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# Options Embedded in ECB Targeted Refinancing Operations

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**Abstract:** In June 2014, the European Central Bank (ECB) announced the implementation of new refinancing operations aimed at supporting bank lending to the non-financial private sector. This paper exhibits and prices options embedded in these *Targeted Longer-Term Refinancing Operations*. In particular, it shows how these options participate to the incentive mechanisms at play in these operations. Quantitative results point to substantial gains –for participating banks– attached to the satisfaction of lending conditions defined by the scheme.

**JEL Codes:** E43, E52, E58.

**Keywords:** unconventional monetary policy, option pricing, TLTRO.

**Résumé:** En juin 2014, la Banque Centrale Européenne a annoncé la mise en place d'un nouveau type d'opérations de refinancement visant à stimuler les prêts bancaires au secteur privé non-financier: les *Targeted Longer-Term Refinancing Operations*. Cet article met en lumière, puis valorise, des options incluses dans ces opérations. En particulier, il est montré que ces options participent aux mécanismes incitatifs à l'oeuvre dans ces opérations. L'analyse quantitative suggère que les conditions de financement offertes par les TLTROs sont particulièrement favorables pour les banques qui satisfont la contrainte de prêt définie dans le cadre du programme.

**Codes JEL:** E43, E52, E58.

**Mots-Clés:** politique monétaire non-conventionnelle, valorisation d'options, TLTRO.

## Non-technical summary

The global financial turmoil incepted in 2007 and its implications on economic activity have triggered unprecedented responses from major central banks. Some of these measures specifically aim at supporting a continued provision of credit to the non-financial private sector, that is to address potential impairments of the bank lending channel. The Targeted Longer-Term Refinancing Operations (TLTROs), announced by the ECB in June 2014, fall in that category.

The weakness of bank lending reflects a range of factors, but one major determinant is the price that banks have to pay for funds. To be successful, funding-for-lending measures have (a) to offer an attractive pricing and (b) to entail mechanisms incentivizing banks to effectively lend to the economy. With this in mind, this paper examines TLTROs funding conditions. It shows in particular that some options, embedded in TLTROs, have to be taken into account when assessing the potential of these operations to meet objectives (a) and (b). One of those options pertains to the possibility, for those banks fulfilling a lending condition defined in the scheme, to pay back their loans before September 2018, which is the maturity dates of TLTROs. Another option relates to the possibility, for participating banks to borrow in the future at a rate indexed on the then-prevailing policy rates.

A specificity of these options is that their payoffs depend on future policy rates –as opposed to market rates–. Since such options are not traded on financial markets, their assessment has to be model-based. To that purpose, we use the model proposed in a companion paper ([Renne \(2014\)](#)). This models explicitly incorporates policy rates and features closed-form formulas for interest-rate options, making it appropriate to the present analysis. The results suggest that those banks fulfilling the lending condition can expect to get funding costs 5 to 10 basis points lower than those resulting from rolling over one-week central-bank loans.

# 1 Introduction

The global financial turmoil incepted in 2007 and its implications on economic activity have triggered unprecedented responses from major central banks. Monetary authorities have cut policy rates aggressively and adopted so-called unconventional monetary policies.<sup>1</sup> Some of these measures specifically aim at supporting a continued provision of credit to the non-financial private sector, that is to address potential impairments of the bank lending channel.<sup>2</sup> The Targeted Longer-Term Refinancing Operations (TLTROs) fall in that category. Announced on 5 June 2014 by the Governing Council of the ECB, these measures aim to "support bank lending to households and non-financial corporations, excluding loans to households for house purchase."

This paper aims at quantifying the attractiveness of TLTROs. While the funding conditions offered through TLTROs have been deemed to be "attractive" by market participants, policymakers and medias alike, we are not aware of other quantitative studies of this aspect at the time of writing.

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<sup>1</sup>See, among many others, [Borio and Disyatat \(2010\)](#), [Bowdler and Radia \(2012\)](#), [Trichet \(2013\)](#) and [Gambacorta, Hofmann, and Peersman \(2014\)](#). For a focus on how ECB intermediation has expanded during the crisis period, see [Giannone, Lenza, Pill, and Reichlin \(2010\)](#).

<sup>2</sup>Indeed, there is evidence that credit supply conditions have become more important for the transmission of monetary policy than before the financial crisis, see e.g. [Gambacorta and Marques-Ibanez \(2011\)](#) or [Cappiello, Kadareja, Kok Sorensen, and Protopapa \(2010\)](#). Specific examples of such measures include schemes operated by the Bank of England ("Funding for Lending", see [Churm, Radia, Leake, Srinivasan, and Whisker \(2012\)](#)), the Central Bank of Hungary ("Funding for Growth Scheme") and the Bank of Japan ("Fund-Provisioning Measure to Stimulate Bank Lending").

condition defined in the scheme, to pay back their loans before September 2018, which is the maturity dates of TLTROs. Another option relates to the possibility, for participating banks to borrow in the future at a rate indexed on the then-prevailing policy rates.

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The remaining of this paper is organized as follows. [Section 2](#) presents the TLTRO scheme. [Section 3](#) proposes an assessment of the TLTRO funding conditions and [Section 4](#) concludes.

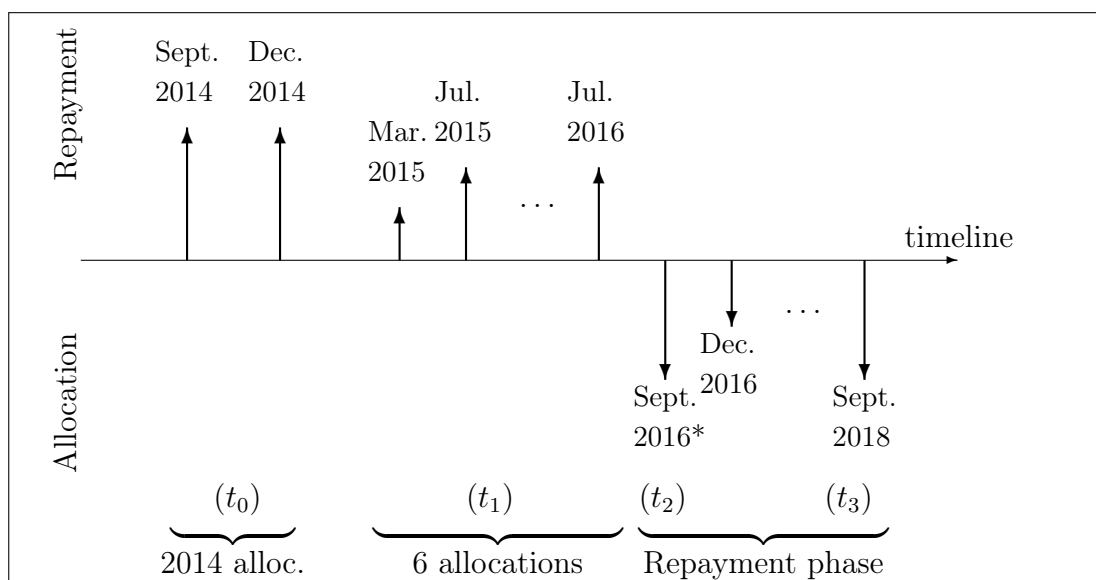
## 2 The TLTROs

The modalities of the TLTROs are presented in [European Central Bank \(2014\)](#); an exhaustive description of the scheme is given by [Governing Council of the ECB \(2014\)](#). The different TLTRO steps are represented in [Figure 1](#). A series of TLTROs will be conducted between September 2014 and June 2016. The interest rate of these operations will be fixed over the life of the operation; the interest rate will be the MRO rate prevailing at the time of take-up, plus a fixed spread of 10 basis points. For instance, the MRO being of 5 bps in fall 2014, the rate of the first two TLTROs is 15 bps.

The amounts banks will be able to borrow during these operations are capped in the following way:

- For the first two operations (September and December 2014), each bank will be able to borrow up to 7% of the amount outstanding on 30 April 2014 of eligible loans granted

Figure 1: TLTRO steps



**Notes:** See Section 2 for explanations. Note that the length of the arrows appearing on this figure are arbitrary and have no specific meaning. \*: Mandatory early repayment will take place in September 2016. Dates  $t_0$  to  $t_3$  are used in Section 3 (see Subsection 3.2).

by the bank.<sup>3</sup> This limit implies that the maximum allotted amount will be close to EUR400bn.

- For the subsequent six allotment dates, from March 2015 to June 2016, the maximum amount borrowed by a bank will depend on the net lending of this bank between May 2014 and the allotment date. More precisely, at the  $k^{th}$  TLTRO, taking place at month  $m_k$ , the bank will be allowed to borrow up to 3 times the difference –if positive– between (a) its net lending over the period between May 2014 and month  $m_{k-2}$  and (b) a benchmark based on the net lending of this bank between May 2013 and April 2014.

Banks that will have borrowed in the TLTROs but whose eligible net lending in the period from May 2014 to April 2016 is below the benchmark will be required to pay back

<sup>3</sup> Outstanding amounts of eligible loans refer to outstanding loans on the balance sheet net securitized or otherwise transferred loans which have not been derecognized from the balance sheet (see [European Central Bank \(2014\)](#)).



their borrowings in September 2016. This condition will refer to as Condition C in the sequel of this note. Moreover, the banks that do (do not) satisfy this condition will be referred to as *performing* (*nonperforming*) banks.

**Condition C.** *This condition is satisfied by a given bank if its net lending in the period from May 2014 to April 2016 is equal to –or above– its benchmark.*

### 3 TLTRO pricing

Banks will participate to the TLTRO if these operations are attractive enough for banks. An important ingredient of TLTRO attractiveness pertains to the funding conditions offered by these operations. Subsection 3.1 presents a rough assessment of TLTRO funding conditions. Subsection 3.2 introduces a stylized view of the TLTRO framework. Subsection 3.3 formulates TLTRO features as options. Subsection 3.4 values these options and Subsection 3.5 exploits this valuation exercise to build a comprehensive assessment of TLTRO funding conditions.

#### 3.1 At first sight

A first gauge of TLTROs' attractiveness is obtained by comparing the rate of the initial TLTROs with alternative funding costs for banks. However, finding a relevant benchmark rate is not straightforward for several reasons. First, banks do not constitute an homogenous group and funding conditions diverge across them. Second, TLTROs are secured operations and the type of collateral accepted by the Eurosystem is wider than the one accepted in standard market repo operations.<sup>4</sup> This latter point implies that private-market repo rates cannot be directly compared to TLTROs' ones.

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<sup>4</sup>The importance of the collateral framework is e.g. demonstrated by [Eisenschmidt, Hirsch, and Linzert \(2009\)](#). For a recent survey on central-bank collateral frameworks and practices, see [Bank for International Settlements \(2013\)](#).

While it is difficult to find private market operations similar to TLTROs, it is nevertheless instructive to compare TLTRO conditions with the funding costs associated with different borrowing operations.<sup>5</sup> In that preliminary exercise, we focus on 4-year yields, which is the longest maturity of TLTRO operations. We consider two "extreme" benchmarks.

The first corresponds to a (synthetic) 4-year general-collateral repurchase agreement. Repos for such long maturities do not exist; they can however be synthesized and the resulting rates can be proxied by Overnight Indexed Swaps (OIS) rates.<sup>6</sup> Since the class of collateral eligible to such repo is much narrower than for Eurosystem refi operations, the rate of such an operation is expected to be lower than the 4-year TLTRO one.

A second benchmark rate is that of unsecured borrowing, which we proxy by an average of 4-year unsecured bond yields. These bonds constituting a non-collateralized funding, this second benchmark rate is expected to be higher than TLTRO rates. Figure 2 displays the fluctuations of the two benchmark rates. It appears that the initial TLTRO rate (15 bps) is close to the lower bound of the interval delineated by these two yields, pointing to the attractiveness of TLTROs.

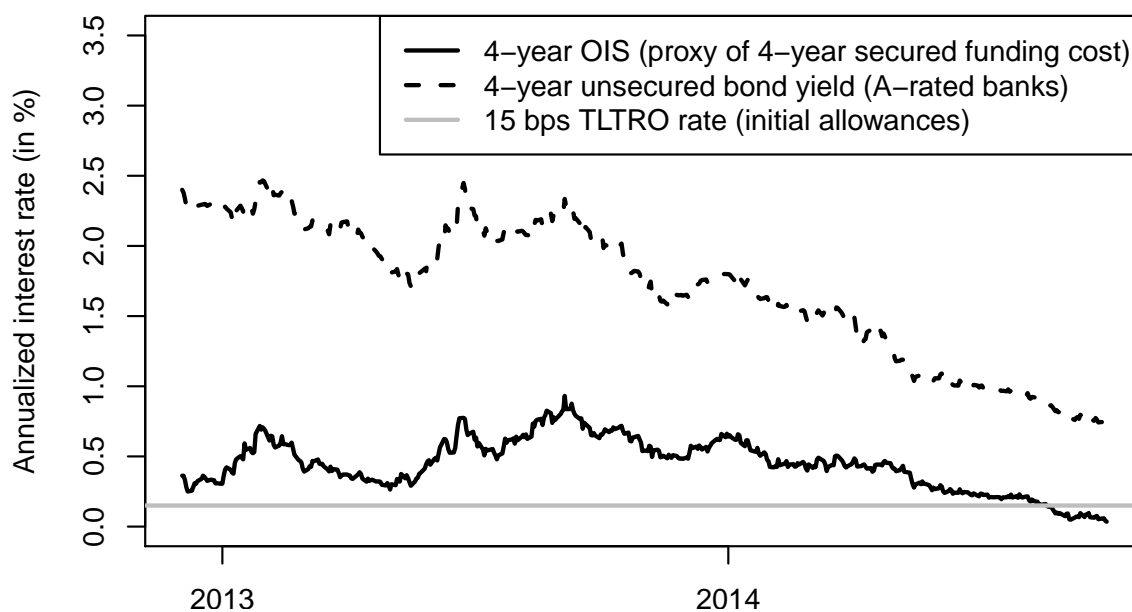
Assessing the values associated with the different collateralizations of these different funding operations (private-market repo, central-bank refinancing operations and unsecured-bond issuances) is beyond the scope of the present paper. The methodology developed in the following rather aims at comparing TLTRO funding costs with alternative central-bank funding operations in order to bypass problems stemming from differences in collateralizations.

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<sup>5</sup>To that respect, there is evidence that ECB TLTROs are seen by banks as partial substitutes to alternatives funding sources (see e.g. [Reuters \(2014\)](#)).

<sup>6</sup>An OIS is an interest rate swap whose floating leg is tied to an overnight interbank rate (the EONIA in the euro-area case), compounded over a specified term. A 4-year repo can be synthetically obtained by rolling a shorter-term repo and to enter in a 4-year OIS contract where the bank pays the fixed rate. This results in a synthetic collateralized funding where the bank pays the 4-year fixed rate (the short-term repo rates paid by the bank being approximately covered by the capitalized EONIA rates resulting from the 4-year OIS contract).

Figure 2: Proxies of 4-year funding costs of banks



**Notes:** This figure displays two proxies of 4-year bank lending rates. The Overnight Indexed Swap (OIS) rate is a proxy of the rate of a synthetic repo where the collateral is the one accepted in general-collateral private-markets repurchase agreements. The dashed line is an average of the yields-to-maturity of 4-year bonds issued by A-rated European banks (Source: Bloomberg). Time ranges from 3 December 2013 to 1 October 2014.

### 3.2 Stylizing the TLTRO scheme

For expository and computational convenience, let us simplify the TLTRO framework and summarize the different steps of the schemes as follows:

- $t_0$  : Initial TLTRO allocations [2014];
- $t_1$  : Additional TLTROs [March 2015 to June 2016];
- $t_2$  : Early repayment [2016] (compulsory for non-performing banks);
- $t_3$  : Maturity of TLTROs [2018].

As stressed in Subsection 3.1, it is difficult to find a private-market source of funding that is close enough to the TLTRO to serve as a proper benchmark. Nevertheless, there is a basic funding strategy that a bank can follow as an alternative to participating to TLTROs: this strategy simply consists in recurrently participating to the main refinancing operations

(MRO) of the Eurosystem, for which banks get one-week funding at a rate denoted by  $MRO_t$ . The collateral required by those operations is the same as the TLTRO one. Hence, this strategy appears to be a natural and relevant benchmark for TLTRO operations. However, from a given date, the cost of the roll-over strategy is unknown since it depends on future MRO rates. Formally, denoting by  $t^*$  the termination date of this strategy, the date- $t$  value of the associated annualized interest-rate load is given by:

$$y_{t,t^*} = \frac{1}{t^* - t} E_t(MRO_t + MRO_{t+1} + \dots + MRO_{t^*-1}), \quad (1)$$

where  $E_t$  denotes the risk-neutral expectation based on all information available at date  $t$ . The previous formula is actually the one that would be used to price swaps with floating-leg cash-flows indexed to MRO rates; but such swaps do not trade.<sup>7</sup> Notwithstanding, estimates of the previous rates can be derived from an appropriate interest-rate model (Subsection 3.4).

### 3.3 Concept of TLTRO-embedded options

The present subsection shows that some TLTRO features can be expressed in terms of options implicitly given to banks. Specifically, we exhibit three TLTRO-embedded options.

Let us consider a performing bank, which is a bank satisfying Condition C. It is tempting to say that the funding cost attached to the initial TLTRO loans is of 15 bps. However, this neglects the existence of a first option, which pertains to the possibility, for this bank, to repay the loan at date  $t_2$ . This bank will typically exercise this option if, at date  $t_2$ , it expects

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<sup>7</sup>By contrast, a liquid contract indexed on future Fed Funds rates exist in the United States (see [Gurkaynak \(2005\)](#), [Carlson, Craig, and Melick \(2005\)](#) or [Gurkaynak, Sack, and Swanson \(2007\)](#)), markets in most other countries rely exclusively on their local-currency- denominated OIS market for hedging central bank policy. Note that these market instruments are different from OIS, whose floating legs are indexed to overnight interbank rates (EONIA). Before October 2008, the EONIA were on average very close to the MRO rate but this changed with the implementation of the fixed-rate full allotment policy of the Eurosystem. Since then, the EONIA have persistently evolved below the MRO rate, at the bottom of the so-called monetary-policy-rate corridor.

a lower interest cost from a MRO roll-over strategy over the residual time-to-maturity of the loan (i.e. between dates  $t_2$  and  $t_3$ ). That is, this bank will exercise this option at date  $t_2$  if  $y_{t_2, t_3-t_2} < 15$  bps.

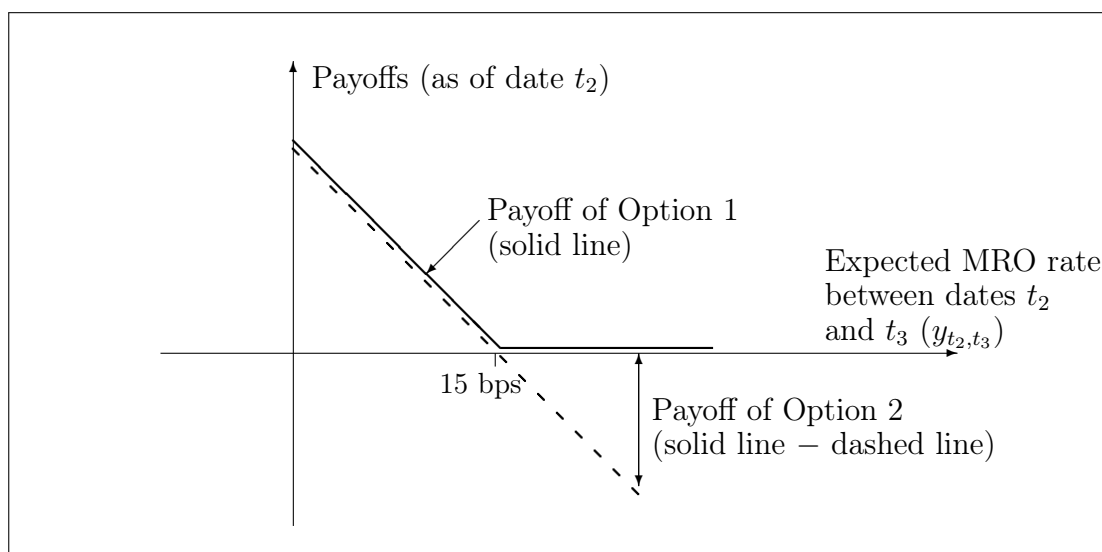
**TLTRO-embedded Option 1.** *The fact that performing banks can –but are not obliged to– repay TLTROs before maturity ( $t_3$ ) implies that TLTRO funding embeds options that allow participating banks to benefit from potential future decreases in alternative funding rates between repayment dates ( $t_2$ ) and the maturity of TLTROs ( $t_3$ ).*

The payoff of this first option is represented in Figure 3. The same figure also shows the payoff of a second option. The latter is very much related to the previous one; to some extent, it can be seen as a rephrasing of Option 1. (Actually, instead of saying that this second option is an option that performing banks have, one should rather say that it is an option that non-performing banks do not have.) This option is nonetheless important because it reflects the incentives banks have to perform. This option reads:

**TLTRO-embedded Option 2.** *The fact that performing banks can go on their initial TLTRO loans after 2016 (date  $t_2$ ) implies that TLTROs embed options that allow performing banks –by contrast to non-performing banks– to be shielded against future potential increases in alternative funding rates between repayment dates ( $t_2$ ) and the maturity of the TLTRO operations (date  $t_3$ ).*

Finally, banks that engage in outperforming Condition C acquire a third type of option. The latter option pertains to the possibility, between March 2015 and June 2016 (date  $t_1$ ), to obtain funding at  $MRO_{t_1} + 10$  bps (up to a given threshold based on the difference between its net lending and the benchmark, see Section 2). Figure 4 represents the date- $t_1$  payoff associated with Option 3.

Figure 3: Payoffs of Options 1 &amp; 2



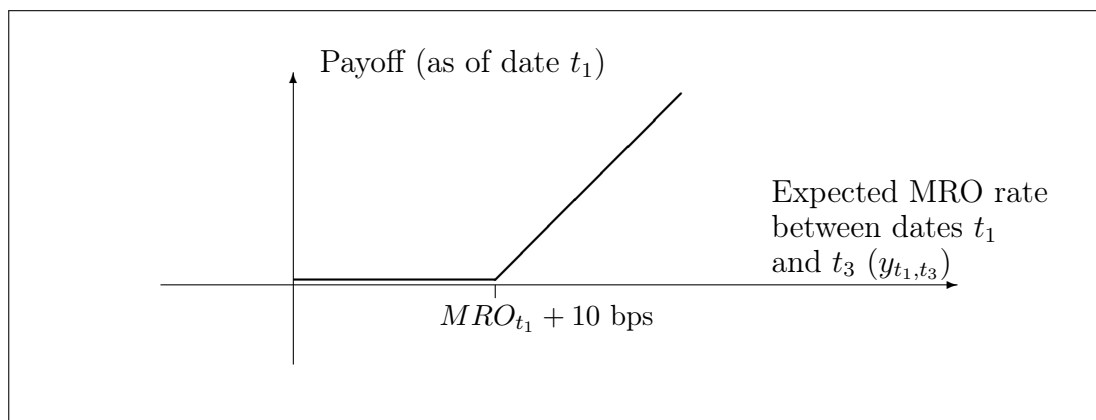
**Notes: Option 1:** The black solid line is the payoff of Option 1. This payoff will materialize at date  $t_2$  (mid 2016). At that date, performing banks –i.e. those that do have satisfied Condition C– have the possibility to keep their initial TLTRO funding until maturity (date  $t_3$ , 2018). They will do so if they expect the MRO rate between  $t_2$  and  $t_3$  (this expectation is denoted by  $y_{t_2,t_3}$ , see Equation 1) to stay above the 15 bps they pay on TLTRO loans. Otherwise, they can choose to switch to MRO funding. This gives rise to the payoff of Option 1. **Option 2:** The payoff of Option 2 highlights the gains banks have to perform, i.e. to satisfy Condition C. Nonperforming banks are compelled to repay TLTRO loans at date  $t_2$ . Hence, compared to performing banks, they face a negative payoff when  $y_{t_2,t_3}$  is higher than 15 bps.

**TLTRO-embedded Option 3.** *Banks that outperform their benchmark acquire the option to get funding at a fixed rate of  $MRO_{t_1} + 10$  bps at the TLTROs that will take place between March 2015 and June 2016 (date  $t_1$ ). The maturity date of these loans is September 2018 (date  $t_3$ ).*

### 3.4 Valuation of TLTRO-embedded options

Options 1 to 3 are not standard options. First, the underlying rates are MRO rates while the payoffs of standard options are indexed on EURIBOR rates. Second, contrary to Option

Figure 4: Payoff of Option 3



**Notes:** At date  $t_1$  (March 2015 - June 2016), performing banks have the option to get additional TLTRO funding at  $MRO_{t_1} + 10$  bps until the TLTRO maturity (date  $t_3$ , 2018). Hence, Option 3 pays off if the rate of the alternative strategy (rolling over MRO fundings between dates  $t_1$  and  $t_3$ , whose expected annualized cost is  $y_{t_1,t_3}$ ) is above  $MRO_{t_1} + 10$  bps.

1 and 2, Option 3 is not structured as a usual swaption<sup>8</sup> in that the strike rate is not known at the inception of the "contract", i.e. at date  $t_0$ : indeed, Option 3 gives to its holder the right to enter, in the future, i.e. at date  $t_1$ , a swap whose fixed rate is  $MRO_{t_1} + 10$  bps, which is unknown as of date  $t_0$ .

Pricing these options hence requires a specific setup. The model proposed by [Renne \(2014\)](#) is relevant in this context. This model, whose broad lines are given in [Appendix A](#), relies on an original specification of the policy-rate dynamics. This model is actually one of the very few term-structure models that explicitly incorporate policy rates, which is required in the current context (notably to compute the MRO-swap yields of [Equation 1](#)). An advantage of this framework is that it offers analytical formulas for the valuation of swaps, swaptions, caps and floors. As a consequence, it can easily be parameterized to fit various market data. Once the model parameters are obtained, the model can further be exploited in order to price other instruments. Typically, in the present case, the estimated

<sup>8</sup>A swaption is an option granting its owner the right but not the obligation to enter into an underlying swap in the future, the fixed rate of the swap being predetermined (at the date where the swaption is contracted).

model can be used to price Options 1, 2 and 3.

The pricing model is calibrated on OIS rates (with maturities of 1, 3 and 6 months, 1, 2, 3 and 5 years), swaption prices (tenors of 1, 2 and 5 years, expiries of 6 month, 1 and 2 years) and 13 cap/floor prices (maturities of 3, 4 and 5y, exercise rates of 0.5%, 1%, 1.5% and 2%). Specifically, the model parameters are estimated as being those that minimize the squared deviations between observed and model-implied prices or yields (see [Renne \(2014\)](#)). Importantly, calibrating the model on option prices makes it consistent with the market valuation of uncertainty. If this was not the case, the subsequent computation of model-implied prices of the TLTRO-embedded options would not be reliable.

Using market prices of 1 October 2014, the obtained values of Options 1 to 3 are as follows:

- Option 1 is worth 0.12% of the notional, that is the initial allowance. For the sake of illustration, the value of this option for a bank that obtains a TLTRO loan of EUR1bn euro is EUR1.2mn. That is, if EUR400bns were allocated at the 2014 TLTROs, the value of these first options would amount to about EUR0.5bn.
- Option 2 is worth 0.40% of the notional value of the loan. That is, for a performing bank, the present value of having the possibility, at date  $t_2$  (2016), to keep a EUR1bn 2014-allocated TLTRO loan until date  $t_3$  (2018) at a rate of 0.15% –instead of being obliged to shift to MRO-based funding between dates  $t_2$  and  $t_3$ – is worth EUR4mn.
- Option 3 is worth about 0.25% of the notional value of the loan. That is, the present value of getting the right to borrow EUR1bn at  $MRO_{t_1} + 10$  bps at the TLTROs that will take place between March 2015 and June 2016 is EUR2.5mn.

It is important to note that the pricing of these options depends on the data used for the model calibration. Since these data correspond to a given date, the pricing is time-dependent. It has however been checked that the pricing has been fairly stable over September 2014.



Besides, while the calibrated model provides a fairly good fit of observed prices, the fit is not perfect (see Appendix A). Therefore, these results should be interpreted with caution. Nevertheless, different checks point to the robustness of the order of magnitude of reported results.

### 3.5 Implications for TLTRO funding

This subsection aims at providing an overall assessment of TLTRO funding conditions. This assessment is going to draw from the previous option analysis. Specifically, the objective is to calculate the date- $t_0$  expectation of the interest-rate charges that a bank participating to TLTROs will have to pay over the loan period.

Let us consider a bank that get a funding of 100 at the first TLTROs.<sup>9</sup> We denote by  $x$  the expected "excess net lending", which is the amount by which this bank expects to outperform its benchmark by June 2016 (date  $t_2$ ).<sup>10</sup> For sake of simplicity, we consider that the change in the net lending occurs just before  $t_2$ .

Let us first consider first a bank for which  $x$  is negative. Over the period  $t_0$ - $t_2$ , this bank pays an interest rate of 15 bps on the initial allowance of 100. Then, at date  $t_2$ , the bank is compelled to repay and has to refund  $100 + x$  ( $< 100$ ). It is assumed that this amount is borrowed from the Eurosystem's MROs. The date- $t_0$  expected interest charges for the period between dates  $t_2$  and  $t_3$  is the MRO-swap forward rate given by:

$$f_{t_0,t_2,t_3} = \frac{1}{t_3 - t_2} [(t_3 - t_0)y_{t_0,t_3} - (t_2 - t_0)y_{t_0,t_2}].$$

Hence, over the next five years, the expected annualized interest rate paid by such a bank

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<sup>9</sup>This implies that  $OL > 10000/7$ .

<sup>10</sup>It comes for instance that this bank fails to satisfy Condition C if  $x$  is negative.

is:

$$\frac{(t_2 - t_0)100}{(t_2 - t_0)100 + (t_3 - t_2)(100 + x)} 0.15\% + \frac{(t_3 - t_2)(100 + x)}{(t_2 - t_0)100 + (t_3 - t_2)(100 + x)} f_{t_0, t_2, t_3}. \quad (2)$$

Now, let us turn to a bank for which  $x \geq 0$ . This bank benefits from Options 1 and 3. To compute the expected interest cost faced by this bank, we take advantage of our options pricing. Specifically, the date- $t_0$  cost is computed as if the banks sold the options at date  $t_0$ , the proceeds of these sales being taken off the interest charges. Further, it is assumed that, at the additional TLTROs of March 2015 to June 2016, the bank draws the fraction  $\theta \in [0, 1]$  of their maximum borrowing allowance. The average interest charge for this bank is then given by:

$$\frac{(t_3 - t_0)100}{(t_3 - t_0)100 + (t_3 - t_1)3\theta x} \left( 0.15\% - \frac{Opt_1}{t_3 - t_0} \right) + \frac{(t_3 - t_1)3\theta x}{(t_3 - t_0)100 + (t_3 - t_1)3\theta x} \left( f_{t_0, t_1, t_3} - \frac{Opt_3}{t_3 - t_1} \right). \quad (3)$$

The expected cost of TLTRO funding can be compared to that stemming from a MRO-based strategy, that is a funding strategy where banks get central-bank funding only through weekly main refinancing operations. In order to get comparable rates, we compute the expected costs associated with this alternative strategy using equivalent funding needs over

time. These alternative funding costs are then as follows:<sup>11</sup>

$$\text{for } x < 0 : \quad \frac{(t_2 - t_0)100}{(t_2 - t_0)100 + (t_3 - t_2)(100 + x)} y_{t_0, t_2} + \frac{(t_3 - t_2)(100 + x)}{(t_2 - t_0)100 + (t_3 - t_2)(100 + x)} f_{t_0, t_2, t_3}, \quad (4)$$

$$\text{for } x \geq 0 : \quad \frac{(t_3 - t_0)100}{(t_3 - t_0)100 + (t_3 - t_1)3\theta x} y_{t_0, t_3} + \frac{(t_3 - t_1)3\theta x}{(t_3 - t_0)100 + (t_3 - t_1)3\theta x} f_{t_0, t_1, t_3}. \quad (5)$$

Figure 5 displays the annualized interest charges associated with TLTRO funding alongside those stemming from the MRO-based strategy. A first result is that TLTRO funding turns out to be more expensive for those banks that do not satisfy Condition C (i.e. those for which  $x < 0$ ). This is because non-performing banks have more funding needs over the first years of the scheme (between dates  $t_0$  and  $t_2$ ), where the MRO rate is expected to remain extremely low. At the limit, assuming that the MRO rate remains at 5 bps over  $t_0$ - $t_2$  and considering a bank that expects no funding need over  $t_2$ - $t_3$ , The annualized funding cost is of 5 bps under the MRO strategy versus 15 bps under the TLTRO one. By contrast, TLTRO offer attractive funding conditions for the banks that expects to outperform their benchmark, the TLTRO rate being between 5 and 10 bps lower than the one associated with the MRO-based strategy.

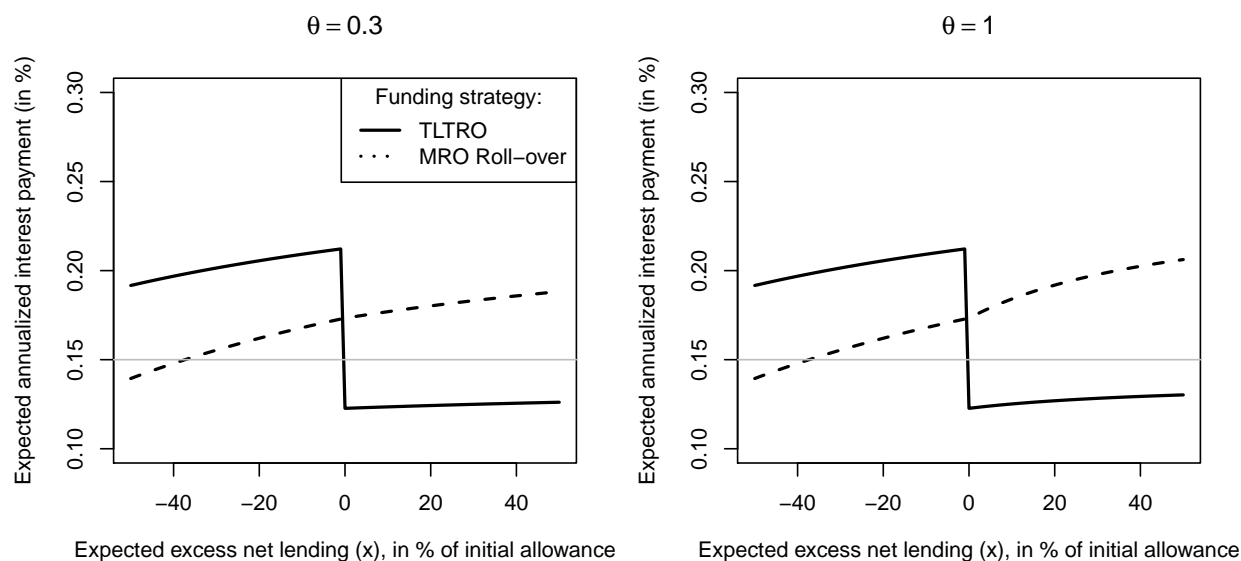
## 4 Concluding remarks

This paper investigates the funding conditions offered by a refinancing operation that has been announced in mid-2014 by the European Central Bank, namely the targeted longer-term refinancing operations (TLTROs). In particular, it exhibits options that are embedded

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<sup>11</sup>It can be noted that Option 2 does not appear in the previous interest-rate formula. Its value is however implicitly contained in the difference between Expressions 3 and 5. Actually, the value of Option 2 is hidden by a call-put-parity-like relationship between  $Opt1$ ,  $Opt2$  and  $f_{t_2, t_3}$ .

Figure 5: TLTROs vs. MROs – Expected annualized funding cost



**Notes:** These plots the expected annualized funding costs associated with two strategies involving Eurosystem financing operations. For  $x < 0$  (respectively  $x \geq 0$ ), the solid line corresponds to Expression 2 (resp. Expression 3). The dashed lines represent the expected annualized costs of a funding strategy whereby the bank gets its funding only through the weekly main refinancing operations (MROs) held by the Eurosystem (Expression 4 and 5). The horizontal gray line indicates the rate of the initial TLTROs (0.15%).

in the TLTROs and shows that these options are key to the incentive mechanisms at play in these non-conventional monetary-policy measures.

It has to be stressed that the analysis developed in this paper solely focuses on pricing aspects and does not provide an exhaustive view of all TLTROs' pros and cons from the banks' point of view. In particular:

- When TLTRO funding conditions are compared to the ones expected from rolling over short-term central-bank loans, it is implicitly assumed that the latter are going to be fully allotted over the next four years; the ECB has however not committed to maintaining its fixed-rate full-allotment (FRFA) policy in place over that horizon.<sup>12</sup>
- The long maturity for these loans is helpful to banks that are concerned about satisfying regulations on net stable funding ratios (Whelan (2014)).

<sup>12</sup>At the time of writing, the ECB has committed to operate refinancing operations under FRFA at least until September 2016.

- Potential costs specifically associated with the fulfillment of the lending-related conditionality involved in TLTRO operations are not taken into account in the present analysis.<sup>13</sup>

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<sup>13</sup>Costs could e.g. arise if, in order to satisfy this condition (Condition C the paper), it had to reduce its lending standards below their usual levels or to reduce its lending rates so as to meet a big enough credit demand. Another form of potential costs relates to stigma effects (see [Cecchetti \(2009\)](#)), whereby a bank may fear to be viewed as being in weak condition if it borrows a lot of money from the central bank.

## A A monetary-policy-based model of interest rates

More details on the modeling approach can be found in [Renne \(2014\)](#).

### Specification of the overnight interbank rate

In the model, the short-term rate is given by:  $r_t = \Delta' z_t + \xi_t$  where  $z_t$  is a selection vector (i.e. full of zeros, except one entry that equals one),  $\Delta$  is a vector of possible values of the MRO rate (that we set to 0.05%, 0.25%, 0.50% . . . , 10%) and where, conditionally to  $z_t$ ,  $\xi_t$  is an i.i.d. random variable. Hence, the dynamics of the short-term rate is mainly driven by that of the state vector  $z_t$ .

### The regimes (represented by $z_t$ )

In addition to indicating the level of the current policy rate, the state  $z_t$  depends (a) on the current monetary-policy phase that can be either "easing" (policy-rate cuts are expected at next governing-council meeting), "tightening" (hikes are expected) or in "status quo" (neither cuts nor hikes are likely) and (b) on the monetary-policy corridor functioning that can be either "normal" (the overnight interbank rate is close to the middle of the corridor  $\equiv$  MRO rate) or "in excess-liquidity" (the overnight interbank rate stands substantially below the MRO rate). Under a normal functioning of the corridor system (respectively under the floor system), the conditional mean of  $\xi_t$  is 0 (resp.  $-\delta$ ).

Formally, we have:  $z_t = z_{c,t} \odot z_{m,t} \odot z_{r,t}$ , where  $z_{c,t}$  is the selection vector of the corridor regime (of dimension  $2 \times 1$ ),  $z_{m,t}$  is the selection vector of the monetary policy phase (of dimension  $3 \times 1$ ) and  $z_{r,t}$  is the selection vector of the policy rate (of dimension  $K \times 1$  if  $K$  is the number of possible policy rates).

### Dynamics of $z_t$ and model parameterization

The selection vector  $z_t$  follows a Markovian process whose matrix of transition probabilities is denoted by  $\Pi$ . This large matrix is parameterized by six parameters (see first six lines in [Table 1](#)). Two additional parameters are required to calibrate the model: the probability

Table 1: Model calibration

| Descriptions  | Parameter values |
|---|------------------|
| Probability of a policy-rate cut at a Governing Council meeting<br>(conditionally on being in an easing phase)                              | 0.86             |
| Probability of a policy-rate hike at a Governing Council meeting<br>(conditionally on being in an easing phase)                             | 0.54             |
| Probability of shifting from easing to status-quo phase   | 0.18             |
| Probability of shifting from status-quo to easing phase   | 0.06             |
| Probability of shifting from status-quo to tightening phase   | 0.03             |
| Probability of shifting from tightening to status-quo phase   | 0.03             |
| Probability of exiting the floor system   | 0.015            |
| Mean of the difference between the MRO rate and $r_t$ (i.e. $\delta$ )<br>(in bps, conditionally on being in the "excess-liquidity" regime) | 14               |

**Notes:** This table presents the calibration of the model used to compute option prices as well as MRO swaps (Expression 1). The probability of exiting the floor system is set at 1 when the MRO is above 1.5%.  $\delta$  is expressed in fraction of the corridor width. For a daily periodicity, transition probabilities are small. Therefore, for sake of readability, these probabilities appear here in monthly terms; that is, if  $\underline{p}$  is the daily transition probability, the table reports  $p$ , where  $(1 - p) = (1 - \underline{p})^{30}$ . This calibration is obtained by minimizing the squared errors between observed prices of fixed-income instruments and model-implied ones (Table 2). See Renne (2014) for details regarding the estimation approach.

of exiting the excess-liquidity regime and  $\delta$ .

As shown in Renne (2014), this framework offers closed-form formulas to price any financial instruments whose future payoffs depend on the future states  $z_t$ . This is exploited in the present note in order to (a) estimate the model parameters and (b) compute the model-implied prices of the TLTRO-embedded options and model-implied MRO-swap rates (Equation 1). Note that while issue (b) could have been dealt with by Monte-Carlo-based pricing, these kinds of computing-intensive methods would not have been well-suited to find an appropriate model calibration (issue (a)).

Tables 1 and 2 respectively present the model calibration and the resulting fit.

Table 2: Model fit

|            | Model | Obs.  |            | Model | Obs. |
|------------|-------|-------|------------|-------|------|
| OIS yields |       |       | Caps       |       |      |
| 1m OIS     | -0.04 | -0.08 | 0.50% - 3y | 0.15  | 0.15 |
| 3m OIS     | -0.03 | -0.08 | 0.50% - 4y | 0.49  | 0.43 |
| 6m OIS     | -0.04 | -0.08 | 0.50% - 5y | 1.13  | 0.92 |
| 1y OIS     | -0.06 | -0.07 | 1.00% - 3y | 0.07  | 0.09 |
| 2y OIS     | -0.05 | -0.04 | 1.00% - 4y | 0.27  | 0.30 |
| 3y OIS     | -0.02 | 0.01  | 1.00% - 5y | 0.69  | 0.68 |
| 5y OIS     | 0.16  | 0.17  | 1.50% - 3y | 0.05  | 0.06 |
|            |       |       | 1.50% - 4y | 0.17  | 0.20 |
|            |       |       | 1.50% - 5y | 0.46  | 0.49 |
| Swaptions  |       |       | 2.00% - 3y | 0.03  | 0.03 |
| 6m - 1y    | 0.04  | 0.02  | 2.00% - 4y | 0.12  | 0.13 |
| 6m - 2y    | 0.10  | 0.07  | 2.00% - 5y | 0.32  | 0.35 |
| 6m - 5y    | 0.44  | 0.37  |            |       |      |
| 1y - 1y    | 0.07  | 0.05  |            |       |      |
| 1y - 2y    | 0.17  | 0.16  | Floor      |       |      |
| 1y - 5y    | 0.72  | 0.72  | 0.50% - 5y | 1.16  | 0.98 |
| 2y - 1y    | 0.15  | 0.13  |            |       |      |
| 2y - 2y    | 0.37  | 0.33  |            |       |      |
| 2y - 5y    | 1.29  | 1.32  |            |       |      |

**Notes:** This table compares observed with model-implied prices of fixed-income instruments. Market data are for 29 September 2014. All data are expressed in percentage points. Swaptions are at-the-money; "6m-1y" means that the expiry of the swaption is 6 months and the tenor is 1 year. For caps and floors, "0.50% - 3y" corresponds to an exercise rate of 0.50% and a maturity of 3 years. Model-implied data are based on the model calibration presented in Table 1.



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