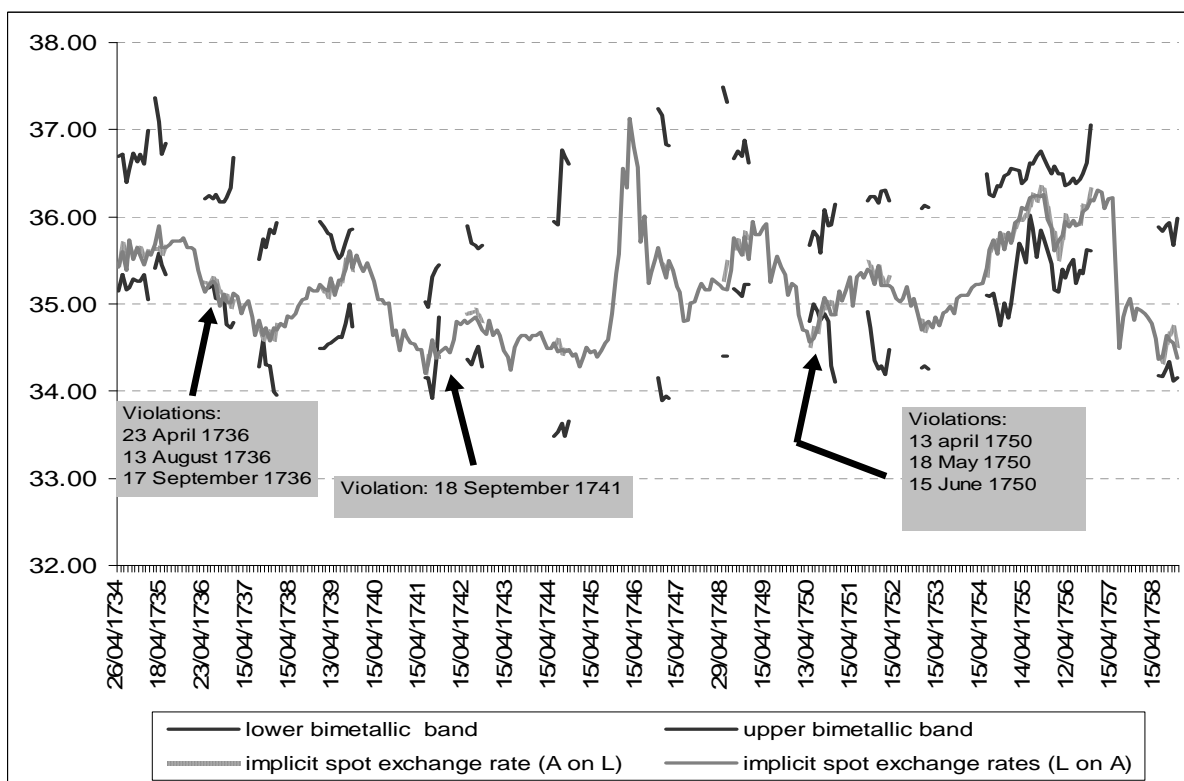
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Figure 5: Silver band of arbitrage equation between London and Amsterdam, 1734 -1758 (monthly observations), shelling bank/sterling pound



Source: see text.

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



Source: see text.

Figures 4 to 6 demonstrate that the specie point mechanism between London and Amsterdam works well, with only few and no persistent breaks occurring. The results show that all breaks are located in the lower band, referring to the profitability in arbitrage from London to Amsterdam. There was only one break for the lower band of gold on 18 September 1741 (Figure 4), while for the lower band of silver there were several 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). The breaks for the bimetallic lower band are the combination of 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 indicate that the exchange rate fell below or rose above the bullion point, such that sending bullion from one centre to the other became profitable. It is important to note that violations were short lived because arbitrageurs bought bullion in the centre with the lowest market price and sold it in the centre with the highest market price, thereby quickly adjusting the prices to eliminate arbitrage profitability. Thus, the process of arbitrage maintained pegged the arbitrated parity to the exchange rate. We observe a different behaviour of exchange rate and bullion points during periods of war and peace. The band defined by the bullion points is narrower and the fluctuation of exchange rate smoother during peaceful periods compared to episodes of war. Exchange rates fluctuated deeply during the War of the Austrian Succession (1742-1748), but the bullion points were not broken because the bullion points opened as a result of the increase in insurance costs from an average of 1.25% in peacetime to 3.5% during the War (see Appendix 2).

Bullion flows between London and Amsterdam were not profitable in the mid-18th century. These results are consistent with our knowledge of capital market integration in the 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 markets were already integrated in the mid-18th century. International arbitrages ensure uniformity in gold and silver market prices. Now that we have determined 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 effectively a bimetallic regime, as explained in section 1. In a “real” bimetallic system with transactions costs, the market bimetallic ratio must remain close but not identical to the legal ratio. The legal ratio between monetary gold and silver can differ from their relative prices as commodities without causing 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 on the market into ingots (melting cost) and in converting the ingots of the undervalued metal on the market into coins (minting cost). These melting-minting costs define the upper and lower legal ratio points; therefore, 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 the market ratio and the legal ratio should be smaller than the transaction costs involved in arbitrage. Otherwise, arbitrage will be profitable. When the difference between the legal ratio and the market ratio is higher than costs, arbitrage will take place because agents will melt down and sell in the market the metal overvalued on the market and buy in the market the metal undervalued on the market to mint. This arbitrage process will drive down the market price of the overvalued metal on the market and drive up the market price of the undervalued metal until the arbitrage profits are cancelled out. As soon as the appreciation in the overvalued metal is lower than the melting-minting expenses, arbitrage stops being profitable. Thus, arbitrage brings the market ratio closer to the legal ratio. The market ratio does not stabilise exactly at the legal ratio, but within the band defined by the melting-minting points that includes the legal ratio. The equilibrium market ratio cannot, therefore, differ from the legal ratio by any amount greater than the legal ratio points (Flandreau 2004).

When the market bimetallic ratio is close to the legal ratio, there is a situation of effective bimetallicism. However, if the market bimetallic ratio greatly differs from the legal ratio and there is no convergence, a monometallic system *de facto* results. The quantity of coins composed of the overvalued metal on the market is so small in the money market that it is not possible to transfer coins from the money market to the commodity market. Because arbitrage is not possible, it cannot stabilise the market ratio at a value close to the legal ratio. A market

ratio far above the legal ratio results in a silver standard *de facto*, and a market ratio far below the legal ratio results in a gold standard *de facto*. The band defined by the melting-minting points indicates the maximum difference between the market and legal ratios that can still 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: its legal monetary value and its commodity market value. Arbitrage occurs when money is transferred from the money market to the commodity market or *vice versa*. Coins of the overvalued metal on the market are converted into ingots (melting cost) to sell in the market in exchange for ingots of the undervalued metal on the market to be converted into coins (minting cost). The melting-minting costs define the upper and lower legal ratio points. Therefore, the 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:

$$p \geq \bar{p} \cdot (1 - s - b) \quad (\text{units: number of units of account / standard ingot}) \quad (18)$$

where p denotes the market price per standard ingot; \bar{p} is the legal price of the ingot before discounting the minting costs; and $\bar{p} \cdot (1 - s - b)$ 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 obtain by melting down the equivalent number of coins per unit of account:

$$p^{-1} \geq \bar{p}^{-1} \cdot (1 - m) \quad (\text{units: weight of standard ingot/unit of account}) \quad (19)$$

where p^{-1} denotes the weight of standard ingots received in the market per unit of account, and $\bar{p}^{-1} \cdot (1 - m)$ denotes the weight of standard ingots obtained by melting 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:

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

$$\text{Silver: } \bar{p}_s \cdot (1 - s_s - b_s) \leq p_s \leq \frac{\bar{p}_s}{1 - m_s} \quad (\text{units of account / standard ingot}) \quad (21)$$

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

$$\frac{\bar{p}_G \cdot (1 - s_G - b_G) \cdot (1 - m_S)}{\bar{p}_S} \leq \frac{p_G}{p_S} \leq \frac{\bar{p}_G}{\bar{p}_S \cdot (1 - m_G) \cdot (1 - s_S - b_S)} \quad (\text{units of account/std. ingot}) \quad (22)$$

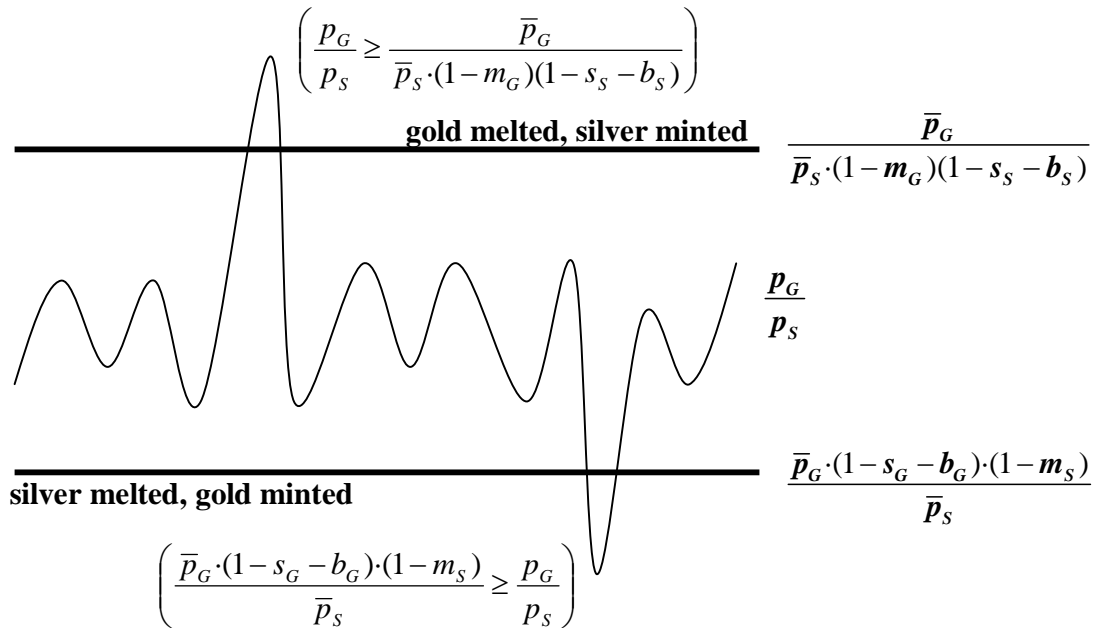
Arbitrage occurs if the market bimetallic ratio breaks the minting-melting bounds (see Figure

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 is melted

down to sell in the market and silver is bought in the market to mint. Arbitrage thus drives down the market price of gold and drives up the market price of silver until the market ratio returns within bounds, so that arbitrage stops being profitable. If the break persists, there is not enough gold in the money market, so it is not possible to melt it to arbitrate. There is already a silver standard *de facto*. Finally, if the market ratio breaks the lower band $\frac{\bar{p}_G \cdot (1 - s_G - b_G) \cdot (1 - m_S)}{\bar{p}_S} \geq \frac{p_G}{p_S}$, silver is melted-down and gold is minted. Arbitrage will

drive down the market price of silver and drive up the market price of gold until the market ratio returns again within bounds, such that arbitrage stops being profitable. If the break persists, there is not enough silver in the money market, so it is not possible to melt it to arbitrate. Thus, there is a gold standard *de facto*.

Figure 7: the violation of the melting-minting points



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

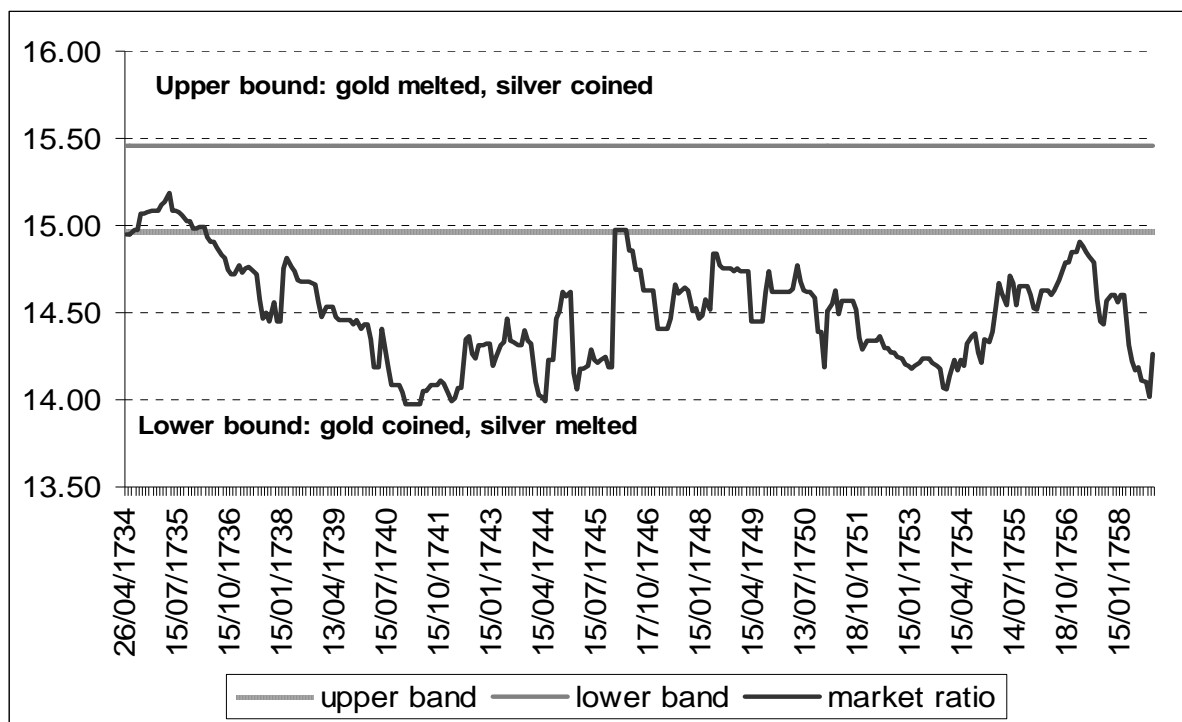
Figure 8 shows the melting-minting bounds in London, and Figure 9 shows the net profitability of arbitrage. The legal bimetallic ratio is 15.21, measured in 100% fineness for both metals.⁸ Minting was free in Britain and the melting cost has been estimated as 1.613%, so the melting-minting band is the interval [14.96, 15.46] (see Appendix 3). In Figure 8, the market bimetallic ratio is systematically below the lower bound, except for the period from April 1734 to March 1736. Therefore, arbitrage between gold and silver was profitable, such that silver was melted and gold was minted. Figure 9 shows the net profitability of arbitrage. Melting-minting costs are presumed to have been underestimated because the estimation considers only the minimum melting price (i.e., melting cost) and ignores other costs proposed by Friedman (1990, p. 90) and Flandreau (2004, pp. 39-44), such as brokerage and assays, abrasion, insurance fees and loss of interest for delays. Therefore, the net profit estimated in Figure 9 should be interpreted with caution because it is probably overestimated.⁹ However, to push the market ratio into the melting-minting bounds, there would have been a maximum cost of near 8%, which appears to be too high, such that the gold standard *de facto* is accepted. Arbitrage was systematically profitable: melting silver, selling it in the market in exchange for gold and sending gold to the mint. Silver was overvalued on the market (undervalued by the law), and gold was undervalued on the market (overvalued by the law). If silver had been sold in the market and gold had been bought in the market, the silver price would have been driven down and the gold price would have been driven up until the arbitrage profits cancelled out and the market ratio was closer to the legal ratio. Nonetheless, as shown in Figure 8, the market ratio remains systematically outside the band, such that arbitrage did not occur despite the indications of arbitrage profitability (Figure 9). There was not enough silver in the money market to transfer to the commodity market by arbitrage, so London was *de facto* in a gold standard. Silver was demonetised in 1774 in recognition of the

⁸ The gold mint price was 136.568 £/pure kilogram and the 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 the mid-19th century as 15.3 and 15.89 (a spread of 0.59 points) (see also Flandreau, 2004, p. 33-34). The London melting-minting points estimated for the mid-18th century are 14.96 and 15.45 (a spread of 0.49). Higher costs are expected for the mid-18th century compared to the mid-19th century, such that the melting-minting points for London in the mid-18th century are underestimated.

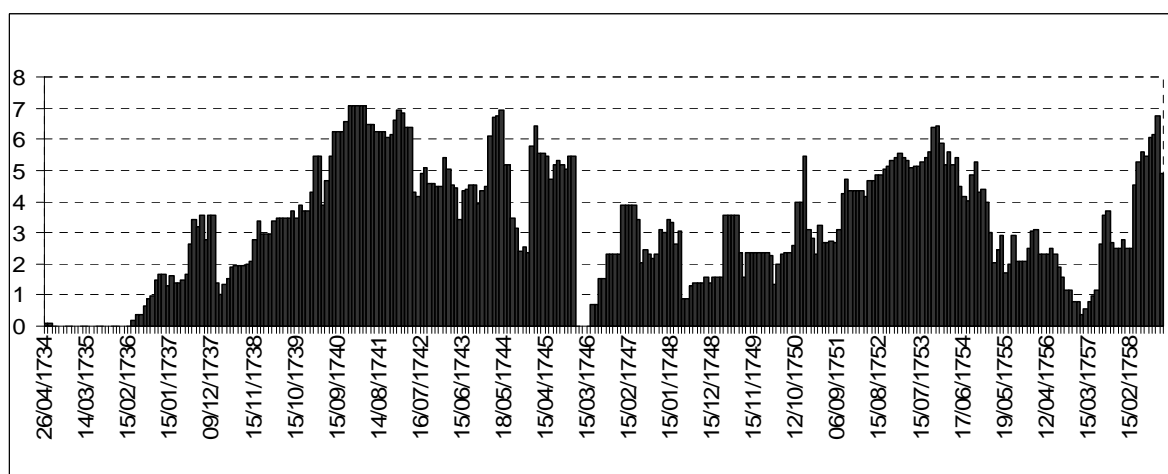
fact that only gold circulated as money in Great Britain.¹⁰ As a result, Britain adopted a monometallic gold standard *de iure* in 1774, but Britain had already adopted a gold standard *de facto* in the mid-18th century.

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



Source: see text.

Figure 9: Net profitability of arbitrage according to melting-minting bounds in London (%), 1734-1758

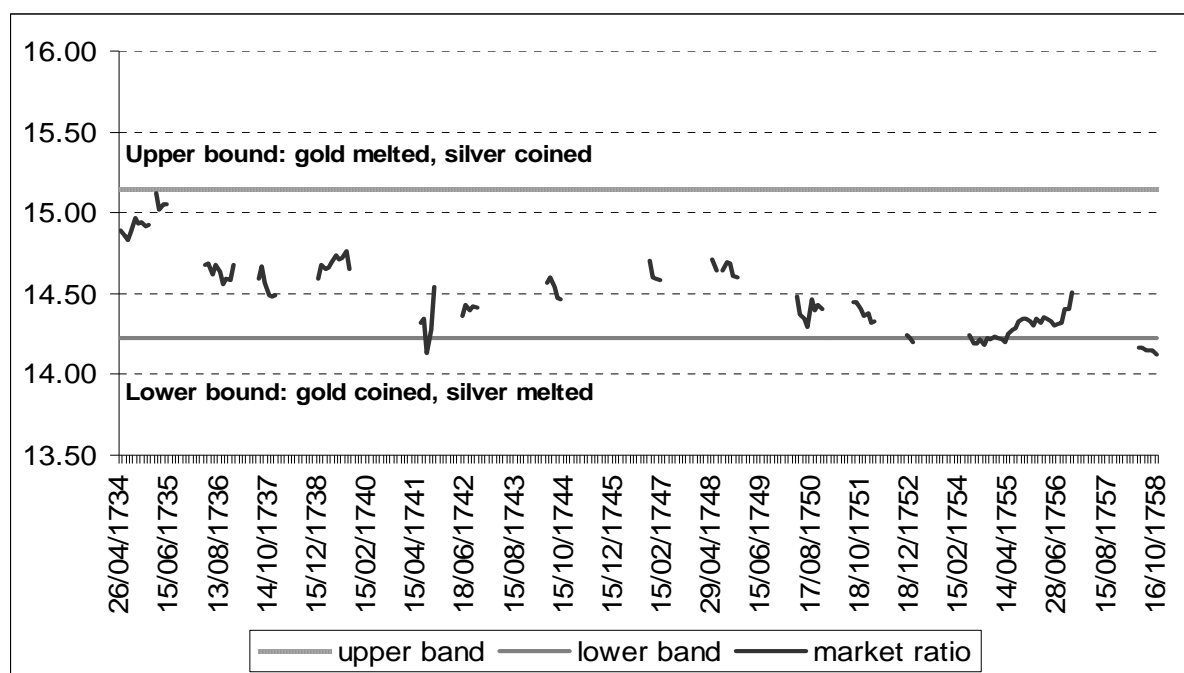


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¹⁰ Frieden (1997), p. 213

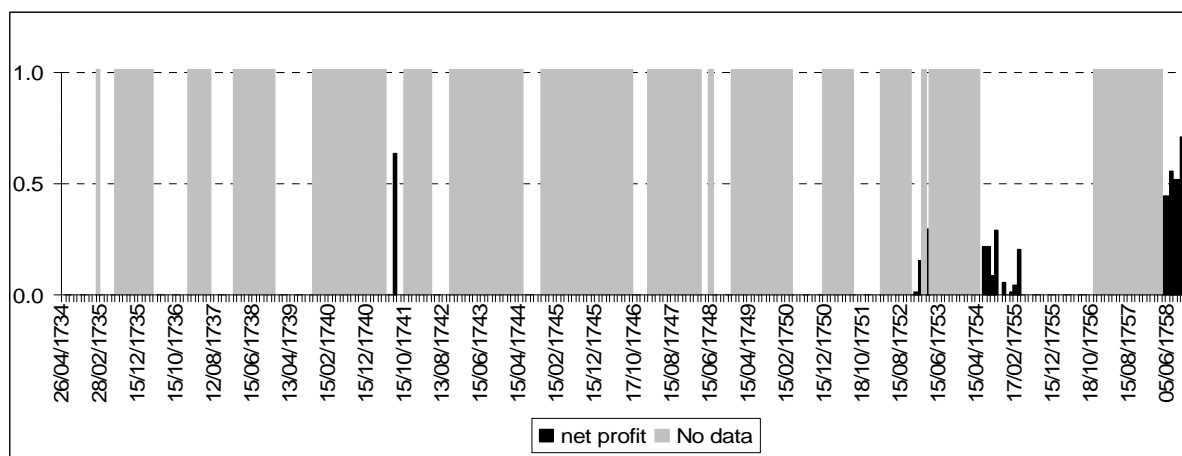
Amsterdam is analysed following the same logic of melting-minting points applied to London. Figure 10 shows the melting-minting bounds in Amsterdam, while Figure 11 shows the net profitability of arbitrage according to the estimated melting-minting points. The legal bank bimetallic ratio between fine 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 that the market bimetallic ratio was systematically within the melting-minting points, so arbitrage was not profitable. The market ratio only breaks the lower band in a few cases in 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 the melting-minting costs that includes the legal ratio. Thus, the bimetallic standard was stable in Amsterdam. The spread of melting-minting points in Amsterdam is greater than in London because Amsterdam had a minting cost, while minting in London was free. However, the stability of bimetalism in Amsterdam is not defined by the spread of the estimated costs but by a market ratio that gravitates around the legal ratio.

Figure 10: Melting-minting bounds in Amsterdam, 1734-1758



Source: see text

Figure 11: Net profitability of arbitrage according to melting-minting bounds in Amsterdam (%), 1734-1758



Source: see text

Amsterdam had a stable bimetallic system in the 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 the London mint had chosen a legal bimetallic ratio that was “too high” and, therefore, 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.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, such that there is only one market price (as demonstrated in section 2), centres should coordinate to fix a legal ratio compatible with the market ratio. But if centres do not coordinate to fix the legal ratio because 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 did not coordinate to fix the legal ratio. The legal ratio in London was 15.21, while the legal ratio in Amsterdam was 14.68. We have also seen in this section that the Amsterdam legal ratio was compatible with the market ratio, so Amsterdam had an effective bimetallic standard; but the London legal ratio was too high to maintain silver in circulation, so London had a gold standard *de facto*. According to the

¹¹ Eichengreen and Flandreau (1997)

model, this case is the second possibility explained in Figure 2 (see now Figure 12). The equilibrium ratio coincides with the legal ratio in Amsterdam and is lower than the 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's legal price of silver was "too low", so all the silver in London was moved from the money market to the commodity market without adjusting the London market ratio to the legal ratio. The legal silver price was too low, so although arbitrage moved all silver holdings from the money market to the commodity market, it was not enough to adjust the market ratio to the legal ratio. The London market ratio was not ruled by the London legal ratio but by the international market ratio which gravitated around the Amsterdam legal ratio.

Figure 12: The bimetallic equilibrium when $\frac{\bar{p}_G^A}{\bar{p}_S^A} = \frac{p_G}{p_S} < \frac{\bar{p}_G^L}{\bar{p}_S^L}$

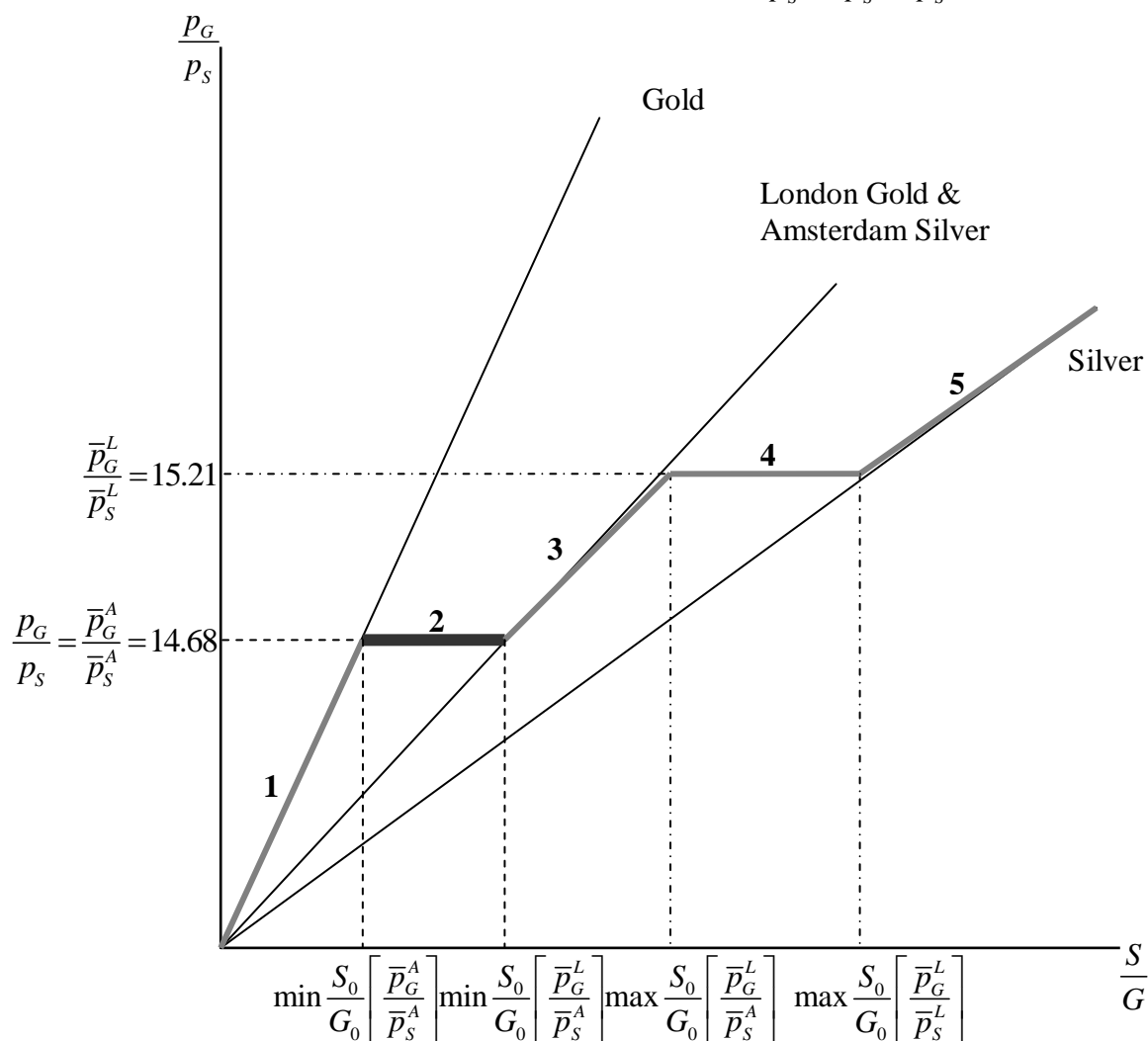
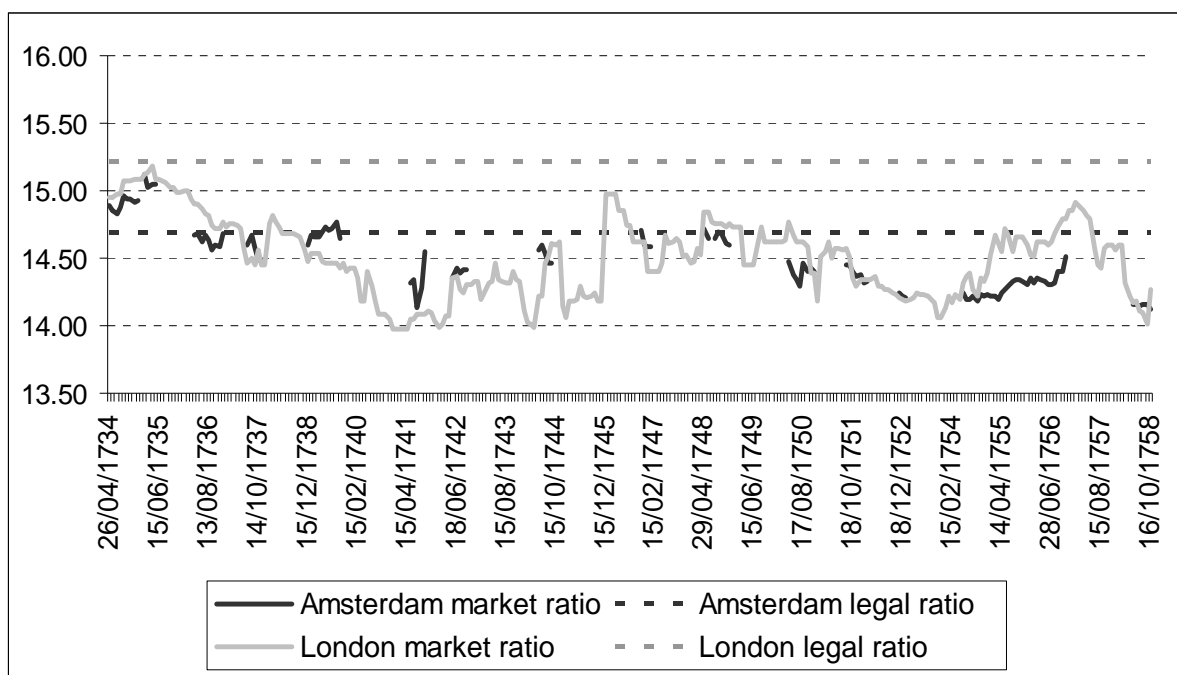


Figure 13 shows the data which support the theoretical model drawn in Figure 12. This figure merges Figures 8 and 10 and represents a summary of the main ideas developed in this paper. First, we observe that the market ratio is equal in London and Amsterdam. There is only one market ratio because London and Amsterdam bullion markets were integrated. This finding is not surprising because both cities had free bullion movements, so we can expect that both markets are integrated and that their prices converge. Second, we observe that the London market ratio did not gravitate around the London legal ratio. Instead, the London market ratio and the Amsterdam market ratio gravitated around the Amsterdam legal ratio. The legal ratio in London was too high to achieve bimetallic stability because London's legal silver price was too low to maintain silver money circulation.

Figure 13: Legal and Market bimetallic ratios in London and Amsterdam, 1734-1758



Source: see text

Finally, we must emphasise the interdependence between the legal ratio and the international market price for a given level of resources. Centres did not have the monetary autonomy to change the legal ratio and peg it to the international market ratio. Any change in the legal ratio would move precious metals between the money market and the commodity market, thereby generating a new equilibrium price. At this new equilibrium price, different situations are possible, as explained in section 1. Economies with bimetallic standard *de iure* can be in the new equilibrium on an effective bimetallic standard, on a monometallic standard

de facto, or on a combination of both (one centre on bimetallism and the other on monometalism). Again, there are nine possible equilibria 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 so that it is compatible with the monetary use of either metal is an interdependent game.

CONCLUSIONS

The stability of bimetallism has been the subject of a wide theoretical debate deriving 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 to the market ratio will demonetise the metal overvalued on the market. The legal ratio was a government-defined fixed price, while the market ratio varied constantly because it was set by supply and demand. Therefore, bimetallism changed systematically to an alternation of *de facto* monometallic standards.

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

Market prices are endogenously determined because precious metals used for monetary purposes represent a very high proportion of the total precious metal stock. The silver used for monetary purposes comprised 45% (16th century), 38% (17th century) and 24% (18th century) of the total silver stock; and the gold used for monetary purposes comprised 29% (16th century), 24% (17th century) and 23% (18th century) of the total gold stock. Legal prices are required to determine market prices. Legal prices define purchasing power, which defines money demand, which defines commodity demands and market prices for a given stock of resources.

Bimetallism is possible, but not at any ratio. The legal ratio must be 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, thereby pegging the market ratio to the legal ratio because its circulation was large enough to move significant quantities and stabilise prices. France had a well-defined legal ratio at a level compatible with gold and silver circulation, which buffered the shocks associated with moving quantities.

But what happens when several countries have different legal ratios? This paper has tested the stability of bimetallism in the mid-18th century for the case of two large centres that had different legal ratios and only one international market ratio. Which ratio is going to prevail in this case? Section 1 (and Appendix 1) develops a general equilibrium model to determine where permissible bimetallic ratios lie. It is an adaptation of the model developed by Flandreau (2004) to the case of two bimetallic centres. When considering several bimetallic centres, they should coordinate 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 coordinate to fix the legal ratio, only the centre whose legal ratio is the equilibrium market ratio will be bimetallic. The other centre will be monometallic *de facto* because its legal ratio differs from the equilibrium ratio.

This result is based on the existence of one market ratio for both centres. Bullion market integration is required to distinguish instability from disintegration. If the bullion markets were disintegrated, two different legal ratios could be stable. For an example, think back to the remote times when markets were disintegrated because bullion movements were forbidden and transport costs were high, times when two centres could have different market ratios. These closed economies could have stable bimetallism with different legal ratios if each legal ratio was equal to the 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 the market ratio to achieve stability.

Bullion market integration in the 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 could be used, along with bills of exchange, to settle international payments. Section 2 (and Appendix 2) calculates the specie-point mechanism and demonstrate that the London and Amsterdam bullion markets were already integrated in the mid-18th century. Integration ensures uniformity in the market price of gold and silver.

Considering only one international market ratio, the legal ratios in London and Amsterdam cannot differ if stable bimetallic systems are to be maintained in both centres. However, the legal ratios did differ. Amsterdam's legal ratio was 14.68, while London's 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 the market ratio gravitated around the legal ratio, but London had a gold standard *de facto*. The London market ratio also gravitated around the Amsterdam legal ratio because their bullion markets were integrated. The market ratio differed too significantly from the legal ratio defined by British government to make possible the use of silver as money.

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APPENDIX 1: THE BIMETALLIC EQUILIBRIA

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

The system can be formally summarised by two equilibrium relations:

$$\left\{ \begin{array}{l} p_G \cdot (G_m^A + G_m^L) = p_G \cdot G \cdot \left[1 - \left(\frac{\mu_G^W}{k^W + \mu_G^W + \mu_S^W} \right) \right] - p_S \cdot S \cdot \frac{\mu_G^W}{k^W + \mu_G^W + \mu_S^W} \\ p_S \cdot (S_m^A + S_m^L) = -p_G \cdot G \cdot \frac{\mu_S^W}{k^W + \mu_G^W + \mu_S^W} + p_S \cdot S \cdot \left(1 - \frac{\mu_S^W}{k^W + \mu_G^W + \mu_S^W} \right) \end{array} \right. \quad (23a)$$

$$\left. \begin{array}{l} p_S \cdot (S_m^A + S_m^L) = -p_G \cdot G \cdot \frac{\mu_S^W}{k^W + \mu_G^W + \mu_S^W} + p_S \cdot S \cdot \left(1 - \frac{\mu_S^W}{k^W + \mu_G^W + \mu_S^W} \right) \end{array} \right\} \quad (23b)$$

The bimetallic economies can be in equilibrium on an effective bimetallic standard, on a monometallic standard *de facto*, or on a combination of both, i.e., one centre on bimetallism and the other on monometalism. There are nine possible equilibria, depending on the legal ratios defined by the English and Dutch governments $\left(\frac{\bar{p}_G^L}{\bar{p}_S^L}, \frac{\bar{p}_G^A}{\bar{p}_S^A} \right)$. 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:

$$\frac{p_G}{p_S} = \frac{S}{G} \cdot \frac{\mu_G^W + k^W}{\mu_S^W} \quad (24)$$

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:

$$\frac{p_G}{p_S} = \frac{S}{G} \cdot \frac{\mu_G^W}{\mu_S^W + k^W} \quad (25)$$

Figure 1 (in section 1) shows the equilibrium ratio between the two precious metals as a function of relative gold and silver quantities when both centres coordinate 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 the “Silver” line $\left(\text{equation 25: } \frac{\mu_G^W}{\mu_S^W + k^W} \right)$ is

smaller than the slope of the “Gold” line $\left(\text{equation 24: } \frac{\mu_G^W + k^W}{\mu_S^W} \right)$, 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* ($G_m^A = 0$), and London is on a gold standard *de facto* ($S_m^L = 0$). Substituting $G_m^A = S_m^L = 0$, the model (equations 1-12) is resolved for the equilibrium ratio as a function of relative gold and silver resources:

$$\frac{p_G}{p_S} = \frac{S}{G} \cdot \frac{\mu_G^W + \beta k^L}{\mu_S^W + k^A} \quad (26)$$

Figure 2 (in section 1) shows 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 $\left(\frac{\bar{p}_G^A}{\bar{p}_S^A} < \frac{\bar{p}_G^L}{\bar{p}_S^L} \right)$. 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 the “London Gold & Amsterdam Silver” line

$\left(\text{equation 26: } \frac{\mu_G^W + \beta k^L}{\mu_S^W + k^A} \right)$ is higher than the slope of the “Silver” line

$\left(\text{equation 25: } \frac{\mu_G^W}{\mu_S^W + k^W} \right)$ and smaller than the slope of the “Gold” line

$\left(\text{equation 24: } \frac{\mu_G^W + k^A + \beta k^L}{\mu_S^W} \right)$. Figure 2 depicts the five possible equilibria for a given level of resources, depending on the relationship between the market and legal ratios in London and Amsterdam.

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

$$\frac{p_G}{p_S} = \frac{S}{G} \cdot \frac{\mu_G^W + k^A}{\mu_S^W + \beta k^L} \quad (27)$$

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 ($\frac{\bar{p}_G^A}{\bar{p}_S^A} > \frac{\bar{p}_G^L}{\bar{p}_S^L}$). The line “Amsterdam Gold and London Silver” represents the silver standard equilibrium for London ($G_m^L = 0$) and the gold standard equilibrium for Amsterdam ($S_m^A = 0$).

The slope of the “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 the “Silver” line $\left(\text{equation 25: } \frac{\mu_G^W}{\mu_S^W + k^A + \beta k^L} \right)$ and smaller than the slope of the “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 relationship between market 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 $\min \frac{S_0}{G_0} \left[\frac{\bar{p}_G^L}{\bar{p}_S^L} \right]$, the equilibrium ratio is lower than the London and Amsterdam legal ratios ($\frac{p_G}{p_S} < \frac{\bar{p}_G^L}{\bar{p}_S^L}$ and $\frac{p_G}{p_S} < \frac{\bar{p}_G^A}{\bar{p}_S^A}$ because $\bar{p}_S^L < p_S$ and $\bar{p}_S^A < p_S$). 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 $\min \frac{S_0}{G_0} \left[\frac{\bar{p}_G^L}{\bar{p}_S^L} \right]$ and

$\min \frac{S_0}{G_0} \left[\frac{\bar{p}_G^A}{\bar{p}_S^L} \right]$, the equilibrium ratio coincides with the legal ratio in London and is lower than

the legal ratio in Amsterdam ($\frac{\bar{p}_G^L}{\bar{p}_S^L} = \frac{p_G}{p_S} < \frac{\bar{p}_G^A}{\bar{p}_S^A}$ because $\bar{p}_S^A < p_S$). 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 $\min \frac{S_0}{G_0} \left[\frac{\bar{p}_G^A}{\bar{p}_S^L} \right]$ and

$\max \frac{S_0}{G_0} \left[\frac{\bar{p}_G^A}{\bar{p}_S^L} \right]$, the equilibrium ratio is higher than London's legal ratio and lower than

Amsterdam's legal ratio ($\frac{\bar{p}_G^L}{\bar{p}_S^L} < \frac{p_G}{p_S} < \frac{\bar{p}_G^A}{\bar{p}_S^A}$ because $\bar{p}_S^A < p_S$ & $\bar{p}_G^L < p_G$). 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 $\max \frac{S_0}{G_0} \left[\frac{\bar{p}_G^A}{\bar{p}_S^L} \right]$ and

$\max \frac{S_0}{G_0} \left[\frac{\bar{p}_G^A}{\bar{p}_S^A} \right]$, the equilibrium ratio coincides with the legal ratio in Amsterdam and is higher

than the legal ratio in London ($\frac{\bar{p}_G^L}{\bar{p}_S^L} < \frac{p_G}{p_S} = \frac{\bar{p}_G^A}{\bar{p}_S^A}$ because $\bar{p}_G^L < p_G$). Amsterdam is on a bimetallic standard, but London is on a silver standard.

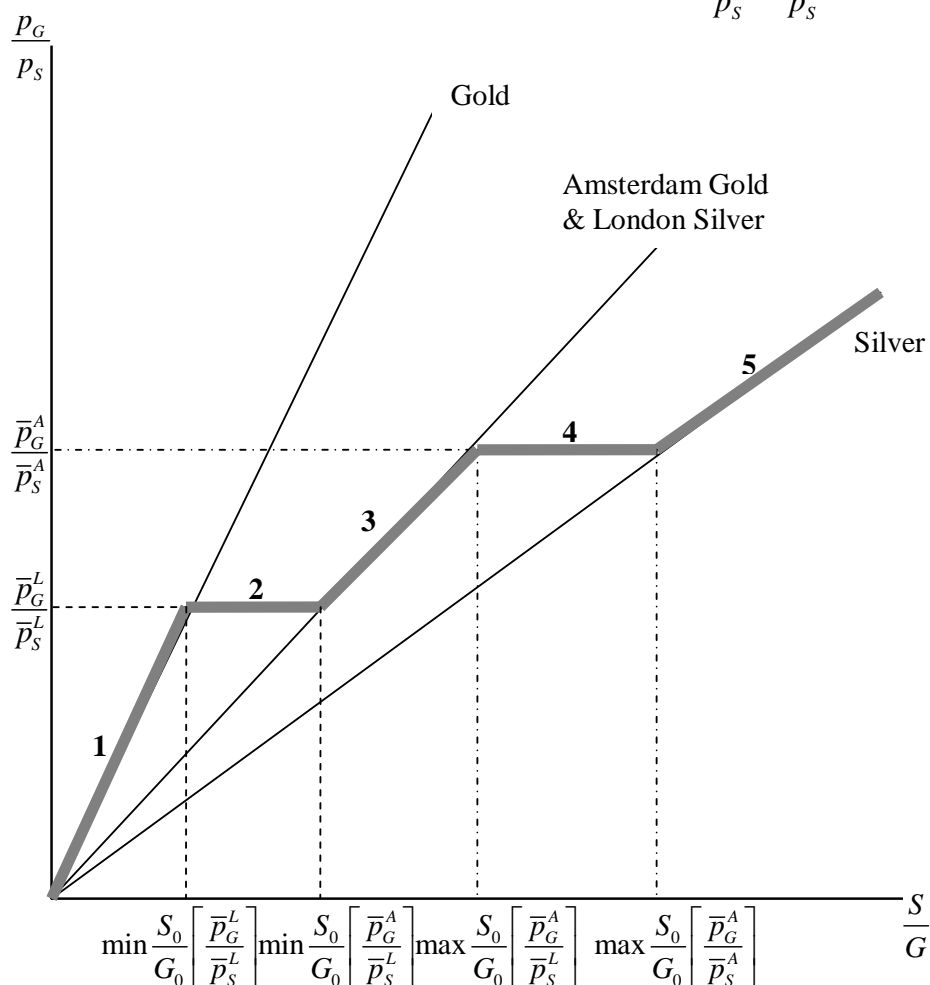
- Possibility 5 (part 5 of the grey line): for a level of resources higher than $\max \frac{S_0}{G_0} \left[\frac{\bar{p}_G^A}{\bar{p}_S^A} \right]$, the

equilibrium ratio is higher than Amsterdam's and London's legal ratios

($\frac{p_G}{p_S} > \frac{\bar{p}_G^L}{\bar{p}_S^L}$ and $\frac{p_G}{p_S} > \frac{\bar{p}_G^A}{\bar{p}_S^A}$ because $\bar{p}_G^L < p_S$ and $\bar{p}_G^A < p_S$). Both London and Amsterdam are on

a silver standard *de facto*.

Figure 14: The bimetallic equilibria when $\frac{\bar{p}_G^A}{\bar{p}_S^A} > \frac{\bar{p}_G^L}{\bar{p}_S^L}$



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 ($\frac{p_A^g}{p_L^g}$ and $\frac{p_A^s}{p_L^s}$), the spot exchange rates between London and Amsterdam (x_{LA} and x_{AL}), and the costs of trading gold and silver from London to Amsterdam (c_{LA}^g and c_{LA}^s) and from Amsterdam to London (c_{AL}^g and c_{AL}^s).

Arbitrated par of exchange

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

The **market prices for gold and silver in London** are taken from the British financial bulletin titled *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 reported the price of gold in bars and foreign coins¹³ and the 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 were reported in a range, I converted the ranges to the midpoint. England used the Julian calendar until 2 September 1757 - followed by the Gregorian calendar on 14 September - so I have corrected the dates of the Julian calendar (Old Style) into the Gregorian calendar (New Style) 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 17th and 18th century;¹⁵ however, despite its importance, no scholar has exploited Amsterdam market prices. This is likely due to the fact that Amsterdam market prices for bullion are difficult to locate. Financial bulletins comprised exchange rates, sometimes the prices of stocks and very infrequently bullion prices.¹⁶ However, financial bulletins are scarce, and it is impossible to obtain time series for bullion prices. Newspapers also collected exchange rates and/or prices of stocks, but never bullion prices.¹⁷ Commercial bulletins are an alternative source of bullion prices when financial bulletins are scarce.¹⁸ *Kours van Koopmanschappen tot Amsterdam* is a commercial bulletin of Amsterdam

¹² The equivalences among the units of account are as follows: 1 pound sterling (£-*librae*)=20 shilling, 1 shilling (s-*solidi*)=12 pennies (d-*denarii*). 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”. Gold had 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 coins refers to foreign coins because the export of domestic coins was forbidden until 1819 (Viner, 1955, p. 4). The coins of gold were restricted to Portuguese gold coins in February 1798.

¹⁴ The exact date corresponds to the same date as the Amsterdam quotations used to calculate the 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, bullion prices were hand-written in the reverse of the bulletin.

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.

¹⁸ See McCusker and Gravesteijn (1991) for a description of the sources.

belonging to the *Vereenigde Oost-Indische Compagnie*. N.W. Posthumus, founder of the *Nederlandsch Economisch-Historisch Archief*, ordered copies of the *Kours van Koopmanschappen tot Amsterdam* from the *Arsip Nasional Republik Indonesia* in the 1920s to write his book titled *Inquiry into the History of Prices in Holland*. The copies of *Kours van Koopmanschappen tot Amsterdam* are now housed in the *Nederlandsch Economisch-Historisch Archief*. They are of monthly frequency only. They are low quality photographs, and the data are not available sometimes or the photos are illegible, such that some blanks are unavoidable. Nonetheless, *Kours van Koopmanschappen tot Amsterdam* is the best source for bullion market prices in Amsterdam. I recorded the monthly prices of fine gold and silver bars around the middle of the month from 1734 to 1758. When quotations were reported in a range, I converted such ranges to the midpoint. Gold bars were measured as the percentage of premium over 355 *gulden*/Dutch mark.¹⁹ Silver bars were measured in *gulden* and *stuiver* units of account.²⁰

Amsterdam had two types of units of account in the 18th century: current money and bank money. Current money and bank money fluctuated according to agio.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 was to compare the arbitrated parity with the exchange rate, I needed to transform the units in current money of the arbitrated parity to units in bank money. I converted current money to bank money according to agio (equation 28) (Hayes 1719, pp. 12-14; Quinn and Roberds 2009, p. 60).

$$\text{Current Money} = (1+\text{agio}) \cdot \text{Bank Money} \quad (28)$$

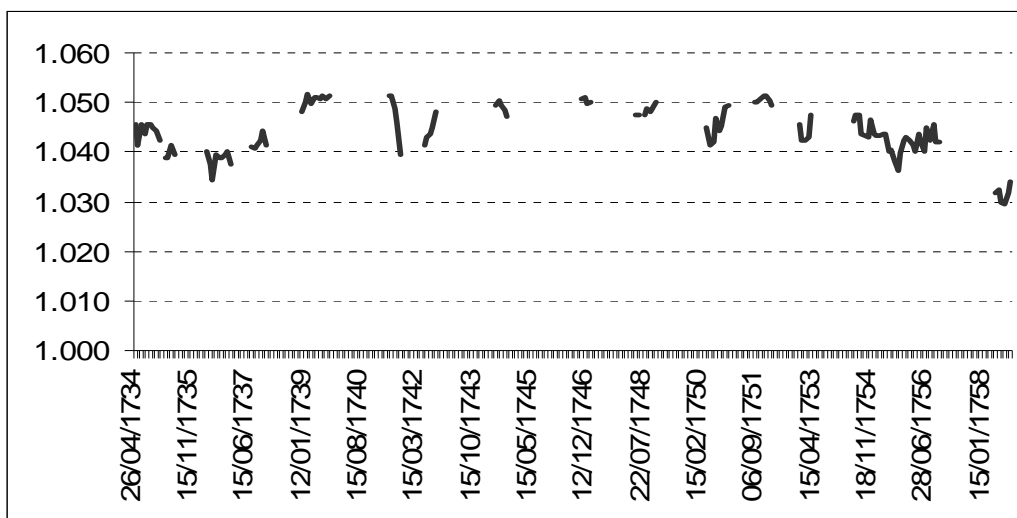
Agio data are taken from *Kours van Koopmanschappen tot Amsterdam* (Figure 15 shows the fluctuation between bank and current money in Amsterdam).

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.

²⁰ 1 *gulden*=20 *stuiver*. McCusker (1978), p. 44.

²¹ Newton (1729/1731), Hayes (1739, p. 259), Shaw (1895, p. 345-359), and McCusker (1978, p. 44).

Figure 15: Current money fluctuation in Amsterdam (bank money =1), 1734-1758



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 derived the spot exchange rate from equation 29 (Flandreau, Galimard, Jobst and Nogues-Marco, 2009b):

$$x_{AB} = a_{AB} \cdot (1 + r_B^A) \quad (\text{units of } A/\text{unit } B) \quad (29)$$

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 centre B from centre A between today and the maturity period (r_B^A). Suppose that we also know the commercial interest rate in centre B according to centre A . Then, we can calculate the implicit spot exchange rate (x_{AB}), which 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 calculated the **spot exchange rate in London on Amsterdam** according to equation 29, using the exchange rate in London on Amsterdam at maturity (a_{LA}) from the London financial bulletin *The Course of the Exchange* and the commercial interest rate in Amsterdam from London (r_A^L) reported by Flandreau, Galimard, Jobst and Nogues-Marco (2009b). The exchange rate in London on Amsterdam was expressed in *shellinge* and *groot bank* per

sterling pound²² at 2 usances (occasionally 2 and half usances).²³ I collected monthly data, the precise dates of which correspond to the same dates as the bullion price quotations. I converted the dates of the Julian calendar (Old Style) to the Gregorian calendar (New Style) to maintain the homogeneity of data. When quotations were in a range, I converted such ranges to the midpoint.

I also calculated the **spot exchange rate in Amsterdam on London** according to equation 29, using the exchange rate in Amsterdam on London at maturity (a_{AL}) from the Amsterdam commercial bulletin *Kours van Koopmanschappen tot Amsterdam* and the commercial interest rate in London from Amsterdam (r_L^A) reported by Flandreau, Galimard, Jobst and Nogues-Marco (2009b). The exchange rate in Amsterdam on London was expressed in *shellinge* and *groot bank* per sterling pound²⁴ at 2 usances.²⁵ I collected monthly data corresponding to the same dates for which bullion prices were collected. When quotations were in a range, I converted 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 as the spot exchange rate in Amsterdam on London ($x_{LA} = x_{AL}$). Therefore, I have denoted the spot exchange rate as simply x . Otherwise, x_{LA} refers to the case of transferring specie from Amsterdam to London and x_{AL} refers to the case of transferring specie from London to Amsterdam.

I assume that the implicit spot exchange rate in Amsterdam on London (x_{AL}) is, by simple 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 money markets development, the efficiency of arbitrage and information technology, and the quality of expectations of other markets.

²² Giraudeau (1796) [1756], p. 220. 1 *shellinge*=12 *groot* and 6 *gulden*=20 *shellinge*. Mc Cusker (1978), p. 44

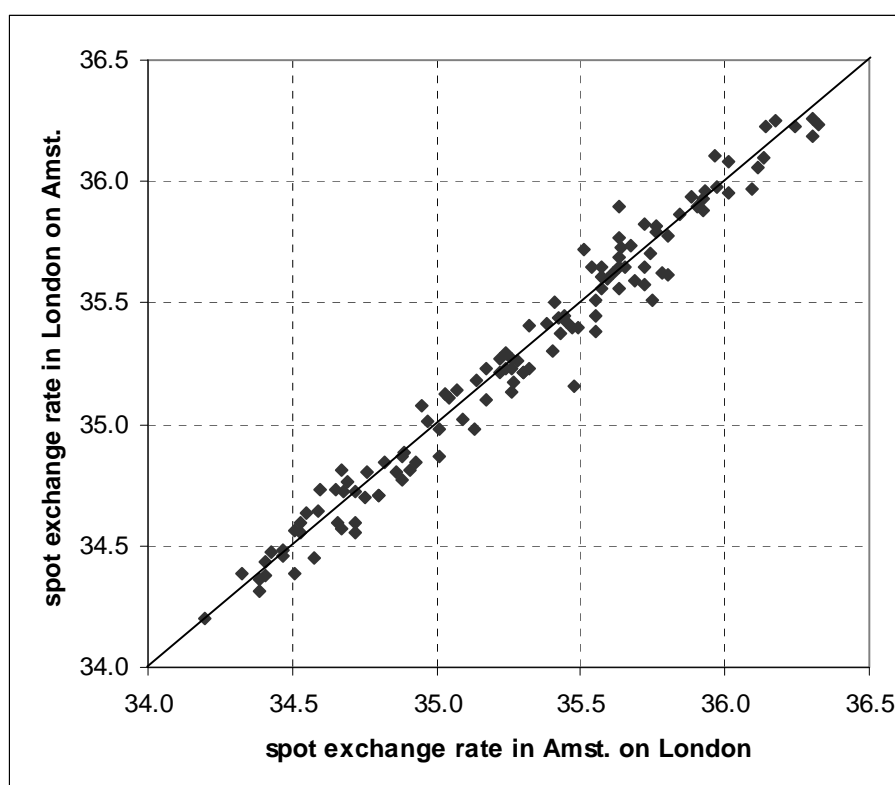
²³ Two months maturity plus 6 days of grace (one usance in London on Amsterdam is 1 month). Flandreau, Galimard, Jobst and Nogues-Marco (2009b), p. 186.

²⁴ Giraudeau (1796) [1756], p. 205.

²⁵ Two months maturity, plus 3 days of grace (one usance in Amsterdam on London is 1 month). Flandreau *et. al* (2009), p. 186.

In the context of the mid-19th century, Flandreau (1996) proved that the London-Paris and Paris-London spot exchange-rates can be used indifferently.²⁶ Figure 16 tests 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), indicating the equality of cross exchange rates.²⁷

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

²⁶ Flandreau (1996), p. 421, footnote 11.

²⁷ Actually, the bulletins reported sight exchange rates in the cases of London and Amsterdam. The sight exchange rate between London and Amsterdam in the mid-18th century was 3 days. Results of the specie-point mechanism do not differ whether using spot or sight exchange rates. I preferred to use spot exchange rates instead of sight exchange rates to provide a general way to calculate the specie-point mechanism when sight data are not available. In the mid-18th century, sight exchange rates 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).

Costs

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

Table 1: Arbitrage cost between London and Amsterdam broken down by main items

	From London to Amsterdam	From Amsterdam to London
Brokerage buying	1/8 % (a)	1/2 ‰ + 1/2 % (f)
Charges of loading	1/12 % (b)	1/8 % (e)
Insurance	see graph 12 (c)	see graph 12 (c)
Freight	1/4 % + 1/12 % (d)	1/4 % + 1/12 % (d)
Charges of unloading	1/8 % (e)	1/12 % (b)
Brokerage selling	1/2 ‰ + 1/2 % (f)	1/8 % (g)

(a) Hayes (1739, pp. 285-286)

(b) Hayes (1739, pp. 285-286)

(c) *Kours van Koopmanschappen tot Amsterdam* reported insurance costs from London to Amsterdam and from Amsterdam to London (see Figure 17)

(d) ¼% freight for the London-Rotterdam trip and 1/12% freight for the Rotterdam-Amsterdam trip. Hayes (1739, pp. 285-286)

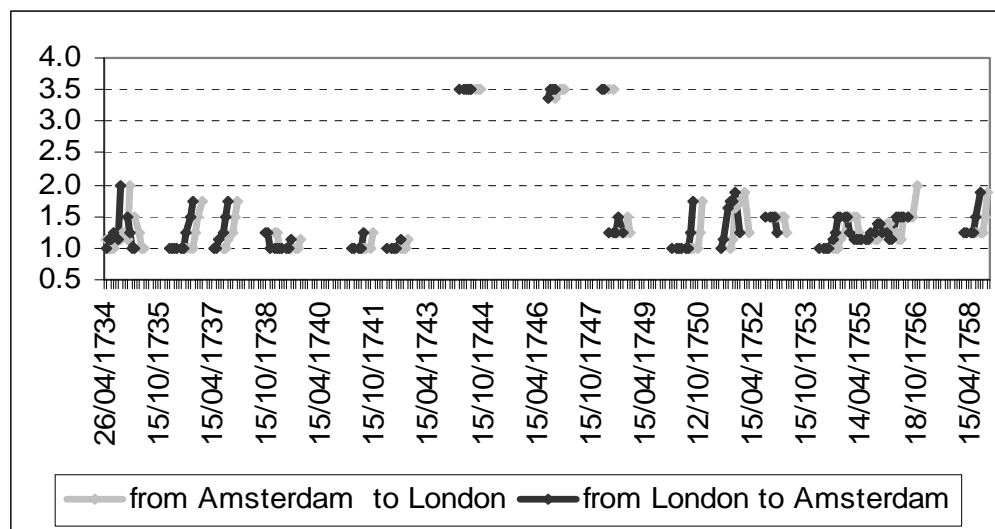
(e) Hayes (1739, pp. 285-286)

(f) ½ ‰ brokerage and ½ % commission. Brokerage in Amsterdam was 1‰, 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 commissions of ½ % for bullion were the same as for financial products (Neal, 2010, p.21).

(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 performed by the *Banco de San Carlos* in London in 1804. It is the same value as the brokerage buying in London (a). This commission of 1/8 % found in the London Stock Exchange at the beginning of the 19th century was maintained from the beginning of the 18th century. A 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 % pertained to both purchase and sale commissions. The London Stock Exchange finally established formal rules pertaining to the minimum commissions that members could charge in 1912, and the

minimum commission was set at 1/8 % of the book value of government bonds. That rate had been established in practice 200 years earlier (Neal, 2010, p. 10-12).

Figure 17: Insurance costs between London and Amsterdam, 1734-1758 (%)



Source: *Kours van Koopmanschappen tot Amsterdam*

APPENDIX 3: MELTING-MINTING POINTS

Melting-minting points in London

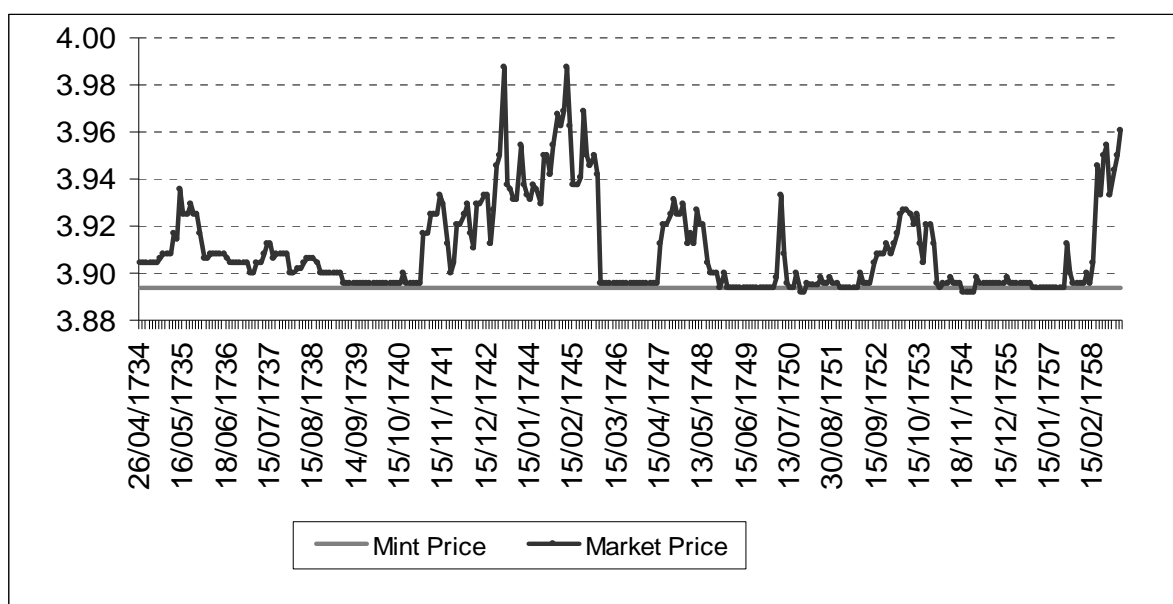
The market prices for gold and silver in London are taken from the British financial bulletin *The Course of the Exchange* (see Appendix 2). The mint price is the fixed legal price in the London money market.²⁸ One pound Troy of standard silver (37-fortieths) was struck in 12 2/5 crowns or 62 shilling. 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 1/2d per standard ounce. Melting down or exporting

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"

English coins was forbidden in England in the 18th century.³⁰ According to Locke (1696), the melting-down cost for silver was 1 penny per standard ounce.³¹ I used the melting cost as the melting price; thus, I did not consider any cost for the risk of the illegal melting-down. I could not determine the melting-down cost for gold, so I assumed it was proportional to the cost for silver (1.613% of weight) to calculate the melting-minting bounds.³² Figures 18 and 19 show the market prices and mint prices for gold and silver, respectively.

Figure 18: Price of Standard Gold Bars in London Stock Exchange, 1734-1758
(monthly observations) pounds sterling/std. ounce Troy



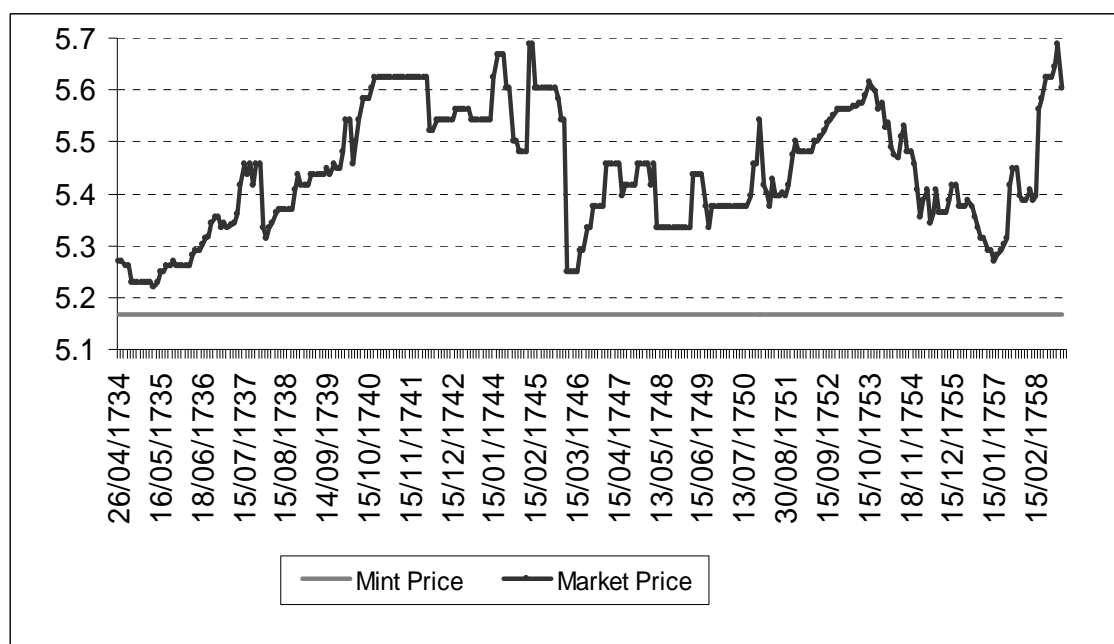
Source: *The Course of the Exchange* for market prices and Feavearyear (1931, p. 347) for mint price.

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, the melting cost of gold is not relevant because the 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 19: Price of Standard Silver Bars in London Stock Exchange, 1734-1758
(monthly observations) shilling/std. ounce Troy



Source: *The Course of the Exchange* for market prices and Feavearyear (1931, p. 346) for mint price.

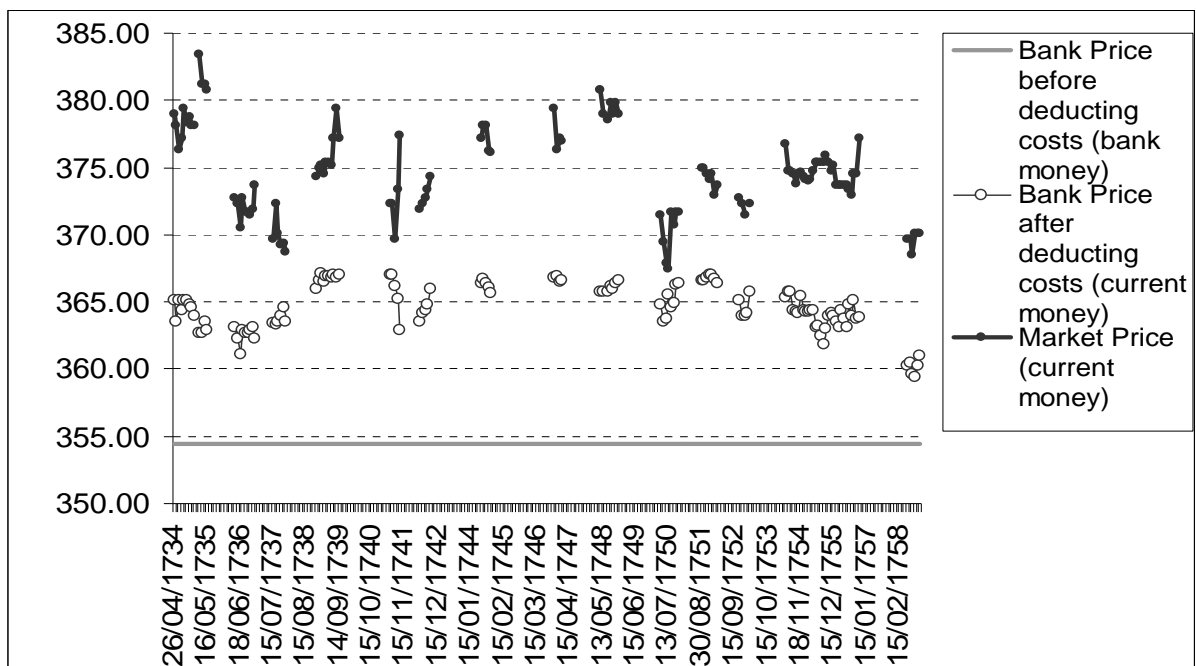
Melting-minting points in Amsterdam

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 Amsterdam money market.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%

³³ Bank price has been obtained from Guillard (2004), p. 145.

for converting bullion into Dutch coins³⁴, 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 silver³⁵. I assigned an average minting cost of 1.5% and used the same melting cost as used for London, 1.613%. Figures 20 and 21 show market prices and bank prices for gold and silver, respectively.

Figure 20: Price of fine Gold Bars in Amsterdam Stock Exchange, 1734-1758
(monthly observations) gulden/Dutch mark

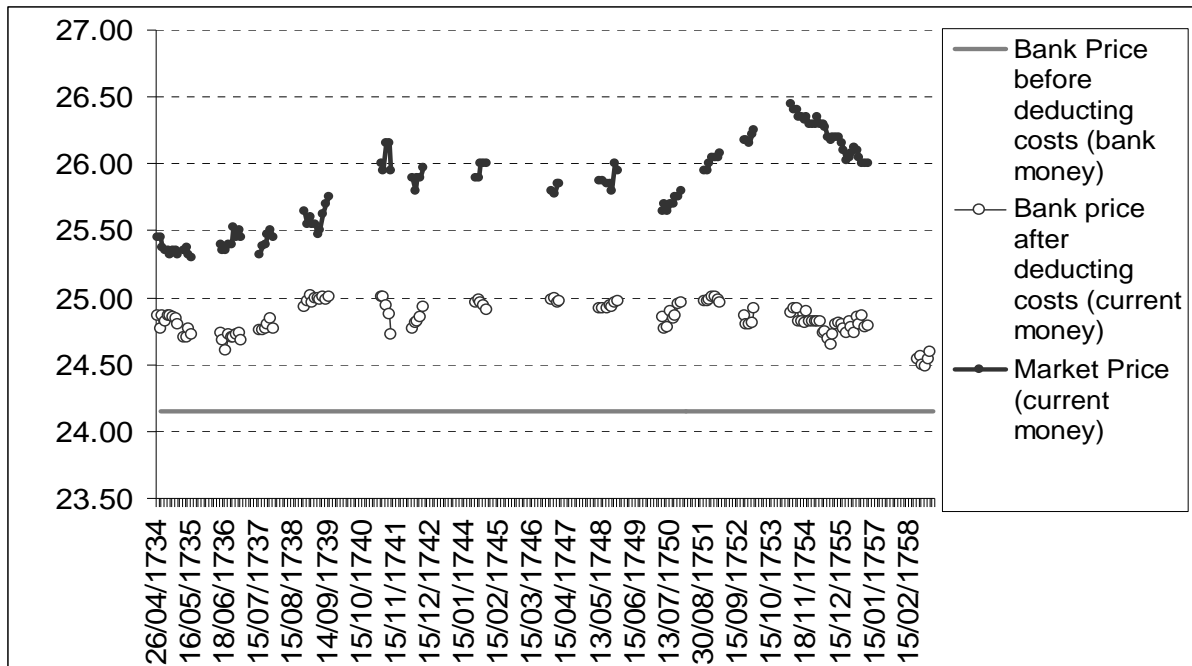


Source: *Kours van Koopmanschappen tot Amsterdam* for market prices and Gillard (2004, p. 145) for Wisselbank price

³⁴ Bank prices are expressed in bank units of account. But market prices are expressed in current units of account. I use the expression: current money = (1+agio) · bank money (equation 28, in Appendix 2) to convert bank units of account to current units of account in Figures 20 and 21.

³⁵ Bank prices are expressed in bank units of account. Also, market prices are expressed in current units of account. I use the expression: current money = (1+agio) · bank money (equation 28, in Appendix 2) to convert bank units of account to current units of account in Figures 20 and 21.

Figure 21: Price of fine Silver Bars in Amsterdam Stock Exchange, 1734-1758
(monthly observations) gulden/Dutch mark



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