East India Bonds, 1718-1763

Exotic Derivatives, Efficiency, and the Financial Revolution

Pilar Nogués Marco and Camila Vam Malle[♣]

Sciences Po, Paris

Abstract

Were 18th century financial markets efficient? Neal (1990) shows that the London and Amsterdam markets were integrated. Yet some scholars find that the London capital market was either not integrated across various classes of securities, or was comprised of ignorant investors who were not knowledgeable enough to arbitrage across securities with different maturities, or was even irrational at times. In this paper, we demonstrate that this misunderstanding arises from an incorrect comprehension of the pricing of the financial instrument they use. After examining certain features peculiar to India bonds overlooked by previous authors, we make it clear not only that 18th century investors were already proficient in international arbitraging, as Neal indicates, but also that they were capable of handling sophisticated options, well before the rise of modern financial mathematics and Black and Scholes' (1973) contribution to options theory.

♣ Chaire de finances internationales – Institut d'Etudes Politiques de Paris, 11 rue de Grenelle, 75007, Paris. mariadelpilar.noguesmarco@sciences-po.org, camila.vammalle@sciences-po.org. We wish to thank Marc Flandreau for his constant support and valuable advice, Mauricio Drelichman, Clemens Jobst, Larry Neal, Patrick O'Brien, and Nathan Sussman and three anonymous referees for their useful comments, and Sciences Po for funding the gathering of data.

Introduction

As Larry Neal (1990) points out, the integration of modern capital markets is not something new, since it existed already in the mid-18th century. By comparing the prices of the same product (English great chartered joint-stock corporation shares) on the London and Amsterdam markets, he observes that the two markets were integrated from about 1720 on, with full exploitation of arbitrage opportunities. On the other hand, some researchers have argued that the early London capital market was either not integrated across various classes of securities (Dickson, 1967, chap. 19), or was comprised of ignorant investors who were not knowledgeable enough to arbitrage across securities with different maturities (Mirowski and Weiller, 1990), or was even irrational at times, especially during the South Sea Bubble (Dale, 2004). These conclusions are somewhat startling: how could the London capital market be so inefficient domestically, when Neal (1990) proved that, internationally, the London market was integrated? We show that this misunderstanding arises from a standard assumption by recent historians that the yield of these securities in the London capital market could be calculated applying a simple coupon/price formula. The yields of the India bonds then show an erratic relation to the yields of other securities, which is interpreted by these historians as an inefficiency in the market.

In this article, we explain the peculiarities of India bonds, which the cited authors used in their analysis. We show that these bonds were highly sophisticated since, although they were nominally short-term, they in fact remained in circulation after their maturity date. This placed them on a level with long-term bonds, with embedded put and call options. Previous authors using India bonds have not taken account of these options, despite the strong influence the options had on the bonds' price which precludes using the coupon/price formula for calculating yields.

Technical computing errors distort not only findings but also how the findings are read, and are therefore responsible for these author's conclusions. A precise understanding of the workings and valuation of India bonds is vital to any analysis of the 18th century English financial revolution, as they constitute a financial innovation which was a crucial technological contribution to the financial revolution and as their mispricing leads to wrong conclusions. Our article provides an exact description of these bonds, thereby showing that they were in practice long-term securities possessing embedded put and call options. Our

main discovery is that investors at the time were perfectly at home with the bonds' mechanisms and knew how to value them correctly, long before modern financial mathematics had come into being, and before Black and Scholes (1973) had made their contribution to options theory. This supplements Neal's (1990) conclusions: whereas Neal was able to prove that the international markets were integrated, our evidence shows that investors were equally capable of performing sophisticated arbitraging among different securities on the home market.

In Part 1, we define the behaviour of India bond and of Consol yields and prices, which suggests a seeming segmentation of the London domestic markets. In Part 2, we show that India bonds, while nominally short-term, are actually long-term bonds containing embedded put and call options. In Part 3, we give graphic models of these options' value and of India bond prices. In Part 4, we check that the observed prices effectively correspond with our analysis, which would prove that investors were capable of pricing India bonds correctly. In the last Part, we outline the reasons why the bonds were invented, and show that the creation of a sophisticated security with embedded options was a financial innovation engendered by a Parliamentary ban prohibiting the East India Company from issuing long-term bonds and not, as is often believed, by market deregulation.

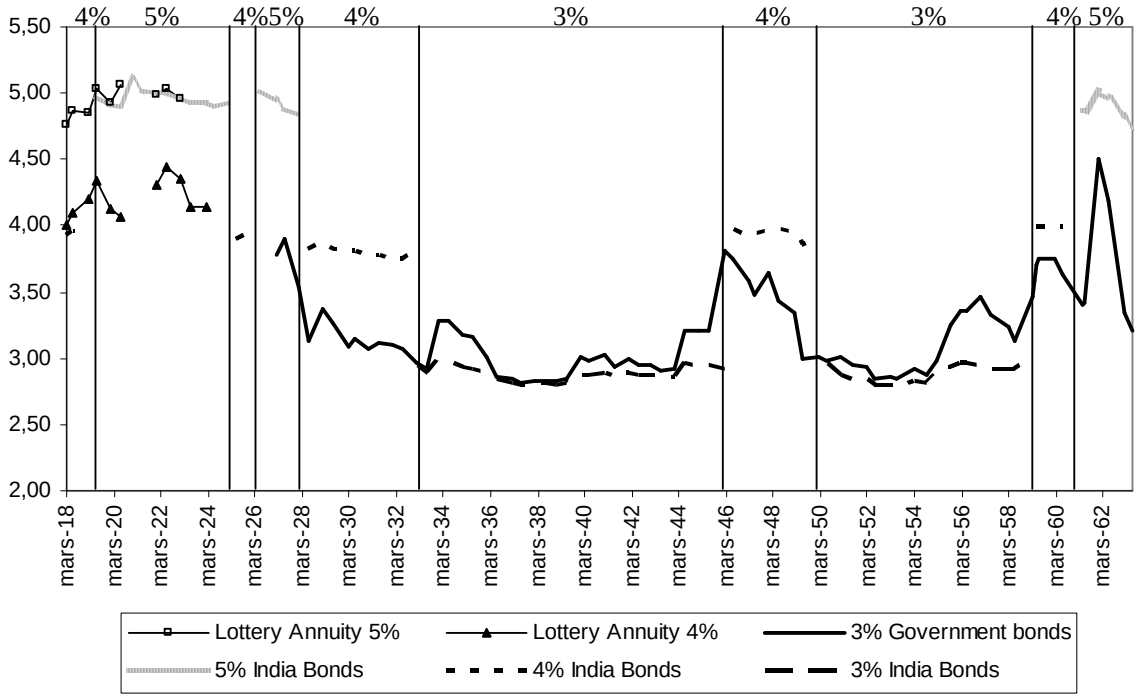
1. No domestic arbitraging on the London market?

Dickson's work (1967) on the financial revolution in England between 1688 and 1756 is the undisputed reference for anyone interested in the birth and development of modern financial markets. Dickson recounts the history of England's public finances, with particular reference to government borrowing and creditors, and the effect of variations in the public debt on the London financial market and the London Stock Exchange. He pays special attention to trends in public and private interest rates between 1688 and 1756. On the basis of quotes extracted from *The Course of the Exchange*, he draws a graph showing the India bond yields at various coupon rates, and the yields on 3% government bonds from 1688 to 1756. He obtains a chart very similar to Diagram 1 below[1] and concludes that the London domestic market was segmented.[2]

[1] See Annex 1 for details on the construction of the database.

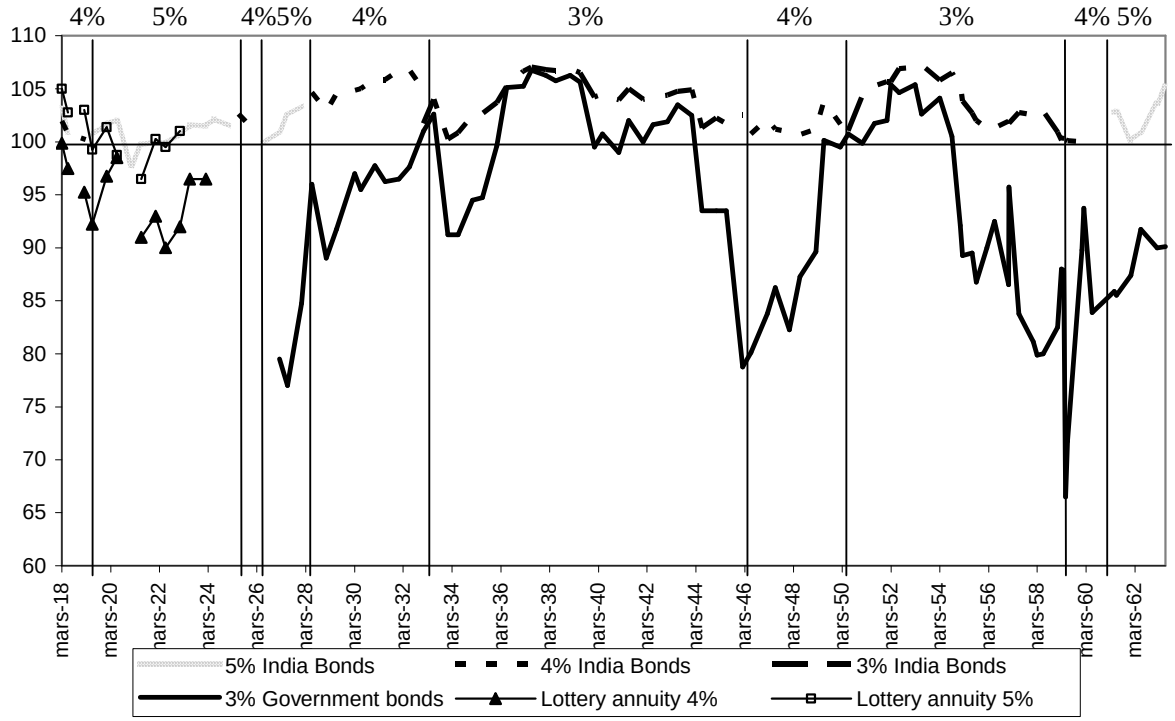
[2] "This suggests that a series of relatively separate and imperfect money-markets were becoming unified as technique improved and financial stability increased" (Dickson, 1967, p. 473).

Diagram 1: Dickson's yields on India bonds and Consols, 1718-1763 (%)



Source: The Course of the Exchange, Lloyd's List

Diagram 2: Trends in Consol and India bond prices, 1718-1763 (nominal value = £100)



Source: The Course of the Exchange, Lloyd's List

Diagrams 1 and 2 above show the course of India bond and Consol yields and prices over the period 1718-1763. The vertical lines show the changes of coupon of the India bonds. The two charts are quite surprising for, according to the arbitrage equation, the yields of the India bonds of different coupon rates should be identical, since the borrower and hence the risk is the same:

(1) $$y_{ib,3\%} = y_{ib,4\%} = y_{ib,5\%}$$

Prices should therefore adjust to equalise the yields, which would give:

(2) $$P_{ib,3\%} = \frac{3}{4} P_{ib,4\%} = \frac{3}{5} P_{ib,5\%}$$

This should provoke "jumps" in the price curve and smooth the yield curve when coupon rates change. The exact opposite is the case: the India bond yield jumps by steps when the coupon rates change, while the price continues to develop smoothly. Yield and price behaviour thus appear reversed as compared with what would normally be expected. Besides, different coupon India bonds do not circulate at the same time[3]: it seems like the India bonds shift to lower coupons when the price of the Consols is high, and shift to higher coupons when the price of the Consols falls.

Dickson is aware of these oddities. Commenting on his graph, he recognises that India bonds were neither arbitraged among their different coupons nor against government bonds. He also remarks that the yield on India bonds is extremely dependent on the coupon rate, and that it hops among different values when coupon rate changes occur: "The yield on East India bonds was highly dependent on their nominal rate: thus the yield fell abruptly in 1728, and again in 1737, when the nominal rate was reduced respectively to 4% and 3%" (Dickson, 1967, pp. 472-473). He explains the lack of arbitraging between India and government bonds by stating that the long-term public and short-term private debt markets were still not integrated: "This suggests that the demand for bonds was relatively constant, and that those who held government stock were not prepared to switch into short-dated bonds instead – for otherwise their price would have risen, and that of government stock would have fallen, until the two yields converged" (Dickson, 1967, pp. 472-473).

[3] Except during two short periods in 1718 and from 1733 to 1737, which we do not show on the graph.

Other authors have worked with India bonds more recently. They, too, reach the conclusion of market inefficiency. Mirowski and Weiller (1990) use India bonds as a proxy for government short-term debt, and work out yields using the coupon/price formula. They obtain a graph much like Diagram 1 above. They next test the influence of rational expectations on the term structure of interest rates, that is, they test whether the long-term interest rate (supplied by Consol yields) comes out as the weighted average of past short-term interest rates (India bond yields). After applying two different evaluation techniques – Shiller variance bounds tests and Flavin's modifications – they find that, with the first technique, the hypothesis is rejected for the whole century and for each sub-period from 1710 to 1793 and, with the second, for over half the cases. They furthermore reject the assumption of a term structure compatible with the theory of rational expectations. Their final conclusion is thus that 18th century interest rates behaved "inefficiently" from the standpoint of neo-classical theory.

Finally, Dale (2004) and Dale, Johnson and Tang (2005) compare the frenzy behaviour of the South Sea subscription share prices during the summer 1720 to the stable behaviour of the 5% India bond prices to show the irrational behaviour of the London capital market through the summer of 1720. Shea (2004) shows that Dale (2004) and Dale, Johnson and Tang (2005) do not price the South Sea subscription shares correctly, as they consider that they created an obligation, which implies their price to be too high, whereas if you consider them as warrants, the price is perfectly rational. We further show that the authors cannot use the India bonds as a benchmark, as these bonds also had embedded options which have to be taken into account when calculating their yields, and that fully explain the stability of their prices.

Every author who has used India bonds for studying interest rate behaviour has obtained curious results, explainable only by market inefficiency or agent irrationality. In the next Part, we show that the problem lies in a faulty understanding of India bonds and in the application of an erroneous formula for calculating their yield.

2. India bonds, forerunners of "callable/putable" bonds

What is the reason for the queer behaviour of India bond yields as seen in Diagram 1? A contemporary author, Massie (1750) highlights the existence of a peculiar feature which

might explain how the East India Company sometimes managed to get better borrowing terms than the government: "…to this it is true, the Condition on which their bonds are issued (*), contributes more than a little, for they may be esteemed ready Cash running at Interest, and consequently are a great Convenience to Bankers, and many other monied Men, who cannot suffer, or do not choose, to have their Money engaged so as not to be able to command it immediately, or at a short Notice" (Massie, 1750, pp. 25-26). A footnote details the peculiar feature:[4] (*) "The East India Company's Bonds are payable [by the Company] upon six Months Notice and the Company receives them as Cash in Payment for Goods bought at their Sales, when six Months Interest is due upon them". This dual characteristic is our subject here.[5]

India bonds, nominally a short-term debt but actually a long-term one with a call option…

In exchange for the long-term loans made available to the government, the government allowed the East India Company to issue debentures, the India bonds. Depending on the moment, these bonds had a six, twelve or eighteen month maturity. Authors using these bonds in their work such as Dickson (1967) or Mirowski and Weiller (1990) therefore treated them as short-term debt. In our opinion, this reading is incorrect. Although the bonds were nominally short-term, they were in practice kept in circulation beyond their maturity date. Once the date was past, the Company could nevertheless buy back the bonds at their nominal value. This explains why changes in the coupon rate (especially downward changes) were discussed with the bond-holders.[6] It was also agreed that, in the event of buy-back, the Company would give six months' notice.[7] If the coupon was down-valued, investors could choose whether to hang on to their bonds and accept the lower rate, or redeem their bonds at their nominal value[8]. In practice then, these securities were long-term bonds carrying what we

[4] As Annex 3 shows, this feature was not explicitly stated in the wording of the bond initially.
[5] Mirowski and Weiller (1990) were aware of this clause and its possible effect on India bond prices, but they did not include it in their calculations (see their note 1, p. 5).
[6] See Dickson (1967, Chapter 16).
[7] "The South Sea bonds created in 1715 were stated to be for six, twelve or twenty-four months at the choice of the lender. Those created in the 1720s were for one year, from Michaelmas to Michaelmas. An issue of the East India bonds in 1732 was for eighteen months, and it seems to have been anticipated that at least six months' notice of repayment would be given. When these bonds were reduced to 3% in 1737, they were put on the basis of six months' notice of repayment" Dickson (1967, p. 409).
[8] Dickson reports the coupon reduction from 4% to 3% in 1733 as follows: "The General Court resolved that bondholders should be paid off on 31 March 1733, with 10% premium in lieu of notice, but might instead exchange their 4% bonds for 3% ones from Michaelmas 1732" Dickson (1967, p. 412).

would now call a call (or conversion) option, exercisable twice a year by the Company when the coupons became payable.

…and a put option

In the trading manuals of the day,[9] we read that the holder of one of these securities could at any time use them at their nominal value to purchase merchandise from the Company. This possibility would have been naturally of interest only if their price would have fallen below their nominal value. [10] Diagram 2 shows that this was never the case, which proves that the mechanism was credible and that the Company was obliged to raise the coupon in order to avoid a mass sale of the bonds when the price of the Consols fell.

If contemporary investors had regarded the India bonds as short-term debt, there would have been no reason for this clause to exist, since in any event the investors would have been repaid at maturity date. It is clear then that India bonds were looked upon more long-term than short-term securities and the feature described above represents what we would call today a put option, exercisable by the holders of the bonds.

Thus, although India bonds were nominally short-term securities, in practice they resemble what are nowadays known as bonds with embedded call and put options, or callable/putable bonds, i.e. bonds which could be bought back by the Company at six months' notice (call option) or resold by investors to the Company at nominal value with six months' interest twice a year at coupon payment time (put option). This kind of stock is no longer very common and there is unfortunately no standard formula for ascertaining its price. The formula of Black and Scholes does not apply since the securities in question do not have a predetermined date for exercising the option.[11] We can therefore not derive a mathematical

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[9] For example: Mortimer (1761).

[10] "When six months Interest are due upon the Bonds, they are receivable by the Company as Cash, in payment of any purchases made at their Sales; but as the Bonds have generally been at a premium, which would be thus lost to the holder, it has been but seldom, that they have been returned to the company. This regulation has a similar effect, but to a greater degree, with that adopted in Exchequer Bills; as it keeps up their credit or value, and prevents their being at any considerable discount." Tate (1819, p. 369).

[11] This resembles an American type of option, and "There are no analytical formulas for valuing American derivatives, even under very simplified assumptions. Numerical methods, essentially trees and finite differences, are usually used for pricing. [...] The pricing of American financial derivatives can also be formulated as a Markov decision process, that is, a stochastic dynamic programming (DP) problem, as pointed out by Barraquand and Martineau (1995). Here the DP value function, that is, the value of the bond with its embedded options, is a function of the current time and of the current interest rate, namely the state variable. This value function verifies a DP recurrence via the no-arbitrage principle of asset pricing, the solution of which yields both

formula, still, we can perform a graphic analysis on these securities so as to understand how they work and discern the moving forces behind the coupon rate changes. This involves modelling the behaviour of India bond prices, in order to explain Diagrams 1 and prove that the London domestic capital market was perfectly integrated.

3. Effect of put and call options on India bond prices: graphic analysis

3.1. Relation between Consol and optionless India bond prices

Without options, India bond prices should parallel Consol prices. Indeed, India bonds were debentures issued by the East India Company as a counterpart for loans made to the government. They were therefore in a sense "secured" by debts due from the government to the Company. This means that the East India Company was monitored by Parliament, which set the volume of debt authorised [12] (see Annex 2 for the volume of India bonds and of East India Company loans to the government). Several authors, such as Mirowski and Weiller (1990), therefore considered the bonds as public debt.

From 1750, the East India Company issued a long-term bond without options, the India annuity.[13] The graph below shows that the yield on these 3% India annuities and on 3% Consols was the same over the period 1751-1763. As the two securities are perfectly comparable, it may be deduced that the investors' perception of risk on the India bond and Consols was identical.

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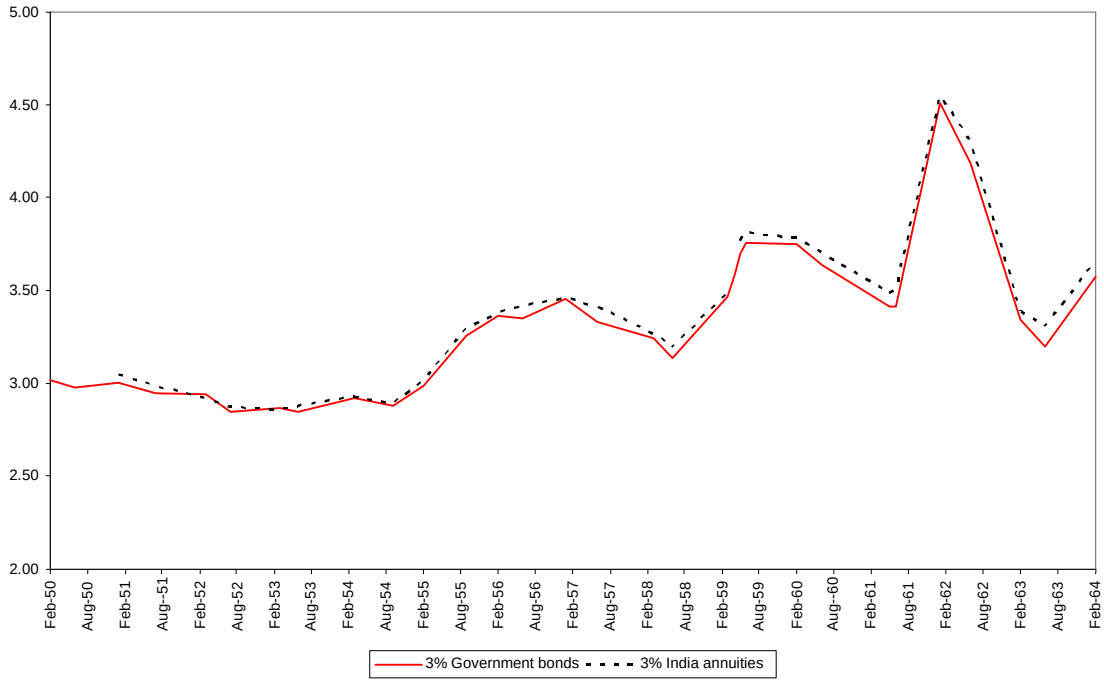
the bond value and the optimal exercise strategies of its embedded options at all time during the bond's life." (Ban-Ameur, Breton, Karoui, L'Equyer, 2006).

[12] "Both the East India and the South Sea bonds were, in effect, secured on the debts due from the government to the two companies. Thus a statute of 1721 empowered the East India Company to take up money on its common seal up to the sum which the government owed the company. (This was an analogous position to that of the Bank of England, whose notes in its early days were, at least in theory, largely backed by the long-term debts which the government owed it.)" Dickson (1967, Chap. 16).

[13] In 1750, Henry Pelham, First Lord of the Treasury, negotiated a reduction of the rates on all government debt to a flat 3 percent with the government's different creditors (including in particular the East India Company). In exchange for the East India Company's agreement to reduce its rate, Parliament gave it the authority to issue a long-term debt instrument, the India Annuity. "Its reduction became involved with the government's proposals to reduce the interest on the National Debt, including the debt owed to the East India Company. One of the moves in this struggle was a government offer to let the company fund part of its debt. […] The government, having run the company into debt by borrowing from it under duress, now used its permission to reduce the debt as a carrot to persuade the East India proprietors to agree (25 April 1750) to a general reduction of interest. [...] It seems clear that by 1755 the total had been reduced from its 1749 level of 4.5 million pounds to just over 2 million." (Dickson, 1967, p. 414).

Diagram 3: Yields on 3% India Annuities and 3% Consols, 1751-1763 (%)



Source: The Course of the Exchange and Lloyd's List

Since, to our knowledge, no major institutional change in the relations between the East India Company and the government occurred between 1718 and 1751, we conclude that the risk on East India Company debts was the same as that on government debts over the whole period 1718-1763.[14] In other words, if the East India Company had issued long-term bonds without options prior to 1750, their prices would have followed the same course as those of government bonds.

This point is essential: accepting as given that the Consol price corresponds to the price that India bonds would have had if they did not contain options, we can by subtraction determine the value of the options in relation to the Consol price and, hence, the price behaviour of India bonds with options.

Without options, we could thus rewrite equation (2) as:

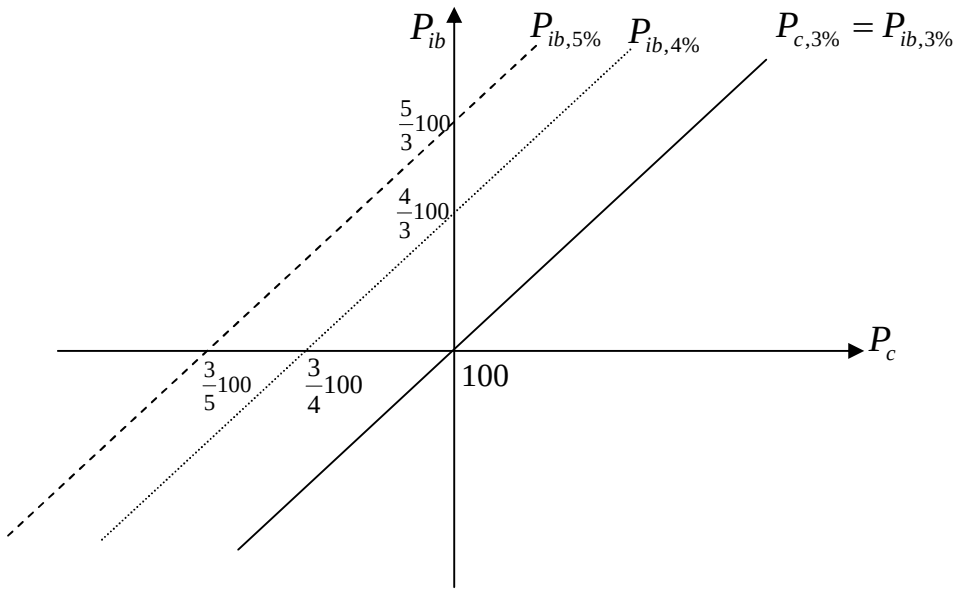
(3) $$P_{ib,3\%} = \frac{3}{4} P_{ib,4\%} = \frac{3}{5} P_{ib,5\%} = P_{c,3\%}$$

[14] For more details on relations between the East India Company and Parliament from 1688 to 1757, see Nichols (1971), Stern (2006) or Sutherland (1949).

where $P_{c,3\%}$ is the price of Consols and $P_{ib,3\%}, P_{ib,4\%}, P_{ib,5\%}$ are the prices of India bonds without options at different coupon rates.[15]

Viewed graphically, the 3% India bond price in relation to the prices of 3% Consols should lie on a 45° diagonal line. With higher coupon rates, arbitrage imposes a higher India bond price for each Consol price (see equation (3)).

Figure 1: Theoretical perfect arbitrage between different coupon bonds



3.2. Relation between Consol price and India bond-with-options price

Intuitively, we should expect that the put and call options embedded in India bonds would prevent the bonds' price from diverging from the nominal value since, if the price fell too far, investors would be tempted to exercise their option and exchange their bonds for goods or cash at nominal value. The Company would then have to issue bonds at a higher coupon rate. If, on the other hand, the price rose too much, investors would anticipate that the Company would use its buy-back right to convert its debt at a lower coupon rate.

[15] For the sake of simplicity, we call all government debts Consols, even though the term is accurate only from 1750 on. See Annex 1 for the different issues that make up the series.

We have seen that India bonds were the equivalent of long-term bonds with put and call options. The 3% India bonds seem, however, to have been in a slightly different class. The government issued annuities at a 3% coupon rate, which was considered very low at the time. It is therefore unlikely that the East India Company would have exercised a call on 3% India bonds and reduced their coupon rate to 2%. We therefore assume that the minimum coupon rate for all debts was 3% and that the 3% India bonds so had a put option only, and no call option.

We further assume that the East India Company could alter its coupon rates by steps only, i.e. that it could propose round figures only as coupon rates. This was, in fact, the case during the period under study, except for the 1733 coupon reduction, when certain investors managed to negotiate coupons at 3.5%. The Company was quick to pay them off, however.[16]

We now present graphically the relation between the price of 3% India bonds with a put option ($P^{p}_{ib,3\%}$) and the price of 3% government bonds (P_c) on the one hand and, between the price of 4% India bonds with put and call options ($P^{c,p}_{ib,4\%}$) and the price of Consols on the other hand. As a call option exercisable by the Company is disadvantageous to investors, it drags down the India bond price. On the contrary, the put option is good for them and so adds to the price. The call and put values depend on the price of 3% Consols. The 3% India bond price is written as follows:

(4) $$P^{p}_{ib,3\%}(P_{c,3\%}) = P_{c,3\%} + VP_{3\%}(P_{c,3\%})$$

and the 4% India price as:

(5) $$P^{c,p}_{ib,4\%}(P_{c,3\%}) = \frac{4}{3}P_{c,3\%} + VP_{4\%}(P_{c,3\%}) - VC_{4\%}(P_{c,3\%})$$

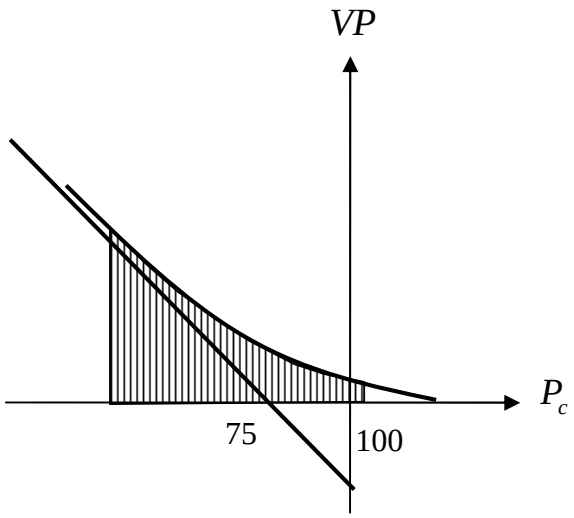
where VC and VP represent call value and put value respectively.

[16] Dickson recounts that, at the moment of the coupon-rate reduction negotiated in 1732, some investors refused the package proposed by the East India Company and were allowed to keep a coupon rated at 3.5%. The Company then decided to repay these bonds as they matured in order gradually to eliminate them. "The General Court seems to have decided to convert £425,000 bonds to 3% and the rest to 3.5%. […] Over the next five years the bonds were being steadily paid off. In December 1736, when it was decided they should carry only 3% interest from Lady Day 1737, less than £250,000 were outstanding" (Dickson, 1967, p. 412).

3.3. Price of Consols and price of India bonds with put option

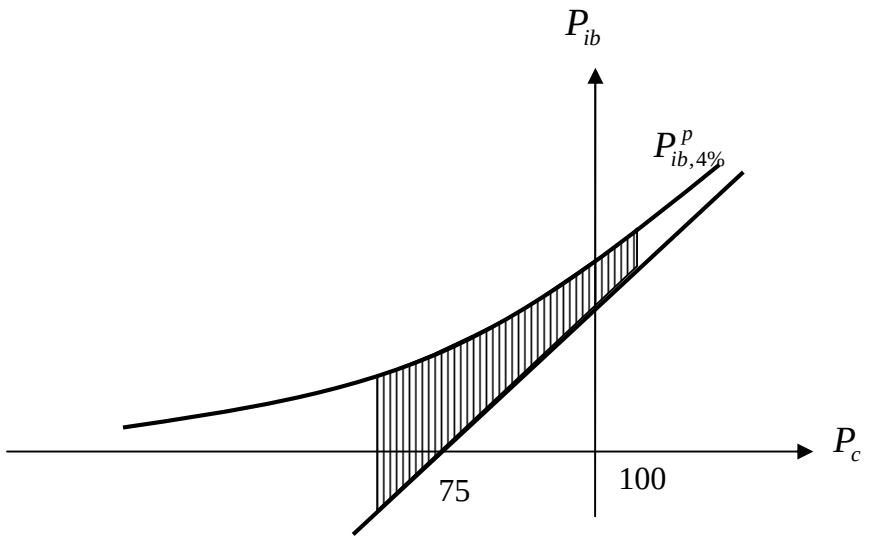
The put option enabled investors to exchange their India bonds for cash at nominal value. The price could never then drop below that value (100£ here). All else being equal, investors will always be prepared to pay more for an India bond than for a Consol, since they buy the option along with the bond. Naturally, the lower the Consol price, the more the option is attractive and the wider is the spread between P_{ib}^{p} and P_c. But the more the Consol price rises above the nominal value, the less valuable is the option and the smaller is the spread between the two prices. The vertical lines in figure 2 represents the value of the put option for different Consol prices. This remains true for every India bond coupon rate.

Figure 2: Value of a put option on a 4% India bond in relation to Consol price



The value of the put option adds to the optionless India bond price, since it benefits investors. On figure 3, it reads as the vertical distance between the curve $P_{ib,3\%}^{p}$ and the downward sloping 45^{o} line representing $P_c = P_{ib,3\%}$ (see vertical lines).

Figure 3: Price of 4% India bond with put option in relation to Consol price



3.4. Consol price and price of 4% India bonds with call option

The call option gave the East India Company the right to buy back its bonds at nominal value, after giving six months' notice. Obviously, the option was of interest to the Company only when the Consol price rose, i.e. when the yield on the possible alternative asset which investors could buy declined. The higher the Consol price rose, the more likely would it be that the Company would exercise its option and the more the cost to investors would grow (loss between market and nominal value if the investor chose to accept the repayment, or fall in the India bond price related to the reduction in coupon rate if he decided to keep the bond and accept the new rate).

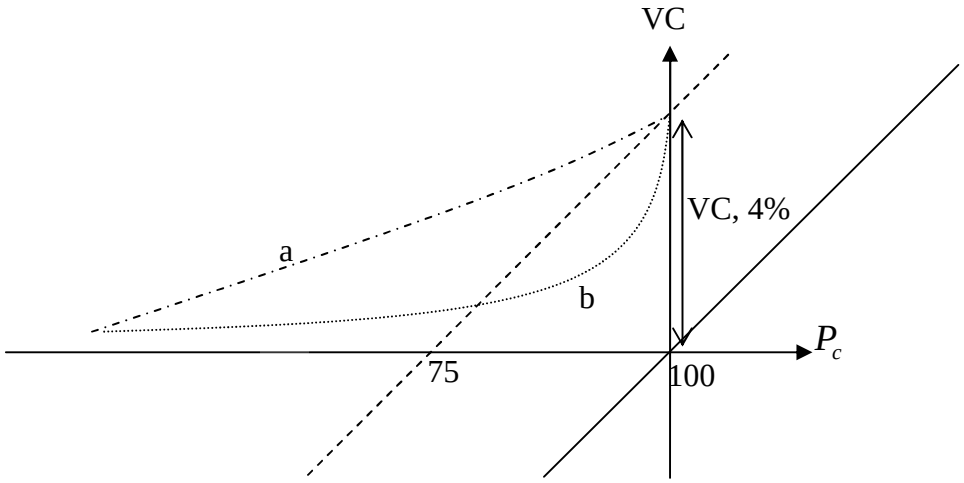
Figure 4 below illustrates the value of the 4% India bond call option in relation to the Consol price. When the Consol price dips significantly below 100, the Company has no reason to convert its bonds and the option price tends towards zero. Supposing the option is exercised systematically when the Consol price reaches 100,[17] the option's value grows along with P_c and, at the point $P_c = 100$, its value is such that an investor would not care whether

[17] There is no way of analytically determining the price at which the option will be exercised. The price depends on the value of the option, which in turn depends on the price at which it is exercised. Empirical observation shows, however, that the conversion is performed whenever $P_c \approx 100$.

he held a 4% India bond with put and call options or a 3% India bond with a put option only. Supposing that the put value approaches zero when $P_c = 100$, we obtain:

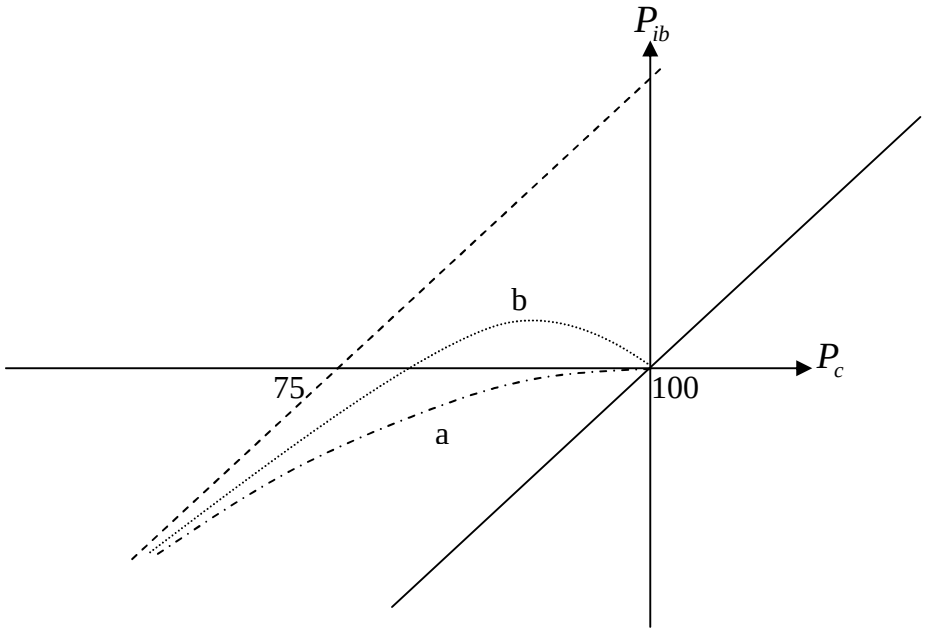
(6) $$P^{c,p}_{ib,4\%}(100) - VC_{4\%}(100) = P^{p}_{ib,3\%}(100)$$

Figure 4: Value of 4% India bond call option in relation to Consol price for the EIC



The shape of the curve will depend on agents' expectations. If they consider it very likely that the Consol price will increase and the option will be exercised, the call option's value will rise linearly with the Consol price (curve a in figure 4), and the price of the India bond will also rise smoothly, as shown by the curve a in figure 5. If, on the other hand, they believe that there is not much likelihood of the Consol price rising to the point where the call option would be exercised, they will attach little worth to the call option up to P_c values approaching 100. In this case, the call value will be rather flat for values of P_c below 100, and will rise, but much more steeply, from P_c values close to 100 (curve b in figure 4). This implies a humpbacked shape to the price of the India bond: while the agents do not anticipate the conversion, the price rises above par, and when they start expecting a conversion, the price of the India bond falls back to the par value (see b curve in figure 5).

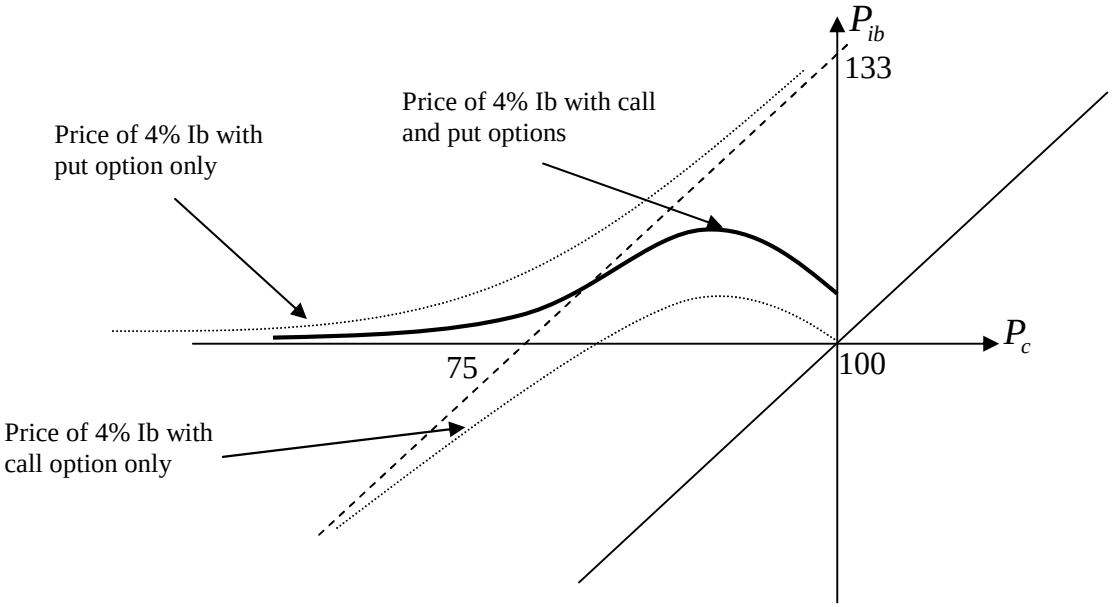
Figure 5: Price of a 4% India bond with call option in relation to Consol price



The 4% India bond carries both a call option (described above) and a put option, discussed in the previous Part. To obtain a graph with the curve $P^{c,p}_{ib,4\%}$, we must therefore subtract the call option value (Figure 4) from the curve $P^{p}_{ib,4\%}$ (Figure 3). Figure 6 below shows the curve: $P^{c,p}_{ib,4\%}(P_{c,3\%}) = P_{ib,4\%} + VP_{4\%}(P_{c,3\%}) - VC_{4\%}(P_{c,3\%})$.[18] The 4% India bond with put and call options crosses the vertical axis above 100, as at this point, investors should be indifferent between holding a 4% India bond with put and call options, or holding a 3% India bond with a put option only, which crosses the vertical axis above 100 as shown in figure 7.

[18] The exact shape of the "hump" will depend on the perceived likelihood of conversion.

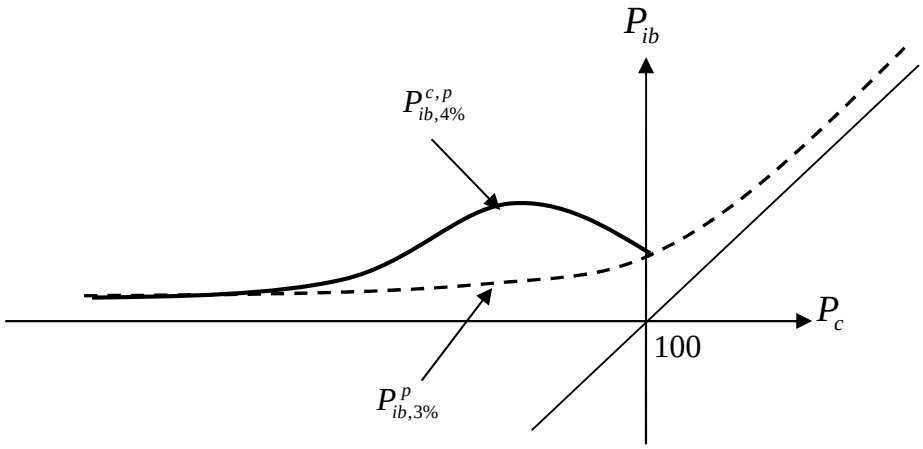
Figure 6: Price of 4% India bond with call and/or put options in relation to Consol price.



3.5. Price of India bonds with different coupon rates in relation to Consol price

Figure 7 below shows the price of 3% India bonds with a put option only and the price of 4% India bonds with both put and call options. Providing contemporary investors understood these kinds of options well and markets were efficient, observations for 4% India bonds should have a non-linear camel-hump shape and no observations of these securities should exist for Consol prices higher than 100, since the East India Company would have converted them into 3% India bonds beforehand. In the case of 3% India bonds, which we have supposed to be devoid of a call option, observations should have two asymptotes: the diagonal $P_{c,3\%} = P_{ib,3\%}$ when $P_{c,3\%} > 100$, and the axis of abscissas when $P_{c,3\%} < 100$.

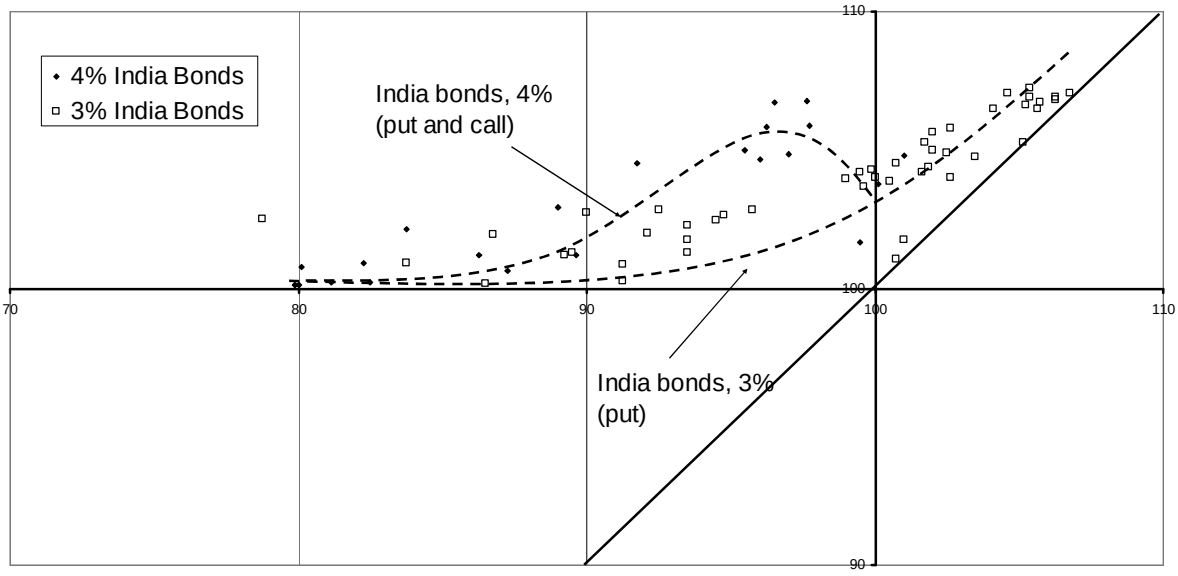
Figure 7: Expected $P^{p}_{ib,3\%}$ and $P^{c,p}_{ib,4\%}$ in relation to $P_{c,3\%}$



4. Course of India bond and Consol prices, 1727-1763

The best way of finding out whether contemporary investors knew how to valuate the options embedded in India bonds would be to test a mathematical relation between Consol price and India bond price. We have seen that this is unfortunately not possible. The question can, however, be answered graphically, by seeing whether the India bond price matches the shapes displayed above. The fact that the expected shapes are non-linear and differ according to coupon rate makes the method all the more reliable.

Diagram 4: Observed India bond prices in relation to Consol prices (£)



Source: The Course of the Exchange, Lloyd's List

Diagram 4 above displays the prices of 3% and 4% India bonds in relation to Consol prices from 1727 to 1763, and the discontinuous lines represent the theoretical shape predicted by our model.[19] All the expected results are there: the 4% India bonds have their non-linear camel-back shape and the 3% India bonds have their two asymptotes; their price never drops below their nominal value and is always higher than the Consol price. Thus it would seem that the 18th century investors understood the options embedded in India bonds and were capable of valuating them correctly. The empirical hump shape of the 4% India bonds is a sign that agents estimated the likelihood of conversion into 3% bonds as small. This is consistent with Dickson's remarks (1967) when he notes that, while the first coupon rate reductions from 6% to 5% did not encounter any resistance, the 1733 cut from 4% to 3% met with strong criticism from investors.[20] It is moreover possible to study the dynamics behind coupon rate changes and find that the actual changes took place at the times predicted by theoretical analysis. This gives strength to the claim that investors were quite capable of arbitraging between India bonds and Consols.[21]

5. What was the purpose of using these securities?

As we have just shown, back in the early 18th century a financial instrument, the India bond, was equipped with sophisticated features that foreshadowed what we now term call and put options. Even in our day, as we have seen, there is no stock formula for calculating these options' value and, with it, the India bond price. Despite that, we have noted that investors at the time were fully aware of how they worked, since they were capable of determining their price in relation to that of the Consols.

While it may seem surprising to see such a complex instrument being used on such a wide scale so soon after the emergence of the London financial market, it is logical to wonder why and how it came into being. Why did the East India Company not simply issue option-

[19] We restrict our empirical analysis to the 1727-1763 period, as there are no 3% government bond quotations prior to 1727.

[20] "Early reductions in interest rates seem to have been negotiated in a very gentlemanly style. […] In June 1705 the Committee of Treasury was ordered to pay the bonds due at Michaelmas or to continue them to the following Michaelmas at 5%. Similarly, the South Sea Company laconically noted in November 1714 that the 6% bonds due on 31 December would be continuable at 5% apparently without encountering opposition. As security yields moved towards 3%, however, resistance to further reductions of bond interest understandably grew". *(Dickson, 1967, pp. 410-411).*

[21] See Annex 4 for more details on coupon rate change dynamics.

less debentures? In this Part, we investigate different hypotheses regarding the bonds' inception and discuss each one's validity.

5.1. Reputation and cost of capital

We have not found a contemporary security identical to callable/putable India bonds. An analogous instrument does exist, however, although it does not provide dividends and it comes with a conversion (into shares) option. This is the LYON (Liquid Yield Option Note), a coupon-less, convertible, callable and putable security created by Merrill Lynch White Weld Capital Markets Group in 1985. This type of security is popular with little-known or poorly-rated corporations, as it enables them to obtain loans at rates much lower than would be possible if they issued their own securities without these options. Indeed, investors are guaranteed a minimum return since they can exercise a put (generally, the put price rises with the passing of time, thereby inducing investors to hold on to their securities longer). What is more, they can, if the business becomes profitable, exercise the conversion option and become eligible for dividends in their new capacity as shareholders. Lastly, the corporation reserves the right to buy back its bonds at a predetermined price (which also generally varies in time), in order to issue at lower rates once its reputation has been established.[22]

It is hardly likely, however, that the East India Company was obliged to incorporate these options into its debt securities because of a lack of credibility and in order to obtain good rates on the market. Indeed, we have shown that the Company, whose first charter dates back to 1600, was highly renowned and on very close terms with the government. This made it as secure for investors as the government itself (see Diagram 3, the long-term yields on India Annuities from 1751 on). So, while it may be said that the features of India bonds were similar to those of securities in use today, the reasons for incorporating the options were certainly not the same.

5.2. Liquidity and stability

Diagram 2 shows that the India bond price fluctuates in a much narrower band than the Consol price. This again is a foreseeable consequence of the call and put options. In this

[22] For more information on LYONs and the different mathematical techniques for calculating their price, see, for example, McConnell and Schwartz (1986).

section, we briefly perform a graphical analysis of the expected effects of the options on volatility, and then compare these with observations.

If India bonds did not have options, we should find (see earlier) $P_{c,3\%} = P_{ib,3\%}$. Therefore, if we make a graph of variations in India bond prices in relation to variations in Consol prices, we obtain a 45° diagonal. But given the existence of the call option, the India bond price will never grow as much as the Consol price, since the higher ΔP_c goes, the greater the likelihood becomes of conversion to a lower coupon rate. For a $\Delta P_c > 0$, we therefore expect a widening positive spread between the diagonal and the curve on $\Delta P_{ib}^{c,p}$. Not only that, but the put option will prevent the India bond price from falling below its nominal value. All else being equal, for a growing $\Delta P_c < 0$, the $\Delta P_{ib}^{c,p}$ should not stray far from the horizontal axis. Since invariably $\Delta P_{ib}^{c,p} < \Delta P_c$, the curve should be flatter than the diagonal, as we observe from the dotted line in the Figure 8.

Figure 8: Theoretical variation of India bond price in relation to variation of Consol price

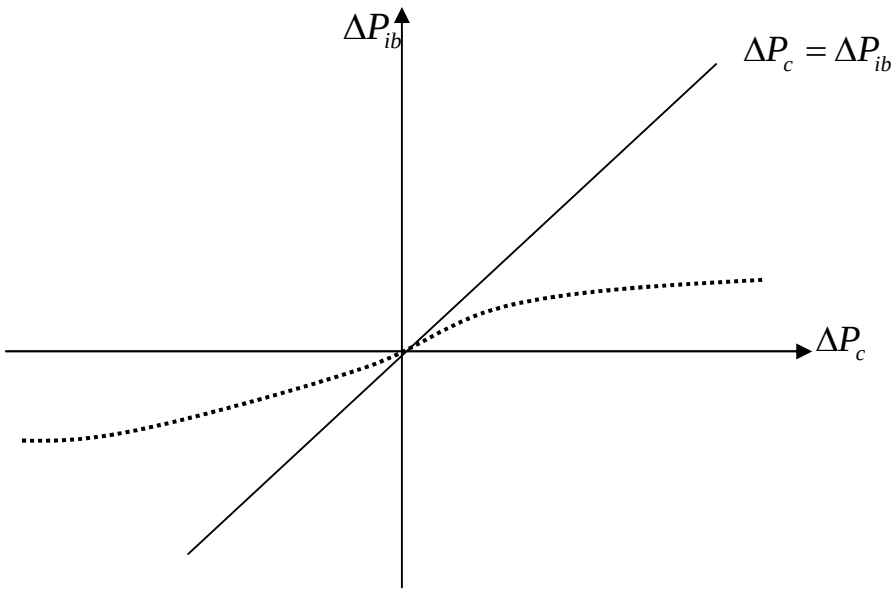
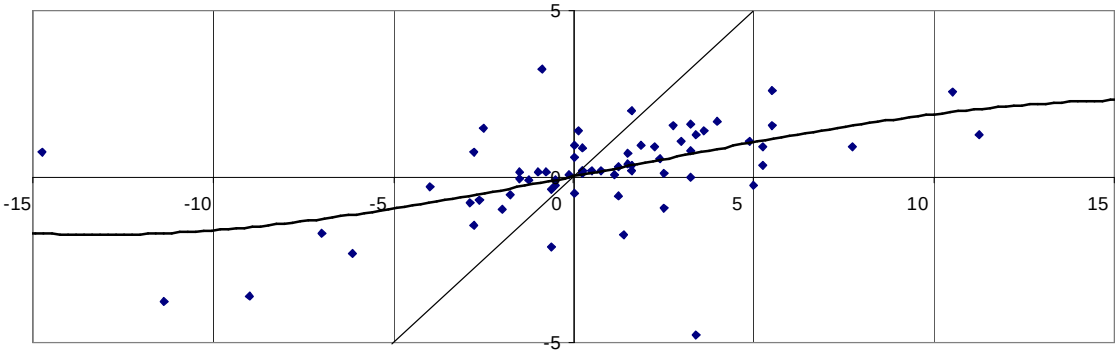


Diagram 5 which follows shows the variations in India bond prices in relation to variations in Consol prices from 1727 to 1763. Here again, we observe a shape consistent with predictions.

Diagram 5: Variation of India bond price in relation to variation in Consol price (1727-1763)



Source: The Course of the Exchange, Lloyd's List

India bonds were thus a very liquid and stable-priced product. They were roughly the equivalent of a modern sight deposit and this goes far to explain their success. We have already quoted Massie (1750, p. 26), who thought that "they may be esteemed ready Cash running at Interest". We might also quote a 1761 trading manual which states: "India bonds are the most convenient and profitable security any person can be possessed of, who has any quantity of cash unemployed, but which he knows not how soon he may have occasion for; the utility and advantage of these bonds is so well known to the Merchants, and Traders of the city of London, that it is wholly unnecessary to enlarge upon it." (Mortimer, 1761, pp. 147-148).

For all this, can it be inferred that they were created in answer to a market demand? Can we really believe that the East India Company, in the early 18th century, understood the market's need for a stable and liquid instrument, knew how to create it and, above all, was prepared to supply it? It is unlikely.[23]

5.3. Effect of regulation

The last of the hypotheses which we examine, and which seems to us the most plausible, is that the features described came into existence, little by little and more or less by chance, as the unforeseen consequence of a Parliamentary regulation.

[23] The put option implied a definite cost to the Company, since it was obliged to increase the coupon rate when the Consol price fell. This increased its debt service at the very time when England was experiencing difficulties (wars, in particular) and, in consequence, when the Company was finding it more difficult to place its products and therefore service its debts.

We claim that even though India bonds were nominally short-term securities, they were viewed as being very secure and liquid and that their holders were keen to buy them up again after redemption.[24] Therefore, gradually and with the investors' blessing, they were kept in circulation beyond the maturity date, with the coupon continuing to be paid twice a year, just as though they were long-term securities.[25] It is more than likely that the East India Company would have preferred to exchange them against long-term bonds – which it in effect hastened to do in 1751 as soon as Parliament authorised it (see annex 2). Until then, Parliament had forbidden the East India Company to issue long-term bonds in competition with the government's or shorter term notes in competition with the Bank of England's. So it was that these securities remained nominally short-term while circulating as long-term. The Company, and the investors, could thus buy (sell) back the securities at their nominal value once the putative maturity date arrived. It was this possibility which is equivalent to put and call options.

India bonds were not in an explicit sense long-term securities incorporating a put option and a call option; they were nominally short-term securities which, as they were kept in circulation after their maturity date, had characteristics equivalent to those of a security carrying a put and a call. This is why we think that their creation was unplanned, that it was rather an unwitting consequence of Parliament's failure to allow the East India Company to issue long-term debt instruments. It could be said then that the birth of such a modern financial instrument at the beginning of the 18th century was nothing more than the paradoxically beneficial effect of Parliamentary economic regulation.

[24] Dickson, speaking of East India Company and South Sea Company bonds issued to buy long-term government debt, says, "From one point of view this application of the 'fund of credit' meant that the companies were lending long and borrowing short. But in practice neither seems to have had any difficulty in renewing their bonds when due, and what was in form short-term borrowing thus became equivalent in practice to long-term debenture finance." (Dickson, 1967, p. 409).

[25] Unfortunately, Dickson (1967, p. 408) states that "no India bonds have been traced" for the period he analyses (1688-1756). The earliest India bond we have found is an India bond for 1812 (see annex 3). There is no more mention to a maturity date. Instead, there is explicit mention of the two conversion features which are equivalent to modern put and call options.

Conclusion

India bonds were among the most liquid securities available on the London market during the first half of the 18th century. They are still used by today's scholars to study the evolution of the London financial market. We have shown that, although nominally short-term, they were in practice equivalent to long-term bonds with embedded put and call options. The coupon rate/price formula hitherto applied in the literature cannot therefore be used to valuate their yield, since it does not take into account the options' value. The results produced by it indicate strange behaviour, often wrongly interpreted as lack of market integration or agent irrationality, whereas it is simply a question of misinterpretation of the bonds' properties.

We have designed a method for graphically determining the India bond price in relation to the Consol price and shown that the course of India bond prices and observed coupon rate changes are consistent with it. This proves that contemporary investors had a fine understanding of how India bonds operated. They moreover knew how to set a correct value on these securities despite the fact that their mathematical tools were not as sophisticated as today's – and Black and Scholes had not yet invented their formula for valuating options. We have thereby shown that investors performed sophisticated arbitraging among the different securities as far back as the early 18th century, which proves that the London capital market was efficient and already capable of pricing options. This adds to Neal's (1990) findings which demonstrate that investors were capable of performing international arbitrages among different financial marketplaces. To conclude, we suggest that the appearance of such a complex and modern financial instrument in the early 18th century was the result of Parliamentary economic regulation.

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Annex 1: Construction of the database

All the data used in this paper was obtained from the primary source The Course of the Exchange except for a few dates where this source was not available for which we used the Lloyd's List. The Course of the Exchange is a twice-weekly financial bulletin, which compiled the exchange rates of the main currencies, the prices of the shares of the most important companies in the London Stock Exchange (mainly the Bank of England, East India Company and South Sea Company), as well as the prices of the public and private debentures. It was created in the years 1696-97 by Mr. Castaing, and its publication was continued throughout the 18th century by various editors, before becoming, in the second decade of the 19th century, the Official List of the Stock Exchange.[26]

Government securities[27]

The prices of annuities and lotteries of the government are given in the 3rd section of the bulletin, next to the prices of the shares of the main companies. Before 1726, the government did not issue annuities, but only lotteries[28]. Diagram 1 gives the yields of various issues calculated with the formula coupon/price. From 1726, the government issued annuities, which were perpetual securities with 3% coupon. The Course of the Exchange gives the prices of annuities for the successive issues: 1726, 1731, 1742-1743, 1744-1745. All prices are expressed as a percentage of the nominal value, and there is almost no difference among the issues. From 1746, the Bank of England starts to manage the national debt (substituting to the Exchequer). The new issues are therefore called: Bank Annuities 1746, 1747, 1748, 1749. In 1750, following Pelham's conversion, all these various securities are consolidated into a unique bond at 3% coupon. Initially, it appeared in the Course of the Exchange under the name "Bank Annuity 3%", and after 1758, it is called "3% Consols"

For the construction of the series "3% government annuity", we used the prices of the 1726 issue until 1746, then the series 3% Bank Annuity from 1746 to 1758, which became 3% Consols in 1758. The formula used to calculate the yield is the standard formula coupon/price.

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[26] For more information about the Course of the Exchange, see Cusker (1979, 1991) and Mirowski (1981).
[27] See Homer and Sylla (2005) for a summary of the different issues of the English government at the 18th century.
[28] For a description of the use of Lotteries in the financing of the English government, see Dickson (19576, Chap. 3) or Cohen (1953).

India bonds

Quotations of India bonds appear in the 5th section of the bulletin, entitled BONDS. The bulletin mentions first the coupon (3, 4 or 5), then the name of the title (for example: India), and finally, the premium or discount compared to the nominal value, expressed in pounds and shillings. The price is given by adding the nominal value, plus the premium (or less the discount), plus the interests accrued at the date of the sale. The premium indicated in the bulletin is thus net of the accrued interests[29] and the nominal value of an India bond is £100.[30]

India bonds changed coupon regularly. We have considered each different coupon like a different series, by converting premiums given in pounds and shillings into a percentage of the price (base 100). We thus have calculated: Price = 100 + premium (pounds) + premium (shillings)/20.

India Annuities

From 1751, quotations of India annuities appear in the Course of the Exchange. Quotations were expressed as a percentage of the price. As these are long term securities, the yield is obtained applying the standard formula coupon/price.

Data

We have collected the prices corresponding to the first observation of January and June (or of the date nearest if the quotations that day were not available).

England adopted the Gregorian calendar on September 14, 1752. For the period previous to this date, we corrected the dates of the Julian calendar into the Gregorian calendar in order to maintain the homogeneity of the data.

[29] Mortimer (1761) gives an example to calculate the final price of an India bond:
"Sold Sir Friendly Wilson, Apr. 20, 1761.

One India bond (B. 207)	100	0	0
Interest 2 months 17 days	1	1	$3^3/_4$
Premium	2	0	0
	£ 103	1	$3^3/_4$"

[30] "These bonds are usually for £100 each, and the seller receives the interest of the purchaser, up to the day he sells" (Mortimer, 1761).

Annex 2: Volume of India bonds and government securities by East India Company, 1702-1753

date	East India bonds	East India annuities	Loans on government	Interest rate on gvt debt held by EIC	Interest rate paid by EIC on bonds
1702	828 586		2 000 000	8	6
1703	1 171 112		2 000 000	8	6
1704	1 137 563		2 000 000	8	6
1705	701 460		2 000 000	8	6
1706	668 159		2 000 000	8	5
1707	882 633		2 000 000	8	5
1708	882 444		3 200 000	5	5
1709	3 303 157		3 200 000	5	6
1710	3 349 105		3 200 000	5	6
1711	2 920 387		3 200 000	5	6
1712	3 083 599		3 200 000	5	6
1713	2 872 154		3 200 000	5	6
1714	2 727 047		3 200 000	5	6
1715	2 718 881		3 200 000	5	6
1716	2 604 692		3 200 000	5	6
1717	3 059 226		3 200 000	5	5
1718	3 107 671		3 200 000	5	5
1719	2 972 317		3 200 000	5	4
1720	3 020 274		3 200 000	5	4
1721	2 989 484		3 200 000	5	4
1722	3 325 175		3 200 000	5	4
1723	3 425 175		3 200 000	5	4
1724	3 427 536		3 200 000	5	4
1725	3 425 210		3 200 000	5	4
1726	3 424 269		3 200 000	5	5
1727	3 424 291		3 200 000	5	5
1728	3 424 280		3 200 000	5	4
1729	3 399 056		3 200 000	5	4
1730	3 226 889		3 200 000	4	4
1731	3 085 287		3 200 000	4	4
1732	3 074 682		3 200 000	4	4
1733	3 068 148		3 200 000	4	3.5
1734	3 067 661		3 200 000	4	3.5
1735	3 013 154		3 200 000	4	3.5
1736	3 012 954		3 200 000	4	3.5
1737	3 360 553		3 200 000	4	3
1738	3 395 436		3 200 000	4	3
1739	3 442 986		3 200 000	4	3
1740	3 424 865		3 200 000	4	3
1741	3 427 595		3 200 000	4	3
1742	3 429 395		3 200 000	4	3
1743	3 430 845		3 200 000	4	3
1744	3 429 595		4 200 000	4	3
1745	4 130 295		4 200 000	4	3
1746	4 008 465		4 200 000	4	4
1747	4 010 441		4 200 000	4	4

1748	4 120 231		4 200 000	4	4
1749	4 242 456		4 200 000	4	4
1750	2 103 922		4 200 000	3	3
1751	900 000	2 993 440	4 200 000	3	3
1752	1 821 353	2 993 440	4 200 000	3	3
1753	2 000 000	2 993 440	4 200 000	3	3

Sources: Dickson (1967), Carey (1821)

Annex 3: Evolution of the India bond

Unfortunately, we don't have the exact wording of an India bond during the period 1718-1763. As Dickson says:

> "No East India bonds have been traced, buty they were presumably in the same form as South Sea bonds, whose wording was decided by the Court of Directors on 12 June 1713 as follows.
>
> No… For £…
> The Governor and Company of Merchants of Great Britain Trading to the South Seas and other Parts of America and for encouraging the Fishery Do hereby oblige themselves and their Successors to pay unto A.B. or his Assigns (by indorsement hereon) ... pounds with Interest after the rate of Six p. cent p. ann. On the … day of … one thousand seven hundred and … For the true payment wereof they bind themselves and their Successors in the penal Sum of …
> London, the … day of … On thousand Seven hundred and …" (Dickson, 1967, p. 108-109)

If Dickson is right and this is the wording of an India bond, then there is no legal statement of the special features of this bond. Still, in practice, the bonds are kept in circulation after maturity date, and as Massie (1750, pp. 25-26) notes, they are payable by the Company at six months notice and receivable as cash in payment for goods bought at their sales.

It is interesting to note that by 1812, the wording of the India bonds has changed : there is no more mention of a maturity date, but instead, it specifies that the bond is payable on six months notice by the Company, or on six months notice to be given by the holder of the bond. This is therefore officially equivalent to a perpetuity with a put and a call option, which we claim has always been the way the India bonds worked in practice.

Form of an East India Bond for 500 £[31]

No. (K) 115 **£500**

THE UNITED COMPANY OF MERCHANTS OF ENGLAND trading to the EAST INDIES, do acknowledge to have received of *John William Smith*, Five Hundred Pounds, which the said Company promise to repay to the said *John William Smith*, his Executors, Administrators, or Assigns (by indorsement hereon), with Interest for the same from the Thirty-first day of March last, after the rate of Five Pounds for One Hundred Pounds for a Year, at the East India House in LEADENHALL STREET, LONDON, on Six Month's notice to be given by the Company in the London Gazette, or on Six Month's notice to be given by the said *John William Smith*, his Executors, Administrators, or Assigns, to the Company's Accomptant, in Writing, at the EAST INDIA HOUSE aforesaid; for the true payment whereof, in manner aforesaid, the said Company do hereby bind themselves and their Successors, in the penal Sum of One Thousand Pounds.——IN WITNESS whereof the said Company have caused their common Seal to be hereunto affixed, this tenth day of August, 1812.

No. (K) 115

Signed by Order of the COURT OF DIRECTORS of the said COMPANY. L. S. ( )

Chas. Cartwright.

Geo. Paterson.

[31] Tate, 1819, p. 370

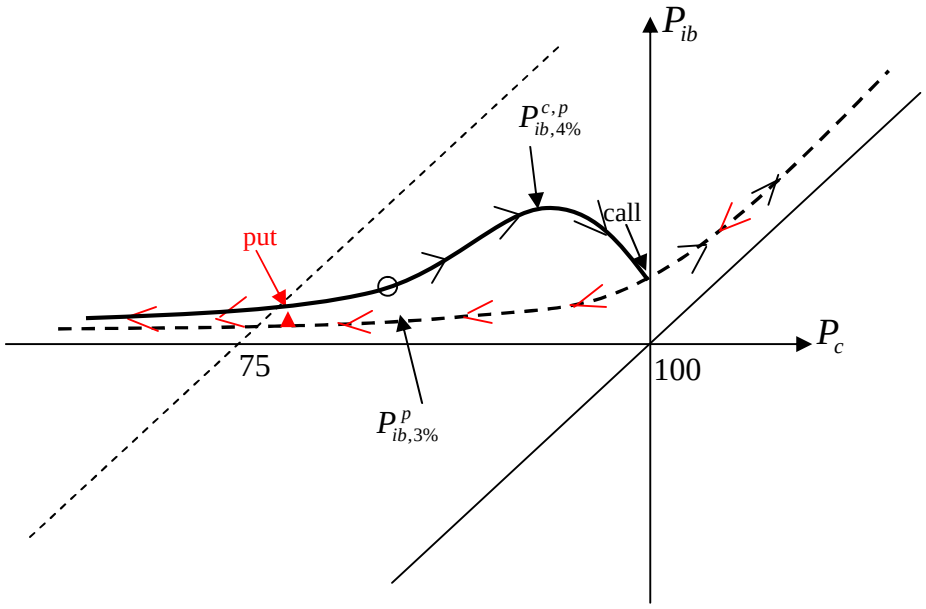
Annex 4: Dynamic of the changes of coupons

Theoretical dynamic

Let us describe the dynamics of the changes of coupons here (figure 9). Suppose that we start with a 4% India bond, and that the price of Consols is rising from an initial value of 85. Initially, the price of the 4% India bond will increase, but as P_c approaches its nominal value, the probability of an India bond conversion to a lower coupon increases. From a certain P_c, the value of the call will be more important than the value of put, and the price of India bond will decrease. When the price of the Consol reaches the par value, conversion is carried out. The price of the India bond will thus continue to increase along the curve $P^p_{ib,3\%}$.

If now the price of Consols starts to decrease, the East India Company will maintain the coupon of 3% as long as the investors do not exercise their put option, that is, as long as $P^p_{ib,3\%} > 100$. If P_c decreases enough, the East India Company will be forced to raise the coupon to 4%, in order to avoid losing its investors. Once this change of coupon is carried out, if the price of Consols rises again, we are back in the initial case; on the other hand, if it continues to decrease, there will come a moment when the East India Company will be forced to increase its coupon to 5%. The price of 5% India bond will have the same shape compared to the price of Consol as the 4% India bond, but shifted towards the left.

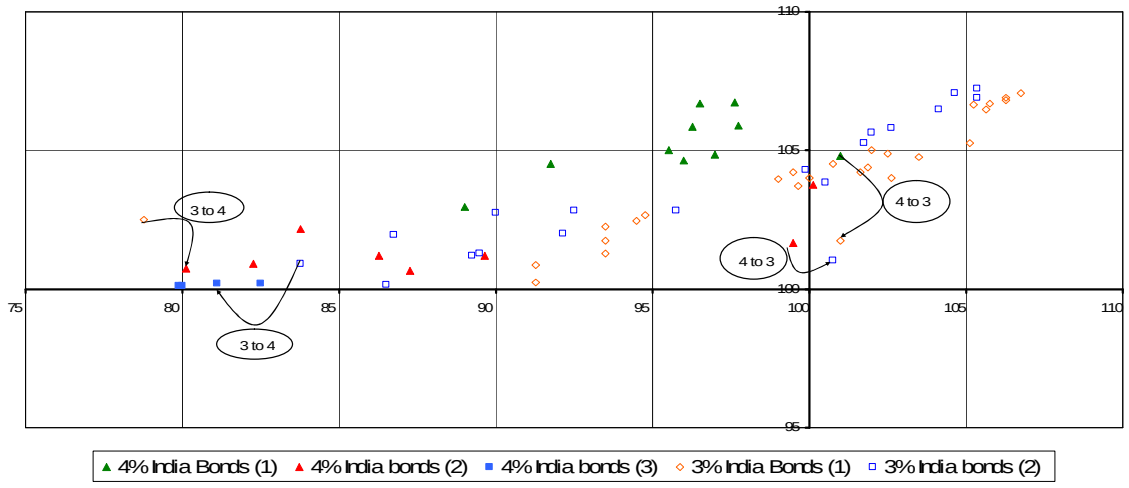
Figure 9: theoretical dynamic of the changes of coupons



Observed dynamic

Is this dynamic consistent with the observations? Diagram 6 below represents the price of India bonds of various coupons compared to the price of Consols, and indicates the points of re-entry and exit of the series as well as the different changes of coupons. The coupons change in the expected places, and the effective dynamic is consistent with the theory. This confirms our assumption that the investors new how to price titles with put and call embedded options.

Diagram 6: Dynamic of the prices of 3% and 4% India bonds in relation to the price of Consols



Source: The Course of the Exchange, Lloyd's List