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East India bonds, 1718–1763: early exotic derivatives and London market efficiency

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Were eighteenth-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 article, we demonstrate that these London capital market inefficiencies suggested by previous scholars arise 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 that the London domestic market was perfectly integrated and that investors were capable of handling and pricing sophisticated options.

1. Introduction

Was the eighteenth-century London financial market integrated? As Neal (1990) points out, the integration of modern capital markets is not something new, since it existed already in the mid eighteenth 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), 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 contradiction arises from the miscalculation by the cited authors of the yields of the India bonds,

which they used in their analysis. These yields then show an erratic relation to the yields of other securities, which is interpreted by these scholars as an inefficiency in the market.

In this article, we explain the peculiarities of India bonds. 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. Contemporary authors such as De la Vega (1688) and Pinto (1771) have described the existence of options in the eighteenth century, but very few authors have studied them quantitatively.¹ We develop a graphical analysis of the influence of the call and put options on India bonds' prices and show that investors were perfectly at home with the bonds' embedded options, and knew how to price them correctly, long before the birth of modern financial mathematics. Our analysis also proves that the London domestic market was integrated, as investors were capable of performing arbitrage operations among different securities on the home market. This supplements Neal's (1990) conclusions about international market integration.

Previous authors using India bonds have not taken these options into account, despite the strong influence the options had on the bonds' prices, 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 eighteenth-century English capital market, as their mispricing leads to wrong conclusions and as they constitute an innovation which was a crucial contribution to the financial revolution. Indeed, we show that the call and put options reduced the volatility of India bonds' returns thereby providing the market with a financial instrument which allowed investors to profit from rising markets, while being protected from losses when markets declined. They were therefore precursors of modern hedging instruments.

In Section 2, we define the behaviour of India bond and Consol yields and prices, which suggests a seeming segmentation of the London domestic markets, and we describe India bonds' particular features. In Section 3, we perform a graphic analysis of the influence of these features on India bond prices. In Section 4, we check that the observed prices and changes of coupons effectively correspond with our graphic analysis, which proves that investors were capable of pricing India bonds correctly. In the last section, we outline how these India bonds' features made them early hedging instruments, and study the reasons why these were incorporated into the

¹ See, for example, Shea (2004) for a study the value and volatility of South Sea share options during the South Sea Bubble.

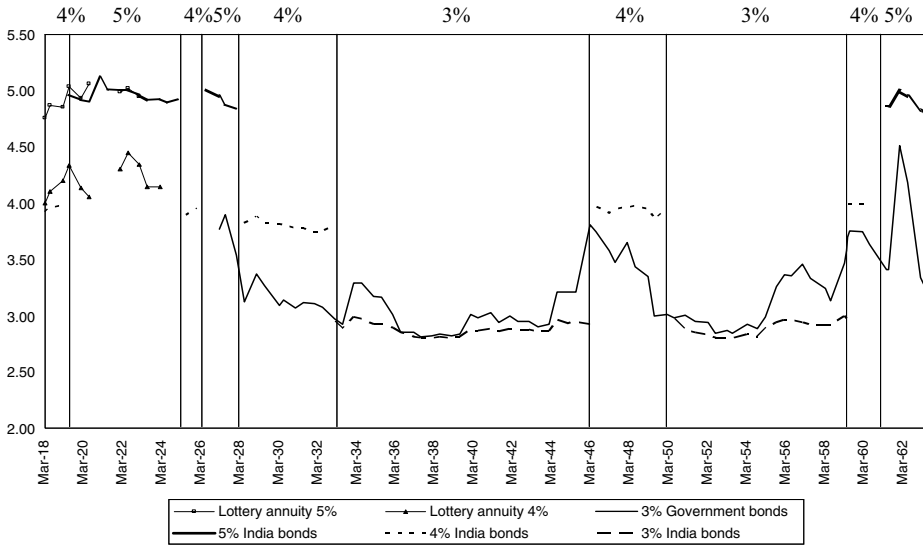


Figure 1. *Dickson’s yields on India bonds and Consols, 1718–63 (%)*

Sources: *The Course of the Exchange* and *Lloyd’s List*.

India bonds. We suggest that the creation of a sophisticated security with embedded options was a financial innovation resulting from a parliamentary regulation prohibiting the East India Company from issuing long-term bonds and not, as is often believed, from market deregulation.

2. India bonds, embedded options and market efficiency

In exchange for long-term loans, the government allowed the East India Company to issue short-term debentures, the India bonds, with coupons ranging from 3 to 6 per cent depending on the period.² Using the quotations from *The Course of the Exchange* and applying the simple formula coupon/price, Dickson (1967, p. 471) draws a graph showing the India bond yields and the yields of 3 per cent government bonds from 1688 to 1756. Figure 1 reproduces Dickson’s yields for the period 1718–63. Figure 2 shows the behaviour of prices of the same securities.

These two graphs show three features. First, changes in the coupon of the India bonds were very frequent.³ Second, the yield of the India bonds jumps

² See Appendix 1 for the volumes of India bonds issued, the loans to the government from 1702 to 1753 and the changes in coupons. See Appendix 2 for the construction of the database.

³ Besides, there are almost never two issues with different coupons at the same time, except during two short periods in 1718 and from 1733 to 1737, which we do not show on the graph.

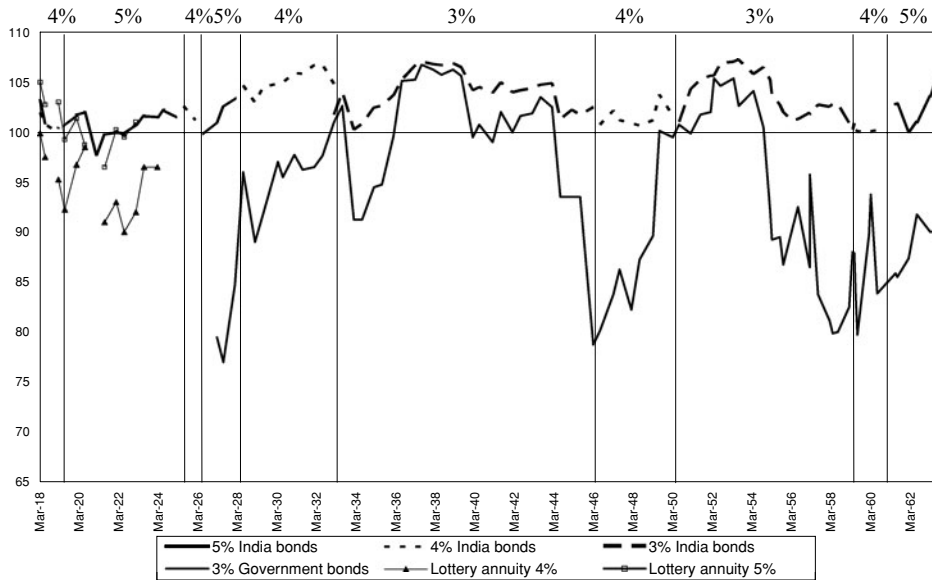


Figure 2. Trends in India bond and Consol prices, 1718–63 (nominal value = £100)

Sources: *The Course of the Exchange* and *Lloyd's List*.

at each change of coupon, whereas their price is smooth, when according to the arbitrage theory, the prices should jump and the yields should be smoothed out, since the borrower and hence the risk are the same. The behaviour of yields and prices thus seems to be reversed. Third, there seems to be a relationship between Consol prices and the changes of coupon of the India bonds, as 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.⁴

Commenting on his graph, Dickson explains the lack of arbitraging between India bonds and government bonds during the period 1688–1756 by stating that the London domestic market was 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. 472–3). He also remarks that the yield on India bonds was extremely dependent on the coupon rate, and that it hopped between different values when coupon rate changes occurred: ‘The yield on East India bonds was highly dependent on their nominal rate: thus the yield fell

⁴ ‘The second conclusion from the chart is that rates of interest in the private sector tended to follow the same trend as yields on government stock. This was true for instance of the East India stock and East India bonds’ (Dickson 1967, p. 472).

abruptly in 1728, and again in 1737, when the nominal rate was reduced respectively to 4% and 3%’ (Dickson 1967, pp. 472–3).

India bonds are important in many respects, and are still used today by scholars to study eighteenth-century London market efficiency. Mirowski and Weiller (1990) use them as a proxy for government short-term debt, and work out yields using the coupon/price formula. They obtain a graph similar to Figure 1 and test the influence of rational expectations on the term structure of interest rates. They apply two different estimation techniques and reject the hypothesis of market efficiency. Dale (2004) and Dale, Johnson and Tang (2005) compare the price volatility of the South Sea subscription shares during the bubble of the summer 1720 to the that of the 5 per cent India bonds. They conclude that the London capital market displayed irrational behaviour.⁵

However, these studies are undermined by a misunderstanding of the financial nature of India bonds. Indeed, a careful analysis of the characteristics of India bonds using contemporary sources reveals that although the India bonds were nominally short-term debts, they were in practice rolled over and thus became equivalent to long-term bonds.⁶ This feature is implicitly understood by recent authors who use India bonds, as they all apply the long-term formula (coupon/price) for calculating the yields.⁷ What is not understood by these authors is the consequence of the roll-over on the bond’s characteristics. Indeed, we claim that as the maturity date was passed, the Company could redeem them at par at any time, and investors could demand to be paid back at par value by the Company at any time. This is equivalent to modern call and put options, and was perfectly understood by contemporary investors, as the trading manuals of the day stated that ‘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’ (Massie 1750, pp. 25–6). 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 We therefore claim that India

⁵ Shea (2004) criticises Dale (2004) and Dale, Johnson and Tang’s (2005) calculations of South Sea subscription shares prices. He argues that a lot of the ‘excess volatility’ can be explained away by considering them essentially as warrants.

⁶ Speaking of East India Company and South Sea Company bonds issued to buy long-term government debt, Dickson 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’ (1967, p. 409).

⁷ Even though some of them, such as Mirowski and Weiller (1990), then use them as proxies of short-term debts.

⁸ Dickson reports the coupon reduction from 4 to 3 per cent in 1733 as follows: ‘The General Court resolved that bondholders should be paid off on 31 March 1733, with 10%

bonds were equivalent to long-term bonds with embedded call and put options.

The call and put options should have several consequences on the price of the India bonds. First, the price should never rise too far above par, as investors would risk losing money if the Company decided to redeem the bonds at par value. Second, the price should never fall below par value as, if it did, investors would cash the bonds at par at the Company instead of selling them on the market. Therefore, when the price of the India bonds falls, the Company must raise the coupon in order to convince investors to hold on to their bonds. Conversely, when the price of the India bonds rises, the Company can save money in interests by lowering the coupon, and the investors would still be interested in keeping the bonds.

We therefore expect to see frequent changes in the coupon rates, very stable prices around par value and no observations below par (as the coupon should be raised before investors cash in their bonds).⁹ This is exactly what we observe in Figure 2. Besides, it is not possible to use the simple formula coupon/price to calculate the yield, as the embedded options must be taken into account. This explains the strange behaviour of the 'yields' in Figure 1, as well as the conclusions of market inefficiency reached by the authors who have used India bond yields computing a wrong formula.

In the next section, we develop a graphical analysis to explain the theoretical behaviour of the price of the long-term callable-puttable India bonds in relation to the price of the Consols. We will then contrast this theoretical behaviour to the observed prices, thereby proving that the London domestic market was perfectly integrated, and that contemporary investors were perfectly aware of the features of the India bonds, and knew how to price them.

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

3.1. Arbitrage between different coupon India bonds

Without options, the arbitrage formula between different coupon bonds of the same issuer is given by:

$$P_{ib,3\%} = \frac{3}{4} P_{ib,4\%} = \frac{3}{5} P_{ib,5\%} \quad (\text{I})$$

premium in lieu of notice, but might instead exchange their 4% bonds for 3% ones from Michaelmas 1732' (1967, p. 412).

⁹ '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).

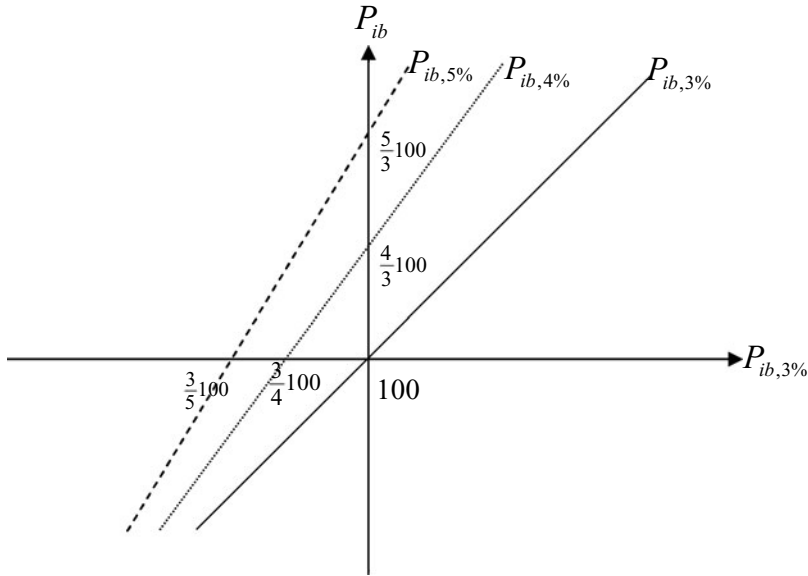


Figure 3. *Arbitrage between different coupon option-less India bonds*

where $P_{ib,3\%}$, $P_{ib,4\%}$, $P_{ib,5\%}$ are the prices of hypothetical India bonds without options at different coupon rates (see Figure 3).

3.2. *Relation between the prices of Consols and option-less India bonds*

The East India Company issued debentures as a counterpart for loans made to the government. These debentures were therefore ‘secured’ by debts due from the government to the Company and the East India Company was monitored by Parliament, which set the volume of debt authorised.¹⁰ Therefore, if it had no embedded options, a long-term debenture issued by the East India Company should be priced as a Consol.

This proposition can actually be tested: from 1750, the East India Company issued a long-term debenture without options, the ‘3 per cent India annuity’.¹¹ The price of these 3 per cent India annuities and of the

¹⁰ ‘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, ch. 16).

¹¹ In 1749, Henry Pelham, First Lord of the Treasury, negotiated with the government’s different creditors (including in particular the East India Company) a consolidation and a reduction of the rates on all government debts. In exchange for the East India Company’s agreement to reduce its rate, Parliament allowed it to issue a long-term debt instrument,

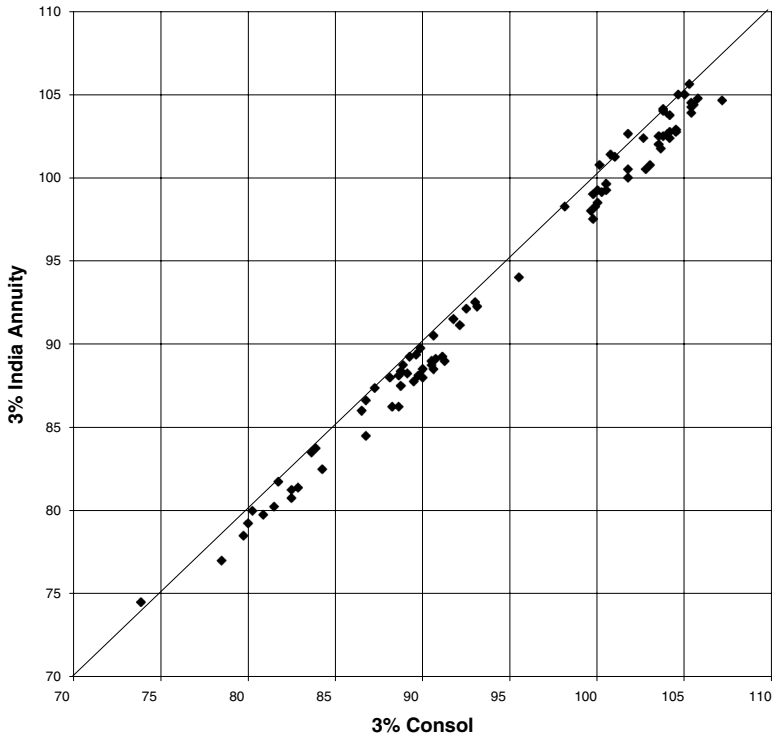


Figure 4. *Prices of 3 per cent India annuities and 3 per cent Consols, 1751–63 (£)*

Sources: *The Course of the Exchange* and *Lloyd's List* (monthly observations).

3 per cent Consols was the same over the period 1751–63, when the two securities coexisted (Figure 4).

Since, 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 1718–63.¹² In other words, if the East India Company had issued long-term bonds without options (India

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 [bonds] had been reduced from its 1749 level of 4.5 million pounds to just over 2 million' (Dickson 1967, p. 414).

¹² For more details on relations between the East India Company and Parliament from 1688 to 1757, see Nichols (1971), Stern (2006) or Sutherland (1949).

annuities) prior to 1750, their prices would have followed the same course as those of government bonds.

3.3. Financial characteristics of India bonds

India bonds were the equivalent of long-term bonds with put and call options. As a call option exercisable by the Company is disadvantageous to investors, it drags down the India bond price. Conversely, the put option is good for investors and so adds to the price. The call and put values depend on the price of an equivalent bond without options (P_{ib}). In the previous section, we have demonstrated that the Consol can be used as a proxy for the option-less long-term India bond (therefore, $P_{ib} = P_c$).¹³ The price of a callable–puttable India bond can therefore be written as:

$$P_{ib}^{c,p}(P_c) = P_c + VP(P_c) - VC(P_c) \quad (2)$$

Where VC and VP represent values of the call and put respectively.

The price of the 4 per cent callable–puttable India bond is given by:

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

The 3 per cent India bond seems, however, to have been in a slightly different class. The government issued annuities at a 3 per cent 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 per cent India bonds and reduced their coupon rate. We therefore assume that the value of the call option on 3 per cent India bonds was zero ($VC_{3\%}(P_{c,3\%}) = 0$).

The 3 per cent (put only) India bond price is written as follows:

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

We further assume that the East India Company could alter its coupon rates by natural numbers 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 per cent. The Company was quick to pay them off, however.¹⁴

¹³ In fact, all government debts also carried a call option, which allowed the government to reduce the interest rate. Still, it was only in 1888 that a conversion took place to reduce the rate from 3 to 2.75 per cent under the National Debt Conversion Act. We can therefore safely suppose that the probability of a conversion and, therefore, the value of the call option on the 3 per cent Consols were zero during the period 1728–61.

¹⁴ 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 3.5 per cent coupon. The Company then decided to repay these bonds as they matured in order to eliminate them gradually. ‘The General Court seems to have

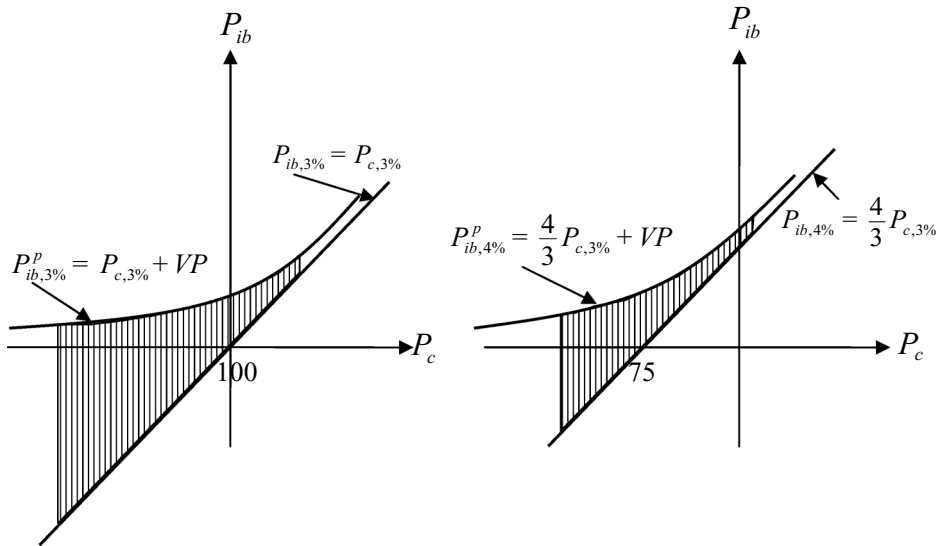


Figure 5. *Price of a 3 and a 4 per cent puttable India bond*

3.4. *Effect of the put option on the price of India bonds*

The put option enabled investors to exchange their India bonds for cash at par 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 with a put option than for a Consol, since they buy the option embedded with the bond. Naturally, the lower the price of the Consol, the more the option is attractive and the wider is the spread between P_{ib}^p and P_c . Conversely, the more the price of the Consol rises above par value, the less valuable is the option and the smaller is the spread between the two prices. The value of the put option adds to the Consol price, since it benefits investors. On Figure 5, it reads as the vertical distance between the curve representing the India bond price with put option and the upward sloping diagonal.

3.5. *Effect of the call option on the price of India bonds*

The call option gave the East India Company the right to buy back its bonds at par 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

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).

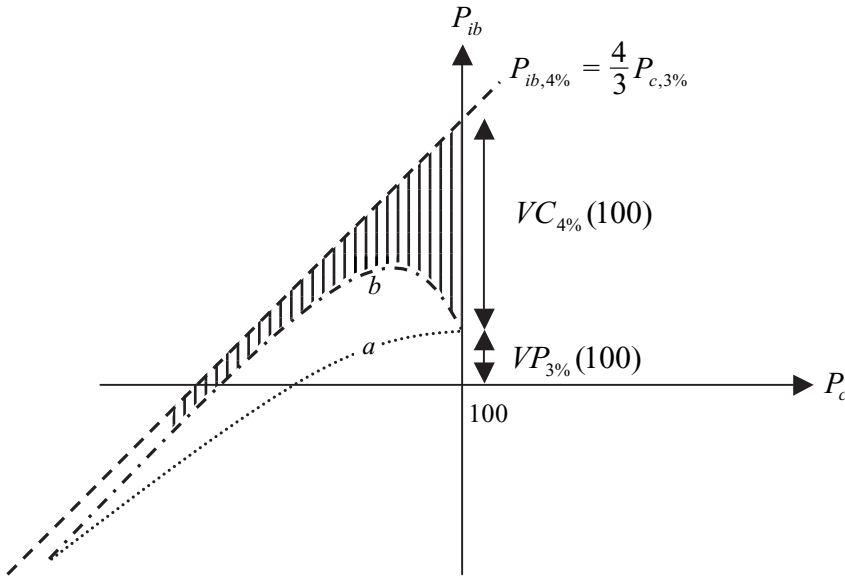


Figure 6. Price of a 4 per cent India bond with call option

on the possible alternative asset which investors could buy declined. The higher the Consol price rose, the greater the probability 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 6 illustrates the value of the call option on a 4 per cent India bond in relation to the Consol price. The value of the call is the vertical distance between the line representing the arbitrage relation between an option-less 4 per cent India bond and a 3 per cent Consol ($P_{ib,4\%} = \frac{4}{3}P_{c,3\%}$), and the curve representing the price of the 4 per cent callable India bond ($P_{ib,4\%}^c$). When the Consol price drops below 100, the Company has no reason to convert its bonds and the option price tends towards zero (the distance between the diagonal and the curve decreases). Supposing the option is exercised systematically when the Consol price reaches 100¹⁵ (i.e. the Company reduces the coupon from 4 to 3 per cent), the option's value grows along with P_c and, at the point $P_c = 100$, its value is such that an

¹⁵ There is no way of analytically determining the Consol price at which the option will be exercised. The price of the India bond depends on the value of the option, which in turn depends on the Consol price at which it is exercised. Empirical observation shows, however, that the conversion is performed whenever $P_c \approx 100$.

investor would be indifferent between holding a 4 per cent callable India bond or a 3 per cent India bond with a put option only.¹⁶ Therefore,

$$P_{ib,4\%}^c(100) = P_{ib,3\%}^p(100) \quad (5)$$

The behaviour of the price of the 4 per cent callable India bond will depend on agents' expectations. If they consider it very likely that the Consol price will increase and the option will be exercised, the value of the call option will rise linearly with the Consol price and the price of the India bond will also rise smoothly, as shown by the curve *a* in Figure 6. If, on the other hand, they believe that there is not much likelihood that the Consol price will increase to the point where the call option would be exercised, investors will attach little worth to the call option up to Consol prices approaching 100. In this case, the value of the call 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 6). 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, following the option-less 4 per cent India bond price (line representing $P_{c,3\%} = \frac{3}{4}P_{ib,4\%}$). Then, when investors start expecting a conversion, the price of the 4 per cent callable India bond falls back to the value of the 3 per cent puttable India bond (see *b* curve in Figure 6).

3.6. *Expected behaviour of the price of India bonds*

The 4 per cent India bond carries both a call option (described above) and a put option, discussed in the previous section. To obtain a graph of the curve $P_{ib,4\%}^{c,p}$, we must therefore subtract the value of the call option (Figure 6) from the curve $P_{ib,4\%}^p$ (Figure 5). Figure 7 below shows the curve: $P_{ib,4\%}^{c,p}(P_{c,3\%}) = \frac{4}{3}P_{c,3\%} + VP_{4\%}(P_{c,3\%}) - VC_{4\%}(P_{c,3\%})$.¹⁷

Figure 8 shows the price of 3 per cent India bonds with a put option only and the price of 4 per cent India bonds with both put and call options. Providing contemporary investors understood these kinds of options well and markets were efficient, observations for 4 per cent 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 per cent India bonds beforehand. In the case of 3 per cent 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 $P_{c,3\%} < 100$. The two curves representing $P_{ib,4\%}^{c,p}$ and $P_{ib,3\%}^p$ should cross for $P_{c,3\%} \approx 100$, as at the moment

¹⁶ In practice, the 4 per cent India bond has a call and a put option, but the value of the put is close to zero when the price of the Consol is close to par. We can therefore ignore it here.

¹⁷ The exact shape of the 'hump' will depend on the perceived likelihood of conversion.

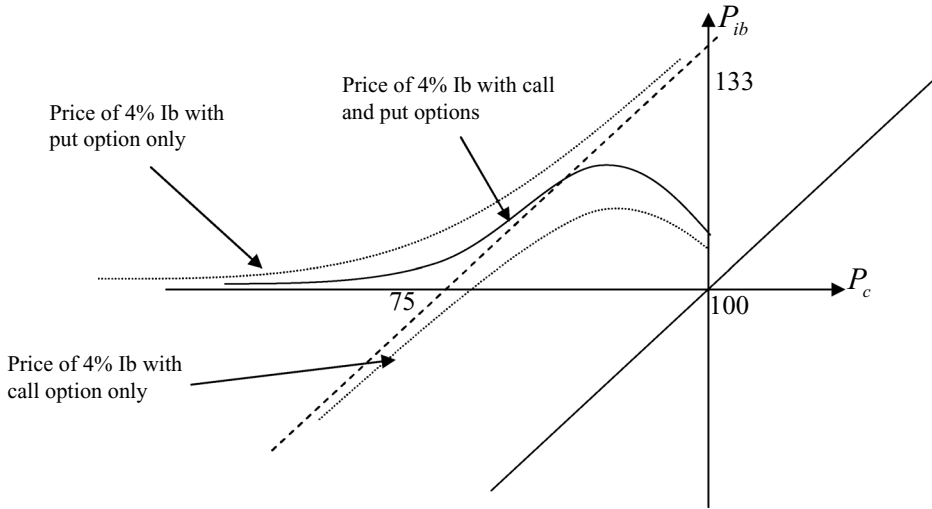


Figure 7. Price of a 4 per cent callable-puttable India bond

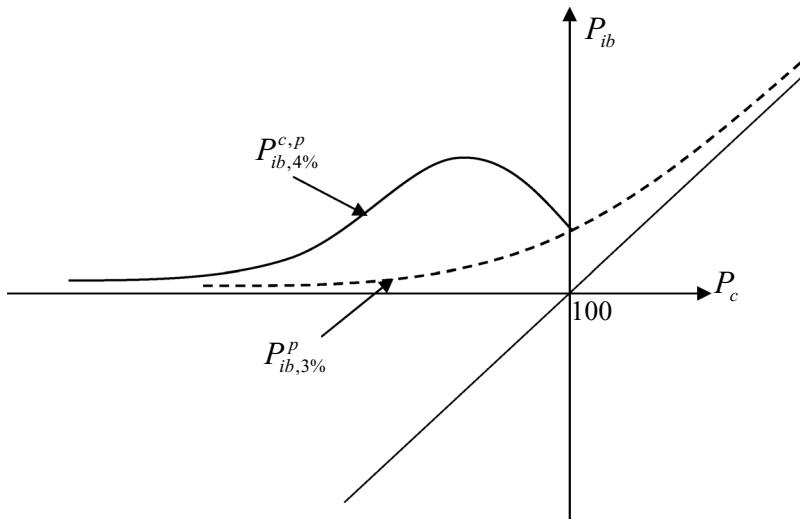


Figure 8. Expected India bond prices in relation to Consol prices

of conversion, investors should be indifferent between holding a 4 per cent callable-puttable India bond or a 3 per cent puttable India bond.

4. London market integration: empirical evidence

4.1. Course of India bond and Consol prices, 1728–1761

In the previous section, we have developed a graphical analysis of the pricing of 3 per cent and 4 per cent India bonds in relation to the Consol prices. If

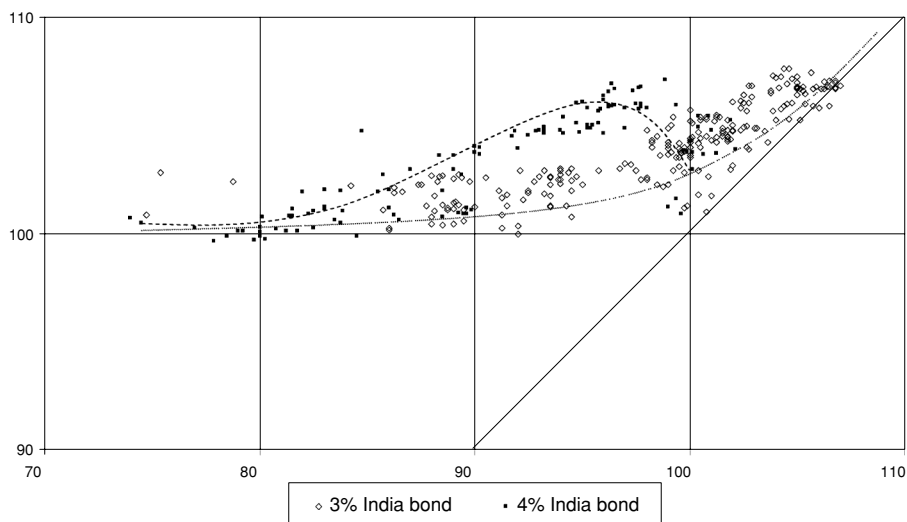


Figure 9. *Observed India bond prices in relation to Consol prices (£)*

Sources: *The Course of the Exchange* and *Lloyd's List* (monthly observations).

the London financial market was integrated, and investors knew how to price bonds with embedded options, the observed prices should match the shapes displayed in Figure 8. The fact that the expected shapes are non-linear and differ according to coupon rate makes the method all the more reliable. We will test this graphical model for the 1728–61 period, as during this period, the coupon of the India bonds alternated between 3 and 4 per cent. The coupon in the previous and following periods was 5 per cent, therefore, not analysed in our model.

Figure 9 displays the prices of 3 per cent and 4 per cent India bonds in relation to Consol prices from 1728 to 1761, and the discontinuous lines represent the theoretical shape predicted by our model. All the expected results are found: the 4 per cent India bonds have a non-linear camel-back shape and the 3 per cent India bonds have two asymptotes; their price never drops below their nominal value and is always higher than the Consol price. This confirms first, that eighteenth-century investors understood the options embedded in India bonds and were capable of valuing them correctly, and second, that the different segments of the London domestic market were integrated.

4.2. *Dynamic of the changes of the India bonds' coupon rate*

We have shown that the behaviour of the prices of the India bonds in relation to the prices of the Consols is coherent with the predictions of the theory. In this section, we show that the changes of coupons also behave according to the theory, which confirms our assumption that the investors knew how to price titles with put and call embedded options. Figure 10 shows the theoretical dynamic of the changes of coupons.

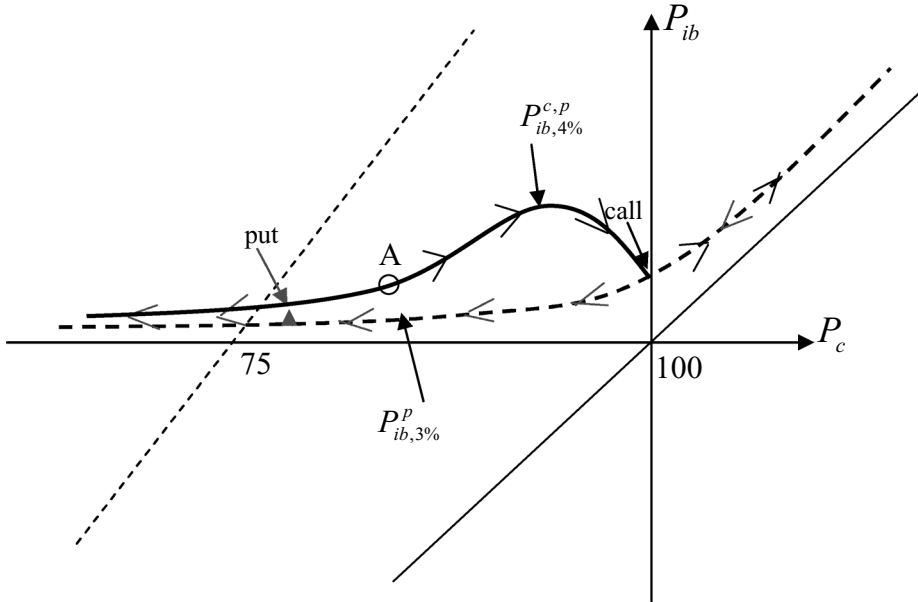


Figure 10. *Theoretical dynamic of the changes of coupons*

Suppose that we start with a 4 per cent India bond, and that the price of Consols is rising from an initial value of 85 (point A). Initially, the price of the 4 per cent India bond will increase, but as P_c approaches its par value, the probability of an India bond conversion to a lower coupon increases. The value of the call will increase until it becomes higher than the value of put, and the price of the India bond will start decreasing. When the price of the Consol reaches the par value, the call is exercised. The price of the India bond will thus continue to increase along the curve $P_{ib,3\%}^p$.

If now the price of Consols starts decreasing, the East India Company will maintain the coupon of 3 per cent as long as the investors do not exercise their put option, that is, as long as $P_{ib,3\%}^p > 100$. If P_c decreases enough, the East India Company will be forced to raise the coupon to 4 per cent, 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 per cent.

There have been four changes of coupons during the period 1728–61. The graphs below (Figures 11–14) show the observed dynamics of the prices for each change of coupon.

During the period from 1728 to 1733 (Figure 11), the price of the Consol rises from about 90 to almost par.¹⁸ The price of the India bonds increases until the price of the Consol reaches 99 (August 1732), and then starts

¹⁸ The monthly prices of Consols and India bonds are available in Excel format at: www.financesinternationales.sciences-po.fr/fr/bases.htm

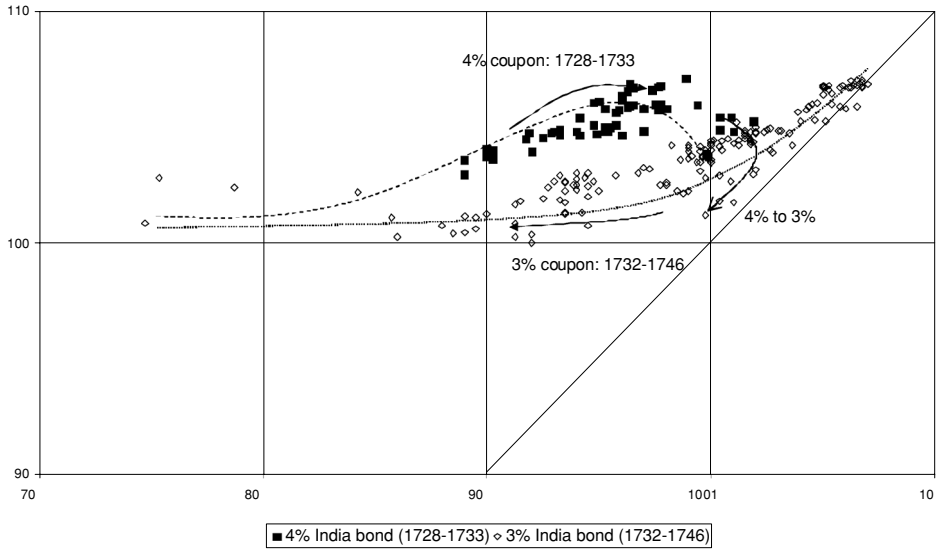


Figure 11. *From 4 per cent to 3 per cent coupon, 1728–46*

Sources: *The Course of the Exchange* and *Lloyd's List* (monthly observations).

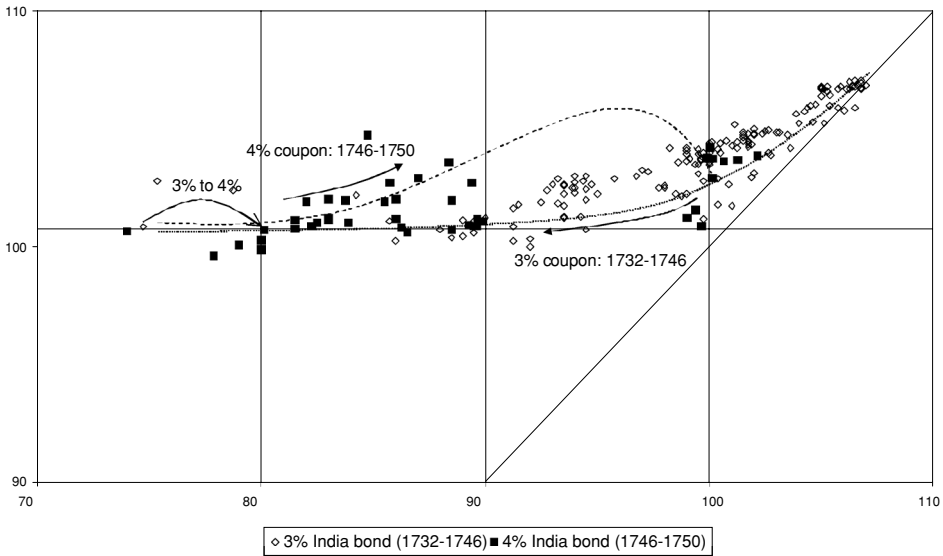


Figure 12. *From 3 per cent to 4 per cent coupon, 1732–50*

Sources: *The Course of the Exchange* and *Lloyd's List* (monthly observations).

declining, as the probability of a conversion to a lower coupon rises. The empirical hump shape of the 4 per cent India bonds is a sign that agents estimated the likelihood of conversion into 3 per cent bonds as small. This is consistent with Dickson's remarks when he notes that, while the first coupon rate reductions from 6 per cent to 5 per cent did not encounter any resistance,

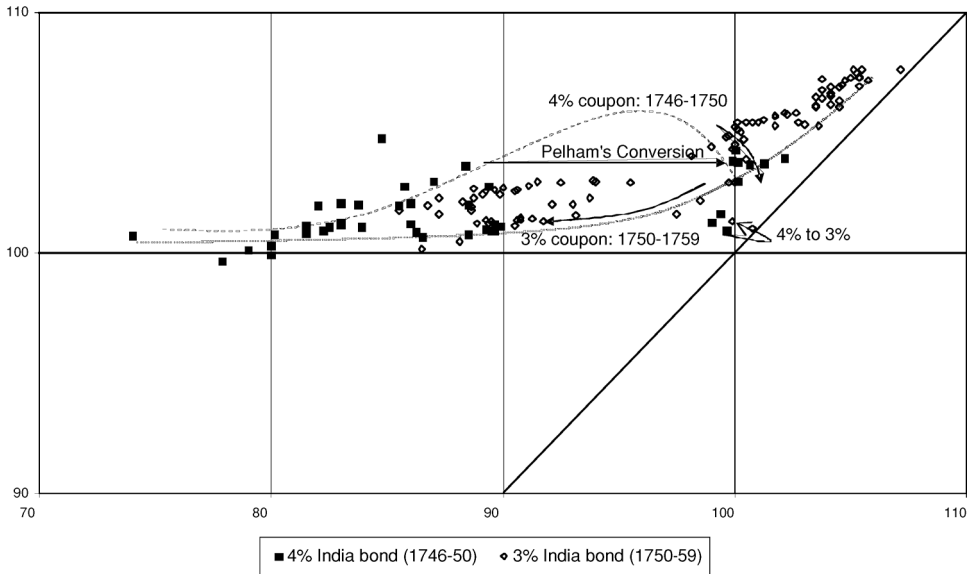


Figure 13. *From 4 per cent to 3 per cent coupon, 1746–59*

Sources: *The Course of the Exchange* and *Lloyd's List* (monthly observations).

the 1733 cut from 4 per cent to 3 per cent met with strong criticism from investors.¹⁹ The 3 per cent India bond starts quoting in November 1732, when the price of the Consol is 99.75.

From 1734 to 1743 (Figure 12), the price of the Consol fluctuates between 95 and 105, but without reaching any critical values for India bond conversions. The price of the India bond fluctuates along the theoretical 3 per cent puttable India Bond curve described in Section 3. From 1744, the price of the Consol starts decreasing, and the price of the India bond also declines from close to 105 in 1743, to just above 100 in 1746. In May 1746, the coupon is raised from 3 to 4 per cent (at a price of the India bond of 100.85). *The Course of the Exchange* of 21 March 1746 simply indicates: ‘The Court of Directors of the India Company have resolved to give 4 per cent. on their Bonds from the 31st Instant.’

¹⁹ ‘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. 410–11). The lack of resistance from investors to the change of coupon from 6 per cent to 5 per cent in 1714 might also be explained by the recent tightening of the usury laws in 1713–14 (see Temin and Voth 2007).

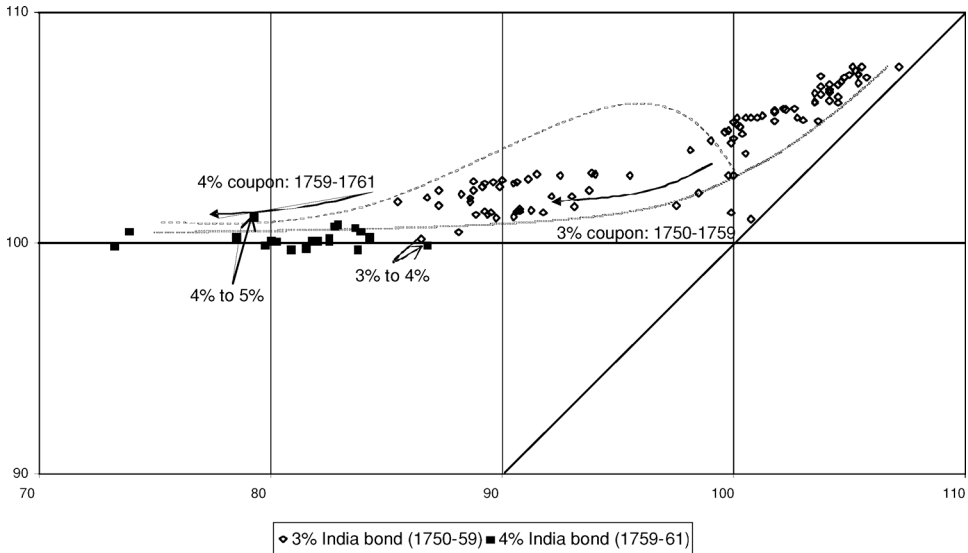


Figure 14. *From 3 per cent to 4 per cent coupon, 1750–61*

Sources: *The Course of the Exchange* and *Lloyd's List* (monthly observations).

During the period 1746–9 (Figure 13), the price of the Consols remains below 90. After Pelham's Conversion in April 1749 (consolidation of all government's floating debts), the price of the Consols rose very fast.²⁰ The coupon on the India bonds being of 4 per cent, 'their reduction in both cost and amount became part of government and company policy. In August 1749, with 3% government stock at a small premium, the East India chairman raised at a Court of Directors the question of reducing the company's bonds to 3%. This proposal seems to have been modelled on that of 1732, and there is little doubt that it was introduced with the government's blessing' (Dickson 1967, p. 413).²¹ In May 1750, when the price of the Consol reaches 99.88, the coupon of the India bonds is reduced from 4 to 3 per cent.

From 1750 to 1755 (Figure 14), the price of the Consol fluctuates above 100, and the price of the India bond remains above 104. From 1755, the price of the Consol starts falling. When it reaches 83.75 in April 1759, the coupon of the India bonds is raised from 3 to 4 per cent. As the price of the Consol keeps falling, the East India Company raises the coupon again from 4 to 5 per cent in May 1761 (at a Consol price of 87.63).

²⁰ This explains the lack of observations of Consol prices between 90 and 98 (Dickson 1967, p. 230).

²¹ Dickson also cites a contemporary pamphleteer who observed in November 1749 that the reduction of interest on the National Debt 'is now pretended to be more practicable, as means have been contrived to raise the three per Cents. above par, and to reduce India bonds from 4 to 3 per Cent.' (Dickson 1967, 231).

The observed dynamics of the prices and changes of coupon is consistent with our theoretical predictions, which thereby confirms our previous assumptions.

5. Consequences and causes of the embedded options

5.1. India bonds: an eighteenth-century hedging instrument

The call and put options embedded in the India bonds explain the observed behaviour of their prices and changes of coupons: the previous section has shown that the prices of India bonds remain very close to par, as an effect of the call option, but never drop below it, as an effect of the put option, and that the changes of coupons are frequent and coherent with the theory. The India bonds were therefore precursors of modern hedging instruments,²² as they provided the market with a financial instrument that limits the volatility in returns. As a consequence of the call and put options, we should observe two things: first, the volatility of returns of India bonds should always be lower than the volatility of the returns of Consols. Second, the average return of India bonds should be lower than the average return on Consols when the price of Consols is rising, and higher than the average return on Consols when their prices fall.

5.1.1. Volatility of monthly returns. The returns of holding India bonds and Consols include both a gain (or loss) in capital, plus the value of the cashed coupons. Equation 6 below gives the monthly return of a security i (i = India bond or Consol) at time t , where c_t^i is the annual coupon and p_t^i the market price of security i at month t .

$$r_t^i = \left(\frac{p_t^i - p_{t-1}^i}{p_{t-1}^i} + \frac{c_{t-1}^i}{12} \right) \quad (6)$$

The volatility of India bonds and Consols' monthly returns (variation from the mean) is given by equation 7, where \bar{r}^i is the arithmetic mean of the monthly returns.

$$v_t^i = r_t^i - \bar{r}^i \quad (7)$$

As expected, Figure 15 shows that the volatility of the monthly returns of the India bonds is lower than that of the Consols (the slope of the India bonds' volatility trend line is smaller than the Consols').

5.1.2. Average annual returns. The average annual return of holding security i from period 1 to period n ($r_{1,n}^i$) is given by equation 8 below:

²² In modern terms, hedging is a strategy designed to reduce investment risk using call options, put options, short-selling, or futures contracts. A hedge can help lock in profits. Its purpose is to reduce the volatility of a portfolio by reducing the risk of loss.

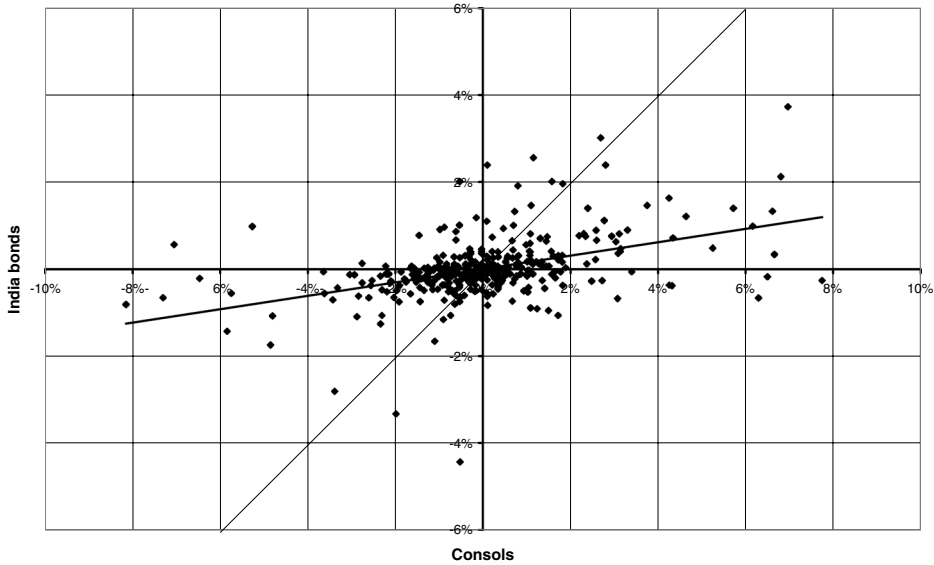


Figure 15. *Volatility of India bonds and Consols' monthly returns*

Sources: *The Course of the Exchange* and *Lloyd's List* (monthly observations).

$$r_{I,n}^i = I2 \times \left\{ \left[\prod_{t=1}^n (I + r_t^i) \right]^{1/n} - I \right\} \quad (8)$$

This average annual return is very sensitive to the periods chosen, as the difference between the buy and sell prices accounts for a large share (the return on the same bond will of course be very different if you buy it at the beginning of a surge in the market and sell in at the climax, or if you buy it before a collapse. . .).

The period analysed is comprised of two periods of rising Consol prices (1728–39, 1746–53), and two periods of falling Consol prices (1739–46, 1753–9). Table 1 shows the average annual returns of India bonds and Consols for each of these different periods. As expected, the average annual returns on India bonds are lower than the Consols' in the periods of rise, but India bonds' average returns are never negative when Consol prices fall (therefore, when the returns on Consols are negative). Besides, as for all hedging instruments, the larger the fall in the alternative security, the greater is the reward of holding India bonds (compare average returns during the first and second falls).

India bonds are thus a very stable and predictable instrument, and were the equivalent of modern hedging instruments. This goes a long way 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

Table 1. *Average annual return of India bonds and Consols (in %)*

		India bond	Consol
First rise period	1728–39	3.53	3.90
First fall period	1739–46	2.12	–2.55
Second rise period	1746–53	0.01	1.18
Second fall period	1753–9	0.13	–0.16
Whole period	1728–61	3.19	2.38

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. 147–8).

5.2. *Why were India bonds created?*

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

5.2.1. *Reputation and cost of capital.* We have not found a contemporary security identical to callable–puttable 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 puttable 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.²³

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

²³ For more information on LYONs and the different mathematical techniques for calculating their price, see, for example, McConnell and Schwartz (1986).

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 Figure 4 and Section 3.2). 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.

5.2.2. Effect of regulation. The second hypothesis 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.

India bonds were not explicitly 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.²⁴ Besides, as soon as it was granted the right to do so (in 1751), the East India Company issued long-term option-less bonds, up to the amount authorised, reducing the volume of India bonds by the same amount.²⁵ 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.²⁶ So it was that these securities remained nominally short-term while circulating as long-term.

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 therefore be said that the birth of such a modern financial instrument at the beginning of the eighteenth century was nothing more than the paradoxically beneficial effect of parliamentary economic regulation.

6. Conclusion

India bonds were among the most liquid securities available on the London market during the first half of the eighteenth century. They are still used

²⁴ 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 one for 1812 (see Appendix 3). There is no mention of a maturity date. Instead, there is explicit mention of the two conversion features which are equivalent to modern put and call options.

²⁵ Appendix 1 shows that before Pelham's Conversion, in 1749, the volume of India bonds was £4,242,000, which roughly equalled the volume of loans to the government (£4,200,000). In 1752, one year after the Conversion, India bonds were reduced to £1,800,000, and the volume of India annuities equalled £3,000,000.

²⁶ 'The East India Company in the 1680s was borrowing from month to month... The Bank was not willing to tolerate rival corporate note-issuers, and in 1708 obtained statutory prohibition of the right of any company, or partnership of more than six persons, to take up money on bills or notes payable at less than six months' (Dickson 1967, p. 408).

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/price formula hitherto applied in the literature cannot therefore be used to value their yield, since it does not take into account the value of these options. 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. We have thereby shown that investors performed sophisticated arbitraging among the different securities as far back as the early eighteenth century, which proves that the London capital market was efficient and integrated, and that agents were 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.

We have then analysed the financial characteristics resulting from the embedded options, and shown that the India bonds were early hedging instruments, whose prices and returns were more stable than the Consols'. Investors thus possessed an instrument which allowed them to benefit from rising markets, while being protected from losses in case of a market crash. This again is a very modern feature which is surprising to find as early as the eighteenth century.

To conclude, we suggest that the appearance of such a complex and modern financial instrument in the early eighteenth century was the result of parliamentary economic regulation.

Acknowledgements

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Lloyd's List, reprinted in 1969 by Gregg International Publishers Ltd of Farnborough, UK.

Appendix I. Volume of India bonds and government securities held by the East India Company, 1702–53

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	3.5–3
1734	3 067 661		3 200 000	4	3.5–3
1735	3 013 154		3 200 000	4	3.5–3
1736	3 012 954		3 200 000	4	3.5–3
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

Appendix 1. continued

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 (%)
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).

Appendix 2. Construction of the database

All the data used in this article were 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 *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 1696–7 by Jonathan Castaing, and its publication was continued throughout the eighteenth century by various editors, before becoming, in the second decade of the nineteenth century, the Official List of the Stock Exchange.²⁷

*Government securities*²⁸

The prices of annuities and lotteries of the government are given in the third section of the bulletin, next to the prices of the shares of the main companies. Before 1726, the government did not issue annuities, only lotteries.²⁹ From 1726, the government issued annuities, which were perpetual securities with 3 per cent 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 for the Exchequer). The new issues are therefore called: '4 per cent Bank Annuities 1746, 1747, 1748, 1749'. In 1750, following Pelham's conversion, 3 per cent annuities (1726, 31, 42, 43, 44, 45) are consolidated into a unique bond at 3 per cent coupon. Initially, it appeared in *The Course of the Exchange* under the name 'Bank Annuity 3 per cent', and after 1758, it is called '3 per cent Bank Consols'.

²⁷ For more information about *The Course of the Exchange*, see Cusker (1979, 1991) and Mirowski (1981).

²⁸ See Homer and Sylla (2005) for a summary of the different issues of the English government in the eighteenth century.

²⁹ For a description of the use of lotteries in the financing of the English government, see Dickson (1967, ch. 3) or Cohen (1953).

For the construction of the series ‘3 per cent Consols’, we used the prices of the ‘3 per cent Annuities 1726’ from 1726 to 1750, then the series ‘3 per cent Bank Annuity’ from 1750 to 1758, which became ‘3 per cent Bank Consols’ in 1758.

India bonds

Quotations of India bonds appear in the fifth 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 interests³⁰ and the nominal value of an India bond is £100.³¹

India bonds changed coupon regularly. We have considered each different coupon as 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 the end of 1750, quotations of ‘3 per cent 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 monthly prices corresponding to the first observation of the month. When the bulletin gives a range of prices, we considered the lowest quotation.

England adopted the Gregorian calendar on 14 September 1752. For the period prior to this, we have changed the dates of the Julian calendar to conform with the Gregorian calendar in order to maintain the homogeneity of the data.

Appendix 3: Evolution of the India bond

Unfortunately, we don’t have the exact wording of an India bond during the period 1718–63. As Dickson says, ‘No East India bonds have been traced, but 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

³⁰ 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

³¹ ‘These bonds are usually for £100 each, and the seller receives the interest of the purchaser, up to the day he sells’ (Mortimer 1761).

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 Accountant, 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) 115Signed by Order of the COURT OF
DIRECTORS of the said COMPANY.

L. S. ()

*Chas. Cartwright.**Geo. Paterson.**Form of an East India Bond for £500³²*

of . . . one thousand seven hundred and . . . For the true payment whereof they bind themselves and their Successors in the penal Sum of . . . London, the . . . day of . . . On thousand Seven hundred and . . . (Dickson, 1967, pp. 408–9)

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. 25–6) 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.

³² Tate (1819, p. 370).