Chapter 6

From Paper to Carbon Money: Financing Forest Conservation and Offset

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Additional information is available at the end of the chapter

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Abstract

As a result of the 21st Conference of the Parties (CoP-21) in 2015, the Paris Agreement formally recognised the importance of finance and forests to tackle climate change. However, Article 9 of the convention calls for the leadership of developed countries in mobilising climate finance, while encouraging other parties to provide financial support voluntarily. This is rather an unstable mechanism, since it is strongly affected by political and economic hardships. Forest finance could be established instead that, just like capital markets, might allow for countries to choose between interest-bearing bonds from forest conservation (natural forests) and/or offset (forest plantations). Bonds demand comes out of carbon savings from forest conservation or offsetting forests, whereas bonds supply arises from investments giving off carbon emissions that must be avoided through forest conservation or offset through forest plantations. A Loanable-Forest Funds (LFF) model is developed which shows that forest conservation scenarios require lower rates of interest on forest bonds than forest offsetting ones. Then, unlike the Kyoto Protocol, which emphasises forest offset (forestry-CDM), the formal inclusion of forest conservation (REDD+) in the Paris Agreement might lower the real rates of return to long-term forest investments.

Keywords: forest assets, forest financing, loanable forest funds, natural capital markets, climate policy

1. Introduction

Recent estimates of the planet's carbon (C) budget found an unaccounted imbalance of about 1.8 Gt (1 Gt = 10^9 tonnes), whose wanting absorption points to the existence of a missing carbon sink that probably lies in forests. Out of the 7 GtC given off yearly by the combustion of fossil fuels and land-use changes around the globe, oceans absorb some 2 GtC, whereas the atmosphere takes up other 3.2 GtC [1]. The amount of atmospheric carbon transformed into forest biomass has been estimated at 25–30 Gt per year. The world's forests can store 283 GtC in their biomass alone. If the carbon held in dead wood, litter and soil is added, carbon storage can reach 762 GtC, which is more than the amount of carbon in the atmosphere [2].

Nonetheless, forests have been cautiously considered by the ongoing climate policy as a safe way to sequester and store carbon emissions. A 'forestry-CDM' (Clean Development Mechanism) was first put forward at the CoP-5,[1] in Bonn, Germany, in 1999, by African, Asian and Latin American forest-rich countries to allow for the inclusion of afforestation and reforestation projects in tackling climate change. These projects, however, concerned unnatural forests or forest plantations. Later on, at the CoP-13, in Bali, Indonesia, 2007, it was argued that 'avoiding deforestation'[2] was the cheapest way to reduce carbon emissions, thereby spurring forest protection rather than forest offset [4]. Thence, the CoP-14, in Poznań, Poland, 2008, approved a mechanism to incorporate forest protection into the efforts of the international community to combat climate change [3].

Although the forest protection feature of the 'avoiding deforestation' approach has meant a step forward regarding carbon offsetting from forestry-CDM, it does not properly encourage forest conservation. It works as a reward for 'not doing something' (not deforesting or not degrading) that is legally forbidden, instead of fostering the production of something additional, such as the storage of new carbon, brought about by forest conservation techniques[3] [5, 6].

Unlike common-sense understanding, conservation does not mean non-use, but rather saving for the future, which amounts to investment [7]. In this sense, it is an economically productive activity that implies transformation over time, and through which goods and services available today are also made available in the future [8]. Forest stocks are thus natural capital assets, whose treatment belongs in the theory of capital and investment [7].

In climate negotiations, such an approach started being outlined at the CoP-15, in Copenhagen, Denmark, 2009. Next, at CoP-16, in Cancún, Mexico, 2010, the Green Climate Fund (GCF) formally allowed for deforestation avoidance (REDD),[2] forest conservation and enhancement of forest stocks (REDD+)[4] [3]. Then, at CoP-21, in Paris, France, 2015, the Paris Agreement stated the

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[1] The Conference of the Parties (CoPs) are formal meetings of the UNFCCC (United Nations Framework Convention on Climate Change) that are yearly held to assess progress in dealing with climate change. They began in the mid-1990s to negotiate the Kyoto Protocol and legally binding obligations for the reduction of greenhouse gas (GHG) emissions by developed countries. As of 2005, the CoPs turned out to bring together the parties to the Kyoto Protocol (Annex I countries) and those that were not parties to it (Non-Annex I countries). As of 2011, the CoPs had also been being used to negotiate the Paris Agreement, concluded in 2015 and meant to be a general path for climate action [3].

[2] This strategy has got to be known by the acronym REDD (Reduced Emissions from Deforestation and forest Degradation). But, as set out at CoP-16, in Cancún, Mexico, 2010, when it is added forest conservation, sustainable management of forests (SFM) and enhancement of forest carbon stocks, a plus (+) sign is attached.

[3] These techniques are encompassed by a wide range of practices labelled under SFM (Sustainable Forest Management). 'Forest management practices to conserve and sequester C (carbon) can be grouped into four major categories: (i) maintain existing C pools (slow deforestation and forest degradation), (ii) expand existing C sinks and pools through forest management, (iii) create new C sinks and pools by expanding tree and forest cover, (iv) substitute renewable wood-based fuels for fossil fuels' [1].

[4] See Footnote 2.

importance of financial resources to encourage deforestation avoidance, forest conservation, sustainable management of forests and enhancement of forest stocks[5] [10].

Anyway, neither for natural nor for unnatural (planted) forests has a forest bond market soundly been attempted yet. So far, the bulk of climate finance comes from financial assistance,[6] flowing from developed to developing countries [11–13]. Moreover, the existing *green bonds* are mostly devoted to funding clean energy, water, low-carbon transport and building[7] [14–16]. Land use, including sustainable forestry and agriculture, is covered by only 0.1% of the green bonds market[8] [17].

In order to stand out as financial assets, forests, as any capital asset, must get their value out of the periodical income flow they are able to yield. Arguably, in the climate policy for a low-carbon economy, that income flow ought to correspond to the amount of carbon a forest can yearly store, that is, to the carbon flux (in GtC or $GtCO_2$ per year) during the time over which the forest removes any given deal of emissions.[9] As the bridge or linkage between income and capital is the interest rate [18], the greater the carbon removal flux,[10] the higher the rate of return (interest) of the forest stand—thereby implying that it can provide larger income (carbon removal) flows per year. Accordingly, an interest-bearing bond grounded in the carbon stock of a forest would pay higher yields, thus driving its rate of return (interest) to rise.

Although usually thought of as a percentage reward upon an amount of money traded off between present and future, the interest rate holds for any other goods or commodity [18], such as carbon storage. Therefore, forest finance had better draw on a commodity money standard [10, 21]. Unlike *paper* or *fiat money*, which is intrinsically useless, commodity money requires an object that is

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[5] This statement sets down, after decades of struggle, the explicit recognition by both developed and developing countries of the role that (particularly, natural) forests have in addressing climate change [9].

[6] During the initial resource mobilisation period (2015–2018), fast-start finance (FSF) for climate (10.3 billion US dollars) in the Green Carbon Fund (GCF) comes from developed countries only. They have agreed to mobilise, until 2020, 100 billion US dollars per year to meet mitigation and adaption needs in developing countries [11, 12]. So far, annual climate finance flows from developed to developing countries have been estimated to lie roughly between 10% (40 billion US dollars) and 25% (175 billion US dollars) of estimated global total climate finance. About half of this share corresponds to grants, with mitigation receiving the largest part, whereas one-third of it is accounted of by ODA (Official Development Assistance) loans provided by multilateral climate funds, whose resources come virtually in full from developed countries' national governments [13].

[7] *Green bonds* have been establishing an increasingly attractive niche in the financial market. In 2014, the issuance of green bonds skyrocketed to a record of 37 billion US dollars, driven by a surge in corporate self-labelled issuance—that is, bonds issued by corporations with proceeds ring-fenced for green investments—as well as by volumes from large international and supranational banks. Regardless of its fast growth, however, the global green bonds market accounts for about 2.5% only of the issuance of corporate bonds in the USA alone, which was worth 1.4 trillion US dollars in 2013 [14, 15].

[8] Approved standards are still missing to set out which land use projects are applicable for bond issuing and certification [16]. Meanwhile, forest funds, which have been essential to tackling deforestation and to laying the groundwork for more sustainable management and governance of the natural assets of countries, rely on results-based finance (RBF), whereby direct payments are made upon delivery of pre-defined climate outcomes, such as verified greenhouse gas (GHG) emission reductions [9].

[9] Even though forest bonds have long been recognised as a potential financing instrument, their use has usually been called for avoiding deforestation, where income flows or revenue streams are not obvious [17].

[10] Sometimes [19, 20], data on net carbon *removals* are represented by a *negative* flux, whereas those on net carbon *emissions* are expressed by a *positive* flux. However, provided that the capital value of a forest is given by its carbon storage, *positive* fluxes throughout this chapter stand instead for net *removals*.

intrinsically useful as an input to production or consumption. A claim to (loan of) long-lived capital, like forests, contains an option to consume a predetermined service flow, such as the storage of carbon emissions, that can be used, like commodity money, as a medium of exchange [21, 22].

Provided that carbon storage is an actual source of forest income, *carbon money* conveys the expected uptake of carbon emissions by a forest. Whereas conservation of natural forests either enhances it or avoids carbon losses from deforestation and forest degradation, forest plantations (unnatural forests) can offset carbon emissions given off by the economic activity. Therefore, either natural or unnatural forests can be used as removal sinks (carbon savers) to carbon-consuming investments (emitting sources). By issuing and supplying carbon-laden bonds, emitting sources may meet carbon-saving sinks whose offering of removal capacity corresponds to a demand for carbon emissions enclosed in bonds. The demand for carbon conservation, through natural forests, or carbon offsetting, through forest plantations, will ride on the rate of return (interest) each forest bond potentially offers to its holder.

The major objective of this chapter is then to find the real rate of return (interest) (r) on natural ($k = n$) and unnatural ($k = u$) forest bonds in both Annex I ($j = 1$) and Non-Annex I ($j = 0$) countries.[11] In this regard, six scenarios have been set out, in which emissions from Annex I and Non-Annex I countries' economies demand removal being supplied by either natural or unnatural (planted) forests. Scenarios vary according to either the removal sinks called in (natural forests, unnatural forests or both) or the emitting sources seeking carbon removal (Annex I, Non-Annex I countries or both). But in none scenario, the rate of interest is supposed to vary according to the quantity or value of money.

The reason for this classical, nonmonetary assumption, discussed in the following sections, is twofold. Theoretically, changes in the rate of interest are ultimately triggered by changes in the demand for real commodities, whose movements affect the demand for money and cause prices to alter [24]. Empirically, carbon is a commodity whose emerging bond market includes a great deal of currencies. At present, there are 25 currencies represented in the labelled green bond market [17]. Therefore, the determination and comparison of money rates of interest would not come without tackling disturbances caused by monetary phenomena affecting each currency (e.g. inflation rates, budgetary imbalances, money and credit supply).

2. Historical background

Long-term options on climate financing started being taken up at CoP-15, in Copenhagen, Denmark, 2009, following the Copenhagen Accord and the Copenhagen Green Climate Fund.

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[11] *Annex* I Parties comprise the industrialised countries that were members of the OECD (Organisation for Economic Cooperation and Development) in 1992, when the UNFCCC emerged out of the Rio Earth Summit, plus countries with economies in transition (the EIT Parties), including the Russian Federation, the Baltic States and several Central and Eastern European States. *Non-Annex* I Parties are mostly developing countries. Certain groups of developing countries are considered to be especially vulnerable to the adverse impacts of climate change; others, whose income is heavily reliant on fossil fuel production and commerce, feel more vulnerable to the potential economic impacts of climate change response measures [23].

At CoP-16, in Cancún, Mexico, 2010, the Green Climate Fund (GCF) was formally put forward to assist developing countries in adaptation and mitigation practices to counter climate change. Concerning mitigation, issues such as avoidance of deforestation and forest degradation (REDD), forest conservation, sustainable management of forests (SFM)[12] and enhancement of forest carbon stocks in developing countries (REDD+) were addressed. Developed countries then committed themselves to provide 30 billion US dollars of fast-track finance in 2010–2012 and to jointly mobilise 100 billion US dollars per year by 2020 [3, 25].

At CoP-17, in Durban, South Africa, 2011, the GCF became, along with the existing Global Environmental Facility (GEF) of the World Bank, another operating entity of the financial mechanism of the UNFCCC (United Nations Framework Convention on Climate Change). However, at CoP-18, in Doha, Qatar, 2012, little progress was made towards the funding of the GCF. Developing countries became suspicious of the provenance of the money pledged to it. They feared that this money could be raised from private sector's wealthy investors who would deny channelling it to poorer regions in need of climate finance resources [3, 10, 26].

At CoP-19, in Warsaw, Poland, 2013, the financing of renewable energy and of technology transfer to developing countries was brought up. Accordingly, climate finance and capitalisation of the GCF were considered the most important milestone. Yet, financial commitments made before by developed countries melted into talks about alternative sources of funding and a rebuttal to support any loss or damage payments to developing countries [3].

A binding[13] and global agreement to reduce climate change was finally reached at CoP-21, in Paris, France, 2015, after a somewhat faint CoP-20, held in Lima, Peru, 2014. The *Paris Agreement*, the legal instrument ruling climate policy as of 2020 in place of the Kyoto Protocol, restated the leadership of developed country parties in providing financial resources to developing country parties for both mitigation of and adaption to climate change (Article 9). These latter countries, though, were encouraged, as part of a global effort, to provide support voluntarily [3, 10, 26].

Despite its shortcomings, the Paris Agreement recognises the need of finance flows to tackle climate change (Articles 2 and 9). However, for reasons just mentioned, there is some controversy about the extent to which capital markets should assist in raising the funds to the GCF. On one hand, by pooling savings, free capital markets are said to provide planned investments with the money needed to carry them out [27, 28]. Put differently, capital markets allow for the so-called

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[12] See Footnote 3.

[13] The Paris Agreement calls forth its signatory parties to set their own emission reduction targets, thereby making their individual contribution towards the worldwide goal of reaching 'global peaking of greenhouse gas emissions as soon as possible' (Article 4). According to Article 2 of the agreement, the achievement of this goal implies holding the increase in the global average temperature below 2°C above pre-industrial levels and limiting the temperature increase to 1.5°C above pre-industrial levels. Each party must, therefore, establish its 'nationally determined contribution' (NDC) on a voluntary, non-binding basis. These national targets are required to be ambitious and to follow close the 'principle of progression', whereby each further contribution must be more ambitious than the previous one. So, in this narrow sense, that the parties' determined contributions must demonstrate progression over time, the agreement can be said to be binding. Yet, in a wider sense, the contributions themselves are not binding. There is no enforcement mechanism to set them, to phase them out, nor for non-compliance with them. Hence, regardless of its outreach coverage, bringing together 217 signatories plus 85 ratifying or acceding countries, the Paris Agreement rests on a fragile consensus. Countries failing to meet their commitments can easily withdraw, which might as well encourage other unsuccessful parties to do the same, thereby bringing about the total collapse of the agreement [10, 26].

finance demand for liquidity—the demand for money arising during the period between the date when the entrepreneur arranges his finance (cash) and the date when he actually makes his investment [28]. Such an investment finance is a special case of finance required by any productive process and lies halfway between the active and the inactive balances [29]. On the other hand, savings are thought to withhold money that could otherwise finance investments. Accordingly, money so withdrawn causes the rate of interest to rise, thereby impairing the investments [28].

The former standpoint shares with the classical *loanable funds* (LF) theory the view that savings support investments, whereas the latter stance draws on the *liquidity-preference* (LP) theory, to which savings lessen investments.

3. Theoretical background

After all, how helpful might capital markets actually be with mobilising climate finance? The answer lies in the extent to which money balances withhold or encourage investments. There are two opposed theoretical views concerning these propositions.

3.1. Nonmonetary and monetary theories of interest

Nonmonetary theories of interest, put forward by the classical economists, argue that it is not money lending or borrowing that regulates the rate of interest,[14] but rather the rate of profits (return on capital), which is totally independent of the quantity or value of money, yet dependent, instead, on the time length of production and the *real* forces of productivity [24, 30–32]. According to nonmonetary assumptions, any decision on saving (not consuming) implies another decision on spending on capital goods (investing). Provided that money is a medium of exchange, there can be no hoard[15] of idle monetary balances. Therefore, savings are turned into an available fund to be loaned for investment. The *real* interest rate is then the price that rewards the lenders of funds (savers) for their postponement of consumption until a certain moment into the future, provided that commodity prices would remain constant [32].

If it is true that people have positive time preferences,[16] thereby preferring the present over the future consumption, then the higher their income, the easier for them to put off their

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[14] Classically, the two nonmonetary reasons underlying the rate of interest are *time preference* and the *physical productivity of capital goods*. On the demand side, *time preference* implies that people generally value present goods more highly than future goods, chiefly because the means to meet present needs are thought to be scarcer than those to meet future needs. The future is believed to be more plentiful, either because people assume that their earning capacity will be greater then, or because their current possession of a durable asset gives them advantage to choose between using it either now or in the future, whereas future possession gives only the advantage of the latter use. On the supply side, the growing productivity of capital goods is, although riddled with controversy, ascribed to some technical superiority—capital goods reproduce more of themselves over time. However, there is at least one aspect of technical superiority on which there is no confusion. The technical superiority of present goods (either capital or consumption goods) is in part due to the fact that the present investment of resources has a greater present value than next year's investment of those same resources [24].

[15] Hoard is defined as the quantity of money supplied *less* the quantity of money demanded by the public to meet its transactions of goods and services or precautionary behaviour [33].

[16] See Footnote 14.

consumption further into the future. Savings, therefore, are encouraged by increasing incomes, rather than by higher rates of interest. This argument bears the gist of the attack of *monetary* on nonmonetary theories of interest, regardless of the latter's reply that, under the assumption of full employment in the long run, neither income, nor the economic output, nor commodity prices are supposed to vary [32]. Yet, monetary theorists insist that there can be savings irrespective of the rate of interest, which is not a reward for waiting or not consuming, but, rather, for not hoarding.[14] Likewise, the rate of return on loans or on investments is not a reward for the wait itself, but, rather, for the preference towards risk. Since, in the contemporary monetary economies, all transactions are carried out in money rather than in commodities, there is a direct and objective relationship between the quantity of money and the rate of interest [33]. The rate of interest responds therefore to changes in the supply and demand of *money*, instead of funds (loans) [24].

3.2. Money rate and natural rate of interest

Nonetheless, nonmonetary theorists maintain that, even in an economy using money, the relation between capital and its yield, or between rent and interest, has no connection with the borrowing and lending of money [24]. 'Money does not itself enter into the process of production' [34]. The borrower of money does not intend to keep it but to exchange it at the first suitable opportunity for goods and services [34]. Moreover, money could, theoretically, be substituted for any other commodity. Yet, in practice, only money is traded off for between present and future. For this reason, in contemporary economies, the rate of interest is often misleadingly defined as the 'price of money' [18].

Actually, this *money* rate of interest is but a kind of aberration from the *real, natural* or *normal* rate, which depends on the efficiency of production, on the availability of fixed and liquid capital[17] and on the supply of labour and land[18] [30]. Accordingly, the *natural* rate

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[17] *Fixed* capital is the one bearing a very *high* and sometimes unlimited *durability*, such as houses, streets, railways, canals, certain improvements in land and certain kinds of machines. They are *rent-earning* rather than capital goods. Unlike *real* capital goods, which are due the payment of interest, rent-earning goods are not, because they contribute to output either with or without the assistance of further labour and land. Instead, they earn for their owners a certain rent, analogous to the rent of land [30]. The determination of the *real, natural* or *normal* rate of interest, therefore, does not rely on this kind of capital, which is more or less fixed or tied up in production. It rather hinges on *liquid* capital, that is, *mobile* capital in its *free* and uninvested form. Unlike commonly thought, this kind of *real* capital consists neither of stocks of manufactured, semi-manufactured and consumption goods, nor of stocks of raw materials. Actually, *free* capital does not have any material form at all. It is accumulated by those who save and abstain from consumption a part of their income. 'Owing to their diminished demand, or cessation of demand, for consumption goods, the labour and land which would otherwise have been required in their production is set free for the creation of fixed capital for future production or consumption and is employed by entrepreneurs for that purpose with the help of the money placed at their disposal by savings' [34]. Thus, *the natural* or *normal real* rate of interest corresponds to the expected yield on the newly created capital.

[18] One landmark assumption in classical theories of interest, like the so-called Stockholm theory of savings and investment, draws on Böhm-Bawerk's proposition that there are only two 'original' factors of production: land and labour. Capital just comes into existence because production takes *time* [31, 35]. Or, as Wicksell states it, 'the characteristic of capitalist production lies simply in the fact that … the main portion of the available labour and land is employed for the purposes, not of *current* consumption, but of consumption in the more or less distant *future*' [30]. Therefore, apart from decreasing returns, the lengthier the period of production, the larger the output. Too lengthy periods of production, however, would be held off by positive time preferences (see Footnote 14). That is, people prefer present over future goods, because of their present needs and uncertainty about the future [31].

follows suit the rate of return on capital and, at best, holds, as it were, only an indirect relationship with commodity prices[19] [30, 34]. It is determined by supply and demand as if no use of money were made and all lending were carried out in the form of real capital goods [24, 30]. Thus, in these circumstances, the use of a *money* rate of interest does nothing more than serving as a cloak to cover a procedure, which could have been carried on equally well without it [30].

3.3. Money rate and own rate of interest

The *money* rate of interest is technically defined as the percentage excess of a sum of money contracted for forward delivery over the *spot* or cash price of that sum. Its analogue for every kind of capital asset is the *own* rate of interest on commodities, which is the rate of interest for every durable commodity in terms of itself [24]. The former rate, set in terms of money, and the latter, set in terms of commodities, indicate a relationship between present and future values of assets (including money), whose most fundamental meaning is that provided by Fisher's marginal rate of return over cost [18, 24], namely: (future income − present income) ÷ present income.

In either case, income can be replaced by the amount of an asset (including money) that could be secured at some future time in return for a given present amount. Lending is, in any event, involved, because futures are bought in exchange for spot claims or, likewise, present assets are converted into future assets. However, if money is lent, the lender sells an immediate claim to buy a future claim. Conversely, when a commodity is borrowed, the borrower buys a spot claim and sells a future claim. Therefore, the relation between *money* and *own* rates of interest builds upon the type of asset used to work them out [24]. Whereas the *money* rate of interest is sensitive to commodity prices, the commodity (*own*) rate of interest will

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[19] As Wicksell remarks, interest on money and profit (return) on capital are not the same thing. Yet, interest and profit connect to one another through the *effect on prices* caused by their difference. Hence, when the rate of interest is lower than the rate of profit, prices must rise. Such a difference between the two rates turns credit easier, thereby bringing about the excess of demand over supply of raw materials, labour, land, and the like, as well as, directly and indirectly, of consumption goods. In the opposite situation, when the money rate of interest is higher than the rate of return on capital, prices fall [30, 36]. Thus, Wicksell's unusual proposition is that rates of interest and prices run in opposite directions. It frontally clashed with the ambiguous view that the money rate of interest depended not only on the excess or scarcity of money but also on the excess or scarcity of real capital. This opposing proposition followed from the usual definition that interest is the compensation paid for the use of capital, not of money. Money is only one of many forms of capital that can be transferred through loans. Therefore, under a system of credit, business men could get money to buy the capital goods (investment) needed to production. On one hand, this would result in an increased output (supply), thereby, given an unchanged output demand, causing commodity prices to fall; on the other hand, the growing demand for capital goods would raise the rate of interest [30]. Yet, followers of the *Banking School* and even of the *Currency School* of money suggested that a low rate of interest cheapened one of the elements of production, thereby bringing commodity prices down, whereas a high rate of interest raised the costs of production, thereby driving commodity prices up [36]. In any event, the rate of interest and prices moved in the same direction. Wicksell, then, wonders: 'How can a scarcity of goods be regarded as a cause of a rise in the rate of interest or a fall in prices?' And he, himself, keeps on to give the answer: 'On the contrary, the smaller the available amount of commodities, the smaller … is the demand for money. It follows that the rate of interest will fall rather than rise and that prices will go up still further' [30].

only be equal to the money rate if the spot price of the commodity is the same as its forward price[20, 21] [24, 30, 37].

Monetary theorists reply that, in contemporary economies, capital is, notwithstanding, lent in the form of money [30, 37]. Because barter is unwieldy, seldom are real and present commodities exchanged for real and future ones [37]. Not even merchandise credit involves any lending of commodities. Rather, it is carried on through a sale where payment is temporarily postponed or where a cash transaction is combined with a money loan [30]. At best, intertemporal trade corresponds to the exchange of present commodities for a pledged cash payment in the future (postponed payment), or, vice-versa, to the exchange of cash for a pledged delivery of commodities in the future (anticipated payment). Hence, in either case, any credit transaction comes down to a *money* loan combined with a spot or forward delivery of goods [37].

3.4. Loanable funds (LF) and liquidity-preference (LP) theories

Unsurprisingly, in the context of monetary economies, nonmonetary theories of interest have been deemed inadequate. They deny that changes in the quantity of money or the desire to hoard can set off but temporary, short-run effects throughout the economy. Drawing on classical concerns, nonmonetary approaches turn instead to *long-run* problems and against money as the exclusive determinant of the rates of interest [24].

Whereas pre-classical writers were men of affairs, concerned with daily events and thus with the *short-run* forces affecting the rate of interest, the classical writers were mostly philosophers of political economy whose concern was less with daily changes than with *long-run* movements [24]. Even though changes in the quantity of money might as well have a lasting effect on the rate of interest, the classical economists were primarily concerned with brushing aside any confusion that might be implied by mixing up *monetary* and *real* capital. Whereas the former refers to financing funds and to a certain deal of money, the latter includes concrete goods and certain amount of them [37]. Which, after all, eventually determines the rate of

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[20] The *own-rate of interest/return* (or the commodity rate of interest/return), r, is given by $r = (Q_2 - Q_1)/Q_1$, where Q_1 is the quantity of the commodity in the present, and Q_2 is the quantity of the commodity in the future. The *money rate of interest/return*, i, is given by $i = (P_2Q_2 - P_1Q_1)/ P_1Q_1$, where P_1 is the spot price of the commodity, and P_2 is the forward price of the commodity. Clearly, if $P_2 = P_1$, then $i = r$. An adjustment factor α can be found which represents the difference between the money rate of interest/return (i) and the own-rate of interest/return (r). This factor measures the influence of the price change ($(P_2 - P_1)/P_1$) on the future quantity of the commodity (Q_2), as if it should continue to be valued at its cash price (P_1). Algebraically: $[(P_2 - P_1)/P_1)]\cdot P_1\cdot Q_2$. In order to express this value as a proportion of the original value, it must be further divided by P_1Q_1. Therefore: $\alpha = \{[(P_2 - P_1)/P_1)]\cdot P_1\cdot Q_2\}/ P_1Q_2 = (P_2 - P_1)/P_1)\cdot (Q_2/Q_1)$ [24].

[21] *Forward* prices must not be mistaken for *future* prices. *Forward* prices are current prices with an addition for interest. They refer to prices accepted today for an immediate delivery of goods which will not be paid for until some point in the future. Therefore, they have nothing in common with prices that will have to be paid in the future for goods or services supplied *in the future*. The level of these *future* prices will be determined by the relation existing in the future between the conditions of supply and demand [30].

interest, the level of savings and investment: the demand for *money* or for *goods*? The *loanable funds* (LF) theory[22] claims that the right answer lies in the excess demand for *goods*; the monetary *liquidity-preference* (LP) theory maintains, on the other hand, that it rests on the excess demand for *money*[23] [40, 41].

Building on the demand and supply of loans, the LF theory holds that *securities* determine the rate of interest [39, 41, 42]. Regulating the supply and demand of 'claims' or interest-bearing securities, the rate of interest becomes the driver of the investors' supply and savers' demand of (loanable) funds that can be borrowed and lent [37, 39]. So, the supply of loanable funds (S) may be thought of as being the demand for claims or securities (B^D), whereas the demand for loanable funds (I) may be regarded as the supply of claims or securities (B^S)[24] [24]. The LF theory, however, emphasises savers' behaviour, because the rate of interest is taken rather as the *cause* than as the effect of saving.

In sharp disagreement with monetary assumptions, this proposition maintains that the rate of interest can neither be a reward for not hoarding or waiving liquidity (i.e. demanding money, the most liquid asset), nor can it be determined by the desire to keep money idle [39]. Savings are directed either to idle balances, through the demand for money, or to active investments, through the demand for securities [24, 27, 39]. Idle balances in the hands of consumers constitute but one of the alternative destinations of savings and absorption of cash, the others being investment market, banks and circulating capital of industry [39].

More generally, 'the rate of interest is simply the price of credit, and it is therefore governed by the supply of and demand for credit [or finance]' [35]. The supply of credit (or finance) is

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[22] Monetary theories of interest have had three major roots: (1) the Swedish approach provided by the Stockholm theory of savings and investment [30, 34, 35, 38, 39], initiated largely by Knut Wicksell and followed by Bertil Ohlin, Eric Lindahl, Gunnar Myrdal and Bent Hansen; (2) the English neoclassical tradition, most fully represented by D. H. Robertson; and (3) the school founded by John Maynard Keynes [29, 33]. The Swedish and English approaches are conveniently grouped together under the head of *loanable-funds theories* (LF); the Keynesian approach is best known as the *liquidity-preference theory* (LP). Yet, it is disputed whether the LF theories tune in to the monetary or to the nonmonetary frequency of the spectrum. As shown in Section 3.2, Wicksell's dynamic analysis builds on the divergence between the *natural* rate and the *money* rate of interest. Whereas the *natural* rate of interest owes to the (classical) nonmonetary tradition, the *money* rate of interest springs from the monetary branch. Therefore, at worst, the LF thinking represents a transitional linkage between one and another theoretical tradition [24]. Nonetheless, its underlying assumptions and analytical framework recall, to a large extent, those of nonmonetary theories.

[23] Assuming that financial wealth (W) may be split into *monetary* assets (money) and *nonmonetary* assets (e.g. bonds), it can, from the point of view of *income*, be expressed as $W = M + B^S$ (where M is money supply and B^S is bonds supply), and, from the point of view of spending, as $W = L + B^D$ (where L is the demand for money and B^D is the demand for bonds). By getting both expressions together, it comes out: $M + B^S \equiv L + B^D$, which, rearranging, gives $(B^S - B^D) \equiv (L - M)$. This macroeconomic identity is said to describe the static partial-equilibrium analysis of the financial market. The left-hand side accounts for *nonmonetary* assets, in which B^S corresponds, in the loan market, to the demand for loanable funds springing from investments (I), and B^D, to the supply of loanable funds brought about by savings (S). Therefore, in terms of goods market, the left-hand side would translate into $(I - S)$. Likewise, the right-hand side accounts for *monetary* assets. The excess demand for goods occurs when $(I - S) > 0$, whereas the excess demand for money comes about when $(L - M) > 0$. In the LF theory, the money market is supposed to be in equilibrium $[(L - M) = 0]$, so that the rate of interest is fully determined in the bonds market. Conversely, in the LP theory, the bonds market is supposed to be in equilibrium $[(B^S - B^D) = 0]$, so that the rate of interest is entirely set by the money market [40].

[24] See **Figure 1**, in Section 4.

given by people's willingness to hold different interest-bearing claims (bonds or equities) and other kinds of assets, whereas the demand for credit (or finance) is governed by the total supply of claims [35]. Yet, credit is closely related to savings and investment, because any saver (supplier of funds) must decide as well on whether to invest (demand for funds), to lend (demand for bonds or equities) or, even, to increase the quantity of cash (demand for money) instead of lending [39]. As loanable funds (or balances) come out of the discrepancies between income and expenditures, changes in idle stocks arising from new hoard (savings) or dishoard (investment) define a *flow* that will respectively give rise to a demand for claims (bonds or equities) and a supply of claims. Therefore, the LF theory is said to take up a *flow*, rather than a stock, approach[25] [24].

The *stock* (portfolio) approach is taken up by the LP theory, according to which the demand for money (or *liquidity preference*) determines the stock of cash held by society. If its individuals prefer to hold money over other assets (e.g. bonds), they will be hoarding and accumulating idle balances instead of increasing the working capital or active investment. Thus, their savings are diverted from the investment market to increase idle balances at the expense of the active ones. So long as the supply of money is assumed to be rigidly fixed, the consequence of an increased propensity to hoard is the rise of the rate of interest, which is, therefore, typically a monetary variable [39].

Since it is set by the supply and demand of money (cash) *solely*, the rate of interest in the LP theory is, unlike in the LF theory, rather the *effect* than the cause of savers' behaviour, which is assumed to be driven by liquidity preference (i.e. demand for money). Given this public's propensity to hold money, the LP theory argues that investments rely less on foregone consumption—that is, existing savings—than on financing—that is, access to money [24, 27, 33, 37]. Thus, investments can never be constrained by the lack of savings, but, rather, by the lack of money [27].

In some instances of the LF theory, on the other hand, the only effect of money is causing prices to change. The money rate and the natural (real) rate of interest mostly differ, because the transfer of capital and the remuneration of factors of production are not made in kind, but 'in an entirely indirect manner as a result of the intervention of money' [30]. So, instead of being lent or borrowed, real capital goods are now bought or sold. Therefore, 'an increase in the demand for real capital goods is no longer a *borrowers'* demand which tends to raise the rate of interest, but a *buyers'* demand which tends to raise the prices of commodities' [30]. Since the LF theory minds the effects of money on the real factors of production, it is often said to link nonmonetary and monetary theories of interest[26] [24].

To wind up, what monetary theories seem to have overlooked is that, although money is credit, credit is not necessarily money. Only when a debt pledge can be transferred to or traded with a third party, does credit get close to money. Then, transferrable debt and money blend into each other to mean the same [43]. Yet, money comes after. There must have been credit or some sort of transferrable fund—whether a debt claim (bond) or an ownership claim (equity)—before. Moreover, the public's holdings of cash (money) and credit, plus what it receives during a period, define its ability to spend or its total (unused) purchasing power. Whether it is exerted in the

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[25] This split, however, is often disputed. A thorough discussion can be found in [24].

[26] See Footnote 22.

present (consumption) or delayed until the future (investment), the purchasing power cannot be said to have diminished whatsoever but simply transferred over time [38]. Unlike in monetary theories, in nonmonetary theories, money does not itself function as a store of value. Therefore, any deferment of purchasing power can only be done by means of nonmonetary assets, like securities (bonds or equities), which are pieces of property that can store value [44].

4. Methodological assumptions

What, after all, does this theoretical discussion have to do with financing long-term productive investments, such as forest conservation or plantations? Natural capital, like forests, is, of

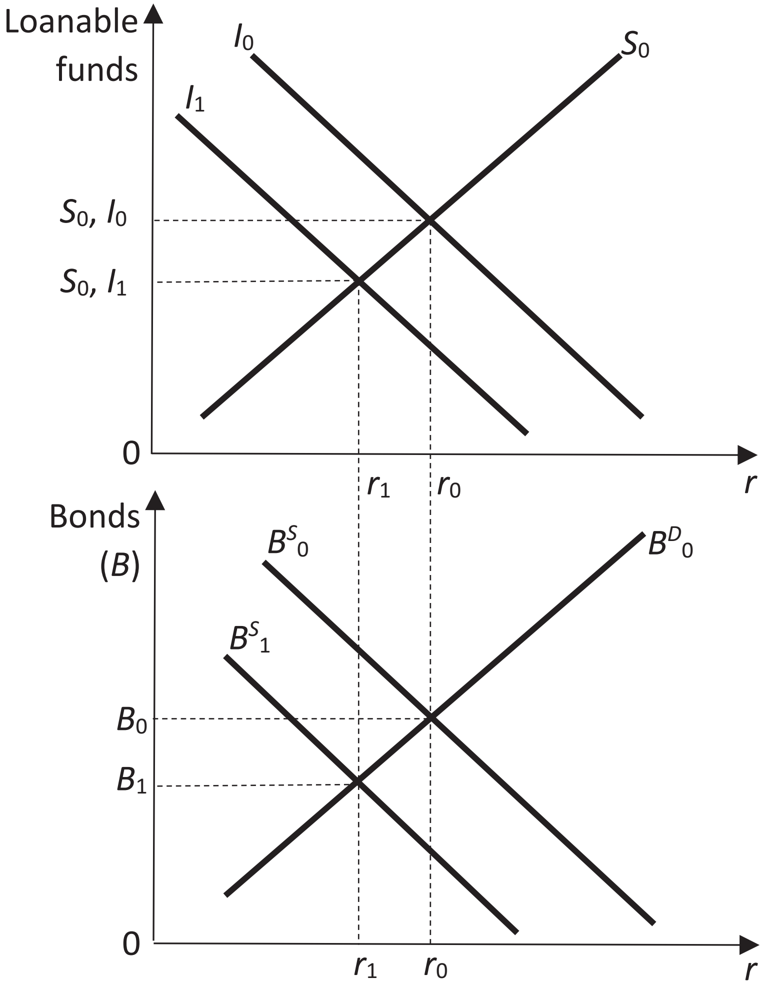

Figure 1. Loanable funds market.

course, a *real* rather than a monetary capital. It delivers concrete goods, namely carbon stocks, whose monetary valuation is laden with uncertainty concerning their future prices. Hence, alternatively, carbon stocks can be thought of as intrinsically useful objects that might serve as media of exchange, since they deliver environmental protection and offsetting services.

4.1. Commodity money

Unlike *paper* or fiat money, which is intrinsically useless, carbon stocks enclose a service flow that can be optionally consumed [21]. Of course, because, as yet, they are neither legal tender tools nor do fully function as unit of account, medium of exchange and store of value, they cannot be taken as money proper. However, they virtually fit in an economy with a *commodity* money standard.[27]

A commodity money system provides an anchor to the price level, so that prices, as claimed by the LF theory, do not affect the rate of interest (see Sections 3.3 and 3.4). In this system, when the value of the commodity-bearing money falls, it becomes preferable to exercise the option and convert it into other, nonmonetary uses, thus reducing the quantity of money and preventing its value from falling further. Conversely, when the value of the commodity-bearing money rises, it becomes preferable to hold more money [21].

4.2. Carbon money and loanable funds model

If carbon stocks are the commodity standard, their outflow (say, because of deforestation) lessens a country's (natural) assets and, therefore, the supply of *carbon* money [45]. For a given demand for carbon removal stocks, the rate of interest on carbon stocks must rise. This upward movement, however, concerns the rate of interest on commodity money. The rate of return on forest assets (i.e. the *natural* rate of interest) is supposed to remain unaffected, provided the removal capacity of forests has not changed yet. Then, if, as in **Figure 1** and in the Wicksell's version of the LF theory (see Section 3.4), the 'commodity money' rate of interest (i) becomes higher than the *natural* rate of interest[28] (r), the demand for loanable forest funds (I) to finance offsetting forest investments (plantations) will fall (from I_0 to I_1). As no further production of carbon offsetting stocks will take place, there will be no additional demand for raw materials or factors of production. Thus, the prices of unnatural forests will go down, thereby diminishing the supply of carbon-laden forest bonds (from ${B^S}_0$ to ${B^S}_1$). So, just like in the Wicksell's system, an initial increase in the (commodity) money rate of interest causes prices to fall.[29]

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[27] The *gold standard* is certainly the most known historical example. For more details, refer to [45, 46].

[28] Ohlin disagrees with Wicksell in respect of the distinction between those rates [27, 35]. 'The distinction between "normal" [natural] and "not normal" interest rates and savings depends on arbitrary assumptions that one kind of economic development, e.g. a constant wholesale price level, is "normal". Besides, it is far from certain that there is always one interest level which guarantees the existence of this normal development. On the one hand, it is possible that *no* interest level can do this. On the other hand, a great many and rather different interest levels may satisfy the condition of being compatible with this development' [35]. Ohlin, therefore, concludes that, in a dynamic analysis, such ideas have to be given up, although, on static assumptions, it is possible to define a certain interest level and the corresponding volume of savings which is compatible with the maintenance of static equilibrium. In this case, savings and interests diverging from them could then be called 'abnormal' or 'artificial' [35].

[29] See Footnote 19.

Eventually, *cœteris paribus*, the rate of interest on loans will end up falling too (from r_0 to r_1). Conversely, because of the inverse relationship between the price of bonds and the rate of interest (Eqs. (1) and (5)), prices of unnatural forest bonds (P_{uj}) will rise. The opposite movements hold for an inflow of carbon stocks (say, because of growing forest conservation).

5. Loanable-Forest Funds (LFF) model

Long-term climate financing laid down in the Paris Agreement is particularly attempted now for forests by applying a loanable funds model. The structure of financial markets in general is shown in **Figure 2**, while that of the *Loanable-Forest Funds* (LFF) model is displayed in **Figure 3**.

Data on net removal of carbon emissions per year by the world's forests come from FAO for the 1990–2015 period[30] [47]. These data are used to estimate the world's supply of carbon removal stocks by forestland (S), whether it is covered by natural or unnatural forest sinks. These carbon stocks are the *funds* that forest sinks of kind k will loan to carbon emission sources j (Annex I and Non-Annex I countries) by demanding carbon-laden forest bonds (B^D). These bonds are supplied (B^S) by the emission *sources*, which demand carbon stocks to prevent or offset the emissions brought about by their industrial[31] investments (I). The issuance of bonds, however, must reckon how long it will take for either kind of sink to fully meet the sources' removal needs. These needs are set by the total emissions of carbon dioxide (CO_2) at *each* source. Thus, the bond price (P) depends not only on the yearly carbon removal flux (Ψ) at each sink but also on the emissions per source. Data on CO_2 emissions per source are provided by the World Bank [48]. Yearly carbon fluxes in natural forests were inferred from [49], whereas, in unnatural forests, they were estimated by [1].

All data related to emissions and removal fluxes have been converted from carbon (C) into CO_2 at the physical-chemically defined rate of 3.67 tonnes of CO_2 per tonne of C. Since all emissions are measured in real CO_2 units, they are more intuitive to the general public than the corresponding C units, preferred by scientists and governments [50]. Data on carbon emissions by countries are statistically regressed on annual real rates of interest informed by the World Bank [48] at each emission source (r_j) to obtain the demand function for carbon funds per source (I_j). The corresponding supply function of carbon funds (S) is arrived at by statistically regressing data on carbon removal by forests on average real rates of interest per annum at sources [$\overline{r} = (1/j)\Sigma_j r_j$].

In line with the LF theory, it is assumed that, if money influences are set aside, S figures fully translate into the demand for bonds (B^D) by *all* carbon-saving sinks k (both natural and unnatural forests), so that $S \equiv B^D$ [24]. The same holds for I_j, which will correspond to the quantity of bonds of kind k supplied by each source j (Annex I and Non-Annex I countries), so that $I_j \equiv \Sigma_k B^S_{jk}$ and then $\Sigma_j \Sigma_k B^S_{jk} \equiv \Sigma_j I_j \equiv \Sigma_k \Sigma_j B^S_{jk} \equiv B^S$.

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[30] These data refer to net emissions/removals by forests, but leave out net emissions/removals from deforestation (forest conversion). This is because deforestation is an emission source (demand for carbon removal stocks), rather than an emission sink (supply of carbon removal stocks).

[31] The adjective 'industrial' here is employed in an as broad meaning as to comprise any industry or productive activity. In this sense, sectors like agriculture and commerce, for example, are also considered 'industries'.

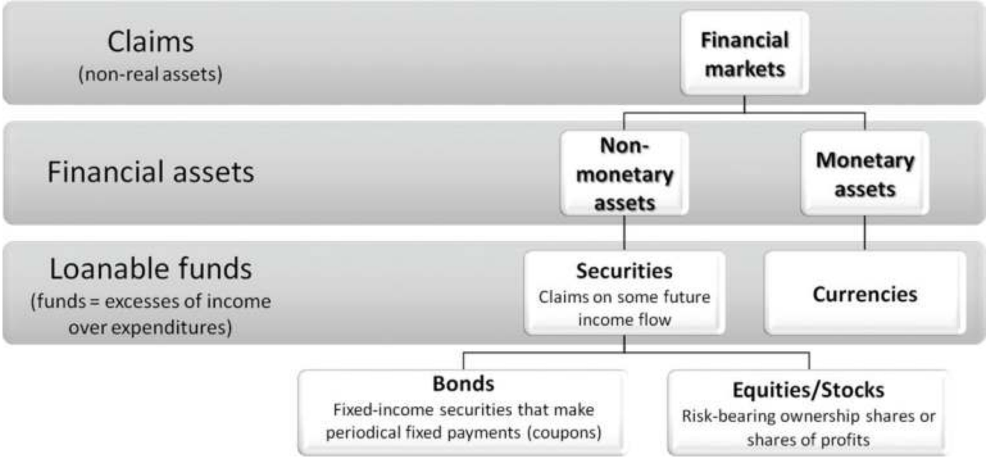

Figure 2. General structure of financial markets. Sources: Refs. [24, 42].

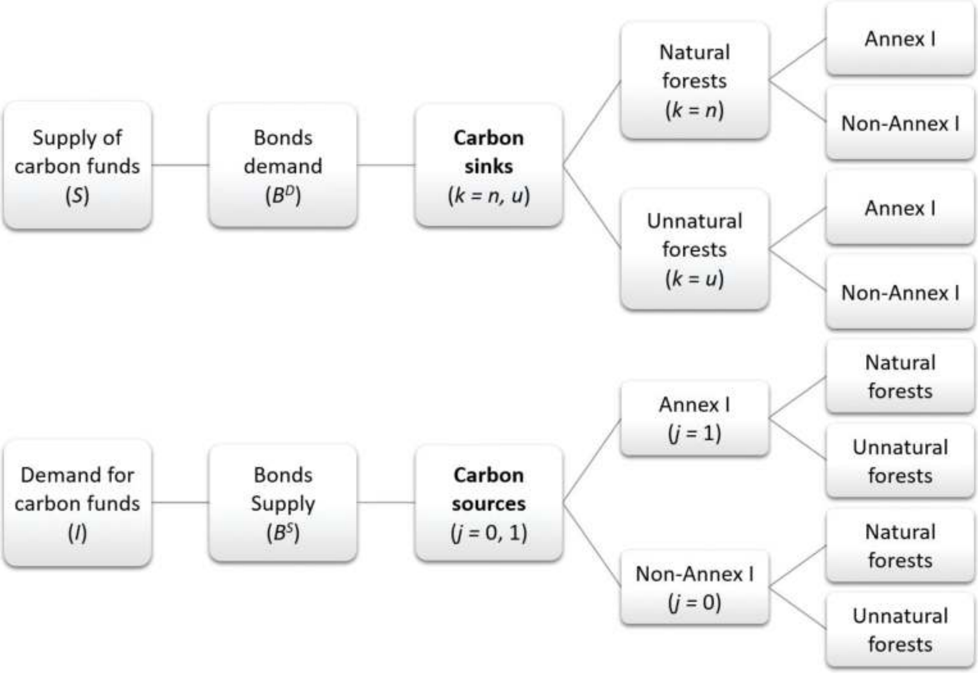

Figure 3. Loanable-Forest Funds (LFF) model.

The LFF model's interest is twofold. First, it is concerned with the total supplies of bonds made up in the last column of **Table 1**, that is, $B^S = \Sigma_k \Sigma_j B^S_{jk} = B^S_n + B^S_u$, which corresponds to the *row* sums. These *row* sums highlight the potential contribution of each forest sink to taking up the emissions

		Sources (j)		
		Non-Annex I ($j = 0$)	**Annex I ($j = 1$)**	**Total**
Sinks (k)	Natural ($k = n$)	$B_0{}^{S,n}$	$B_1{}^{S,n}$	$\mathbf{B}^{S}{}_{n} = I^{n}$
	Unnatural ($k = u$)	$B_0{}^{S,u}$	$B_1{}^{S,u}$	$\mathbf{B}^{S}{}_{u} = I^{u}$
	Total	$\mathbf{B}_0{}^{S} = I_0$	$\mathbf{B}_1{}^{S} = I_1$	$\mathbf{B}^{S} = I$

Table 1. Bonds-supply matrix.

given off by whichever bond-supplying source. Second, the LFF model is concerned with the *column* sums ($B^S = \Sigma_j \Sigma_k B^S_{jk} = B^S_0 + B^S_1$), which split up the total supply of bonds between the emitting sources. To hold on to the LF theory's assumptions, forest sinks are like 'capital goods' (or carbon savers) producing carbon stocks, whereas emitting sources are like consumers that cannot save for increasing those stocks.

One last assumption of the LFF model is that bringing forest assets under bonds rather than equities (**Figure 2**) appears more financially sound. Since bond issuers (emission sources j) owe 'money' (carbon stocks) to bond purchasers (forest sinks k), bonds, in general, and forest bonds, in particular, stand for *debt securities* [42].

Because forests are long-standing assets, the LFF model considers forest bonds as *perpetuities*, a special kind of coupon bond that does not repay its face value (principal), but makes fixed periodic payments (coupons) indefinitely[32] (Eq. (1)) [44]. In carbon-money forest finance, however, coupon payments are made in the form of commodity money (carbon stocks). Therefore, the sink k (bond purchaser) to which the forest bond refers is required to periodically deliver a uniform income flow that makes available, as close as possible, the quantity of carbon stocks that meets the removal needs of the emitting source j (bond seller/issuer). Then, ultimately, the coupon payments correspond to the total quantity of bonds annually supplied by each source j (Eqs. (14) and (15)), in order to finance and meet its demand for carbon removal stocks.

$$P_{kj} = B^S_k / r_j, \tag{1}$$

where P is the bond price, B^S is the annual coupon payment in the form of commodity money (carbon stocks), r is the rate of return, j is the emitting source and k is the forest sink.

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[32] This might well be assumed away to allow for bonds with repayment of face value and with a definite maturity date. However, by Eq. (4), for a fixed carbon removal flux (Ψ_k), the closer the maturity date (T_{jk}), the lower the coupon payments ($B_j{}^S$) made by the forest bond. In order for the bond price (P_{kj}) to remain unchanged, the rate of interest (r_j) paid by the security must, by Eqs. (1) and (5), go up. Therefore, the shorter (smaller T_{jk}) unnatural forests are supposed to live, the higher the rate of interest paid on their bonds as compared with the too much lower rates on those of longer-lasting natural forests. This would, at the onset, bring on an unequal competition between natural and unnatural forest bonds, heavily favouring the latter (scenario 2, in **Table 6**, shows how high the rate of interest on unnatural forest bonds would be if natural forests were left out of climate finance). Thus, the lengthier the lifespans of forest bonds, the smoother the forest financial market.

As the coupon payment hinges on the sink of kind k and on the rate of interest holding at the emitting source j (r_j),[33] the bond price will vary accordingly and will correspond to the present value of all the future income flows (yearly carbon removal fluxes) delivered by the forest sink k (Ψ_k) [18]. Thus, the bond price comes out of the solution (Eq. (3)) of the integral in Eq. (2), in which the terminal time (lifespan) of sink k at source j (T_{jk}) is given by Eq. (4).

$$P_{kj} = \int_{t=1}^{t=T_{jk}} \Psi_k e^{-r_j t} dt \tag{2}$$

$$P_{kj} = \frac{\Psi_k}{r_j} e^{-r_j} - \frac{\Psi_k}{r_j} e^{-r_j T_{jk}} \tag{3}$$

$$T_{jk} = B_j^S / \Psi_k, \tag{4}$$

where $B^S{}_j$ is the total annual supply of forest bonds by the emitting source j, and Ψ_k is the yearly flux of carbon removal by sink k. Finally, by bringing together Eqs. (1) and (4), the resulting Eq. (5) clearly shows the variables which the bond price hinges on. Eq. (5) also proves that, ideally, $B^S{}_k = B^S{}_j$, thereby implying that the supply of bonds (demand for carbon stocks) assigned to the sink k should meet the issuance of bonds by the emitting source j.

$$P_{kj} = T_{jk} \Psi_k / r_j \tag{5}$$

5.1. Model data

Table 2 presents the empirical data used to estimate the functions of supply and demand of forest bonds. **Table 3** displays the relevant variables and estimates for the bonds demand function, while **Tables 4** and **5** show them for the bonds supply functions.

The function of *demand for forest bonds* (Eq. (6)) is estimated by taking out of **Table 2** the figures of the total removal of CO_2 by forest sinks (7th column) and statistically regressing them on the values of the average real interest rate (4th column). The functions of *supply of natural* (Eqs. (7) and (8)) and *unnatural* (Eqs. (10) and (11)) *forest bonds* are estimated in a similar way, but now the figures of CO_2 emissions by sources (in the third from last and next-to-last columns of **Table 2**) are statistically regressed on the corresponding rates of return on *natural* (**Table 4**) and *unnatural* (**Table 5**) forest bonds. This means that the source's observed emissions ($B^S{}_j$ in **Table 2**) must be associated with its corresponding rates of return on either natural or unnatural forest sinks. It is not possible for a source to remove its own emissions by considering the rates of return rendered by another's forest bonds. Thus, no source can issue forest bonds that biophysically yield the returns of another's.

5.2. Model equations

Based on the data displayed in **Table 2**, the following equations have been estimated by SPSS Statistics 17.0. All of them have proven to be statistically significant at a 5% level (or within a 95% confidence interval).

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[33] For calculus reasons, the value of r_j in Eqs. (2) and (3) must be divided by 100.

Year	**Real interest rate**[a,b] **(r_j)**		**Average**[c] **real interest rate ($\bar{r}$)**	**CO_2 removals by forest sinks**[d]		**Total CO_2 removal by forest sinks (B^D)**	**CO_2 emissions by sources**[a,e] **($B^S{}_j$)**		**Total CO2 emissions by sources (B^S)**
	% p.a.	**% p.a.**	**% p.a.**	**$GtCO_2$**	**$GtCO_2$**	**$GtCO_2$**	**$GtCO_2$**	**$GtCO_2$**	**$GtCO_2$**
	Non-Annex I	**Annex I**		**Non-Annex I**	**Annex I**		**Non-Annex I**	**Annex I**	
1990	5.53	7.39	6.46	1.5630	1.1642	2.7273	6.30	9.74	16.04
1991	7.36	5.40	6.38	1.5747	1.1651	2.7398	6.62	10.69	17.31
1992	9.99	8.70	9.34	1.5784	1.1817	2.7600	7.46	13.79	21.25
1993	9.62	0.27	4.94	1.5886	1.1825	2.7711	7.84	13.62	21.46
1994	5.74	0.09	2.92	1.6008	1.1833	2.7841	8.21	13.36	21.57
1995	4.05	3.74	3.90	1.6134	1.1841	2.7975	8.54	13.42	21.97
1996	9.15	10.88	10.01	1.6263	1.1850	2.8113	8.91	13.68	22.59
1997	12.69	3.07	7.88	1.6397	1.1858	2.8255	9.07	13.57	22.64
1998	17.76	6.30	12.03	1.6535	1.1866	2.8401	9.04	13.56	22.60
1999	10.39	4.39	7.39	1.6678	1.1874	2.8552	9.30	13.68	22.98
2000	7.39	3.86	5.63	1.6825	1.1882	2.8707	9.71	13.95	23.66
2001	12.87	4.47	8.67	0.6905	1.2436	1.9340	9.95	13.90	23.84
2002	11.10	4.82	7.96	0.6898	1.2445	1.9344	10.28	13.93	24.21
2003	10.27	3.37	6.82	0.6892	1.2455	1.9347	11.37	14.20	25.57
2004	7.08	2.85	4.96	0.6888	1.2464	1.9352	12.54	14.32	26.86
2005	5.64	2.08	3.86	0.6883	1.2474	1.9357	13.25	14.35	27.60
2006	5.61	2.22	3.92	0.7917	1.7635	2.5552	14.28	14.34	28.61
2007	6.84	1.75	4.30	0.7892	1.7656	2.5548	14.95	14.43	29.38
2008	3.61	1.45	2.53	0.7867	1.7677	2.5544	15.74	14.17	29.91
2009	13.61	6.83	10.22	0.7842	1.7698	2.5539	16.65	13.18	29.83
2010	5.12	3.91	4.52	0.7815	1.7719	2.5534	17.55	13.69	31.23
2011	3.99	0.23	2.11	0.5798	1.2732	1.8530	18.79	13.52	32.31
2012	7.10	2.16	4.63	0.5772	1.2735	1.8507			
2013	8.76	4.12	6.44	0.5746	1.2737	1.8483			
2014	9.50	2.78	6.14	0.5719	1.2740	1.8459			
2015	12.06	2.87	7.46	0.5692	1.2743	1.8434			

Sources: Refs. [47, 48].

[a] Ref. [48].

[b] Geometric mean of all countries' real rate of interest.

[c] Arithmetic mean between Non-Annex I's and Annex I's real interest rates (r_j).

[d] Ref. [47].

[e] Until 2011 only.

Table 2. Observed forest and financial values.

Year	Average real interest rate[a] ($\bar{r}$)	Total CO_2 removal by forest sinks[a] (B^D)	Estimated CO_2 removal by forest sinks (demand for forest bonds) Eq. (6)
	% p.a.	$GtCO_2$	$GtCO_2$
1990	6.46	2.7273	2.6324
1991	6.38	2.7398	2.6219
1992	9.34	2.7600	2.6312
1993	4.94	2.7711	2.3411
1994	2.92	2.7841	1.6398
1995	3.90	2.7975	2.0233
1996	10.01	2.8113	2.5269
1997	7.88	2.8255	2.7223
1998	12.03	2.8401	1.9766
1999	7.39	2.8552	2.7110
2000	5.63	2.8707	2.4971
2001	8.67	1.9340	2.6965
2002	7.96	1.9344	2.7221
2003	6.82	1.9347	2.6715
2004	4.96	1.9352	2.3465
2005	3.86	1.9357	2.0104
2006	3.92	2.5552	2.0305
2007	4.30	2.5548	2.1564
2008	2.53	2.5544	1.4640
2009	10.22	2.5539	2.4868
2010	4.52	2.5534	2.2235
2011	2.11	1.8530	1.2618
2012	4.63	1.8507	2.2554
2013	6.44	1.8483	2.6294
2014	6.14	1.8459	2.5876
2015	7.46	1.8434	2.7140

[a] Obtained from **Table 2**.

Table 3. Demand for forest bonds.

a. Demand for forest bonds:

$$B^D = -0.04365r^2 + 0.6894r \tag{6}$$

b. Supply of *natural* forest bonds ($k = n$) by the j emitting sources ($j = 0$ = Non-Annex I countries; $j = 1$ = Annex I countries)

Year[a]	**Forest lifespan (T_{jk})**[b] **Eq. (4)**		**Forest bond price (P_{kj})**[b] **Eq. (3)**		**Rate of return on natural forest bonds (r_j)**[g] **Eq. (1)**		**Estimated supply of natural forest bonds ($\hat{B}_j^{S,n}$)**	
	years	**years**	**$GtCO_2$/%**	**$GtCO_2$/%**	**% p.a.**	**% p.a.**	**$GtCO_2$**	**$GtCO_2$**
	Non-Annex I[c]	**Annex I**[d]	**Non-Annex I**[e]	**Annex I**[f]	**Non-Annex I**	**Annex I**	**Non-Annex I**	**Annex I**
							Eq. (7)	**Eq. (8)**
1990	8.80	13.61	4.29	5.45	1.47	1.79	9.38	14.36
1991	9.25	14.94	4.11	6.64	1.61	1.61	9.99	14.16
1992	10.42	19.28	3.95	6.01	1.89	2.30	11.03	13.44
1993	10.96	19.03	4.17	12.56	1.88	1.08	11.02	11.98
1994	11.47	18.67	5.32	12.53	1.54	1.07	9.71	11.86
1995	11.94	18.76	6.07	8.94	1.41	1.50	9.10	13.90
1996	12.45	19.11	4.64	5.08	1.92	2.69	11.16	11.19
1997	12.68	18.96	3.84	9.58	2.36	1.42	12.37	13.63
1998	12.64	18.94	2.95	7.22	3.07	1.88	13.28	14.36
1999	13.00	19.11	4.42	8.56	2.10	1.60	11.71	14.14
2000	13.57	19.50	5.44	9.10	1.78	1.53	10.67	13.99
2001	13.90	19.42	3.96	8.59	2.51	1.62	12.67	14.17
2002	14.36	19.47	4.46	8.34	2.30	1.67	12.24	14.26
2003	15.89	19.84	4.93	9.65	2.31	1.47	12.25	13.82
2004	17.52	20.01	6.49	10.21	1.93	1.40	11.18	13.58
2005	18.52	20.05	7.53	11.02	1.76	1.30	10.58	13.17
2006	19.95	20.03	7.89	10.87	1.81	1.32	10.76	13.25
2007	20.89	20.16	7.26	11.45	2.06	1.26	11.58	12.97
2008	21.99	19.80	10.16	11.61	1.55	1.22	9.73	12.77
2009	23.27	18.42	4.37	6.81	3.81	1.94	12.85	14.32
2010	24.52	19.13	9.29	8.94	1.89	1.53	11.04	13.99
2011	26.26	18.89	10.94	12.51	1.72	1.08	10.42	11.95

[a] Until 2011 only, because emissions data are not available beyond (see **Table 2**).
[b] $\Psi_{k=n} = 195$ MtC.yr^{-1} = 0.195 GtC.yr^{-1} = 0.7157 $GtCO_2$.yr^{-1} [49].
[c] Using Annex I's emissions informed in **Table 2**.
[d] Using Non-Annex I's real rates of interest informed in **Table 2**.
[e] Using Annex I's real rates of interest informed in **Table 2**.
[f] Using Annex I's real rates of interest informed in **Table 2**.
[g] In which the numerator ($B^S{}_k = B^S{}_j$) corresponds to the CO_2 emissions by sources *j*, informed in **Table 2**.

Table 4. Supply of *natural* forest bonds ($k = n$).

Year[a]	Forest lifespan (T_{jk})[b] Eq. (4)		Forest bond price (P_{kj})[b] Eq. (3)		Rate of return on unnatural forest bonds (r_j)[g] Eq. (1)		Estimated supply of unnatural forest bonds ($\hat{B}_j^{S,n}$)	
	Years	Years	$GtCO_2$/%	$GtCO_2$/%	% p.a.	% p.a.	$GtCO_2$	$GtCO_2$
	Non-Annex I[c]	Annex I[d]	Non-Annex I[e]	Annex I[f]	Non-Annex I[h]	Annex I	Non-Annex I[h]	Annex I
							Eq. (10)	Eq. (11)
1990	0.86	1.33	−0.99	2.21	−6.35	4.42	5.27	9.56
1991	0.90	1.46	−0.67	3.14	−9.85	3.41	5.79	11.20
1992	1.02	1.88	0.11	5.70	70.28	2.42	7.05	13.36
1993	1.07	1.86	0.46	6.26	17.22	2.18	7.59	14.03
1994	1.12	1.82	0.82	6.01	10.06	2.22	8.15	13.90
1995	1.16	1.83	1.15	5.77	7.42	2.33	8.65	13.61
1996	1.21	1.86	1.42	5.42	6.27	2.52	9.02	13.10
1997	1.24	1.85	1.50	5.96	6.04	2.28	9.12	13.75
1998	1.23	1.85	1.40	5.68	6.47	2.39	8.95	13.46
1999	1.27	1.86	1.74	5.95	5.34	2.30	9.46	13.69
2000	1.32	1.90	2.17	6.25	4.47	2.23	10.07	13.88
2001	1.36	1.89	2.24	6.15	4.44	2.26	10.09	13.79
2002	1.40	1.90	2.57	6.15	4.00	2.27	10.52	13.78
2003	1.55	1.93	3.54	6.53	3.21	2.18	11.67	14.04
2004	1.71	1.95	4.73	6.69	2.65	2.14	13.05	14.14
2005	1.81	1.95	5.46	6.80	2.43	2.11	13.86	14.23
2006	1.94	1.95	6.39	6.77	2.24	2.12	14.71	14.21
2007	2.04	1.97	6.86	6.91	2.18	2.09	15.01	14.29
2008	2.14	1.93	7.94	6.69	1.98	2.12	16.21	14.20
2009	2.27	1.80	7.47	5.31	2.23	2.48	14.74	13.20
2010	2.39	1.86	9.36	6.00	1.87	2.28	17.03	13.74
2011	2.56	1.84	10.67	6.16	1.76	2.20	18.05	13.98

[a] Until 2011 only, because emissions data are not available beyond (see **Table 2**).

[b] $\Psi_{k=u} = 2\ GtC.yr^{-1} = 7.34\ GtCO_2.yr^{-1}$ [1].

[c] Using Non-Annex I's emissions informed in **Table 2**.

[d] Using Annex I's emissions informed in **Table 2**.

[e] Using Non-Annex I's real rates of interest informed in **Table 2**.

[f] Using Annex I's real rates of interest informed in **Table 2**.

[g] In which the numerator ($B^S{}_k = B^S{}_j$) corresponds to the CO_2 emissions by sources *j*, informed in **Table 2**.

[h] Negative figures have been left out for the estimation of Eq. (10).

Table 5. Supply of *unnatural* forest bonds ($k = u$).

$$B_0^{S,n} = -1.287r^2 + 8.277r \tag{7}$$

$$B_1^{S,n} = -4.284r^2 + 15.693r \tag{8}$$

$$B_n^S = B_0^{S,n} + B_1^{S,n} \tag{9}$$

c. Supply of *unnatural* forest bonds ($k = u$) by the j emitting sources ($j = 0 =$ Non-Annex I countries; $j = 1 =$ Annex I countries)

$$B_0^{S,u} = \exp\left(1.9286 + \frac{1.6994}{r}\right) \tag{10}$$

$$B_1^{S,u} = 18.956 - 6.3272 \ln r \tag{11}$$

$$B_u^S = B_0^{S,u} + B_1^{S,u} \tag{12}$$

d. Supply of forest bonds of *all* k kinds ($k = n =$ natural forests; $k = u =$ unnatural forests)

$$B^S = B_n^S + B_u^S \tag{13}$$

e. Supply of forest bonds at the emitting source j ($j = 0 =$ Non-Annex I countries; $j = 1 =$ Annex I countries)

$$B_0^S = B_0^{S,n} + B_0^{S,u} \tag{14}$$

$$B_1^S = B_1^{S,n} + B_1^{S,u} \tag{15}$$

f. Supply of forest bonds by *all* j emitting sources ($j = 0 =$ Non-Annex I countries; $j = 1 =$ Annex I countries)

$$B^S = B_0^S + B_1^S \tag{16}$$

g. Objective-function

$$\max Z = B^D - B^S \tag{17}$$

h. Optimisation scenarios

1. $B^D \leq B_n^S$: emissions removal takes place in *natural* forests only;
2. $B^D \leq B_u^S$: emissions removal takes place in *unnatural* forests only;
3. $B^D \leq (B_n^S + B_u^S)$: emissions removal takes place in *both* kinds of forest sinks;
4. $B^D \leq B_0^S$: emissions removal is sought by *Non-Annex I* countries only;

5. $B^D \leq B_1^S$: emissions removal is sought by *Annex I* countries only;

6. $B^D \leq (B_0^S + B_1^S)$: emissions removal is sought by *both* Non-Annex I and Annex I countries.

The condition $B^D \leq B^S{}_{k,j}$ in all optimisation scenarios is required because, in reality, the supply of carbon removal stocks (demand for forest bonds) is by far smaller than the quantity demanded (supply of forest bonds) by the economic activities.

5.3. Model results and discussion

The results yielded by the LFF model sound consistent with the LF theory of the rate of interest. Because the rate of interest is considered a reward for saving (i.e., demanding bonds), there should be a *positive* relationship between the rate of interest and the demand for forest bonds. **Figure 4** does confirm this hypothesis, although there is a maximum value ($dB^D/dr = 0$) for the rate of interest ($r = 7.89\%$ per year), beyond which savings of carbon stocks (demand for forest bonds) will decrease until get vanished ($B^D = 0$, $r = 15.77\%$ per year). Certainly, this owes to the biophysical limits to *carbon* money, as opposed to losing or missing limits to *paper* (fiat) money.

Somewhat paradoxically, **Figure 5** shows that the expected *negative* relationship between investments (supply of bonds) and the rate of interest does not holdfully true for natural forests, although it does, as shown by **Figure 6** for unnatural forests. Again, natural forests are more heavily affected by ecological constraints and irreversibilities than unnatural forests. Therefore, the search for financing for carbon emitting investments through issuance of forest bonds cannot exceed certain biophysically established limits to conservation or offsetting of carbon stocks.

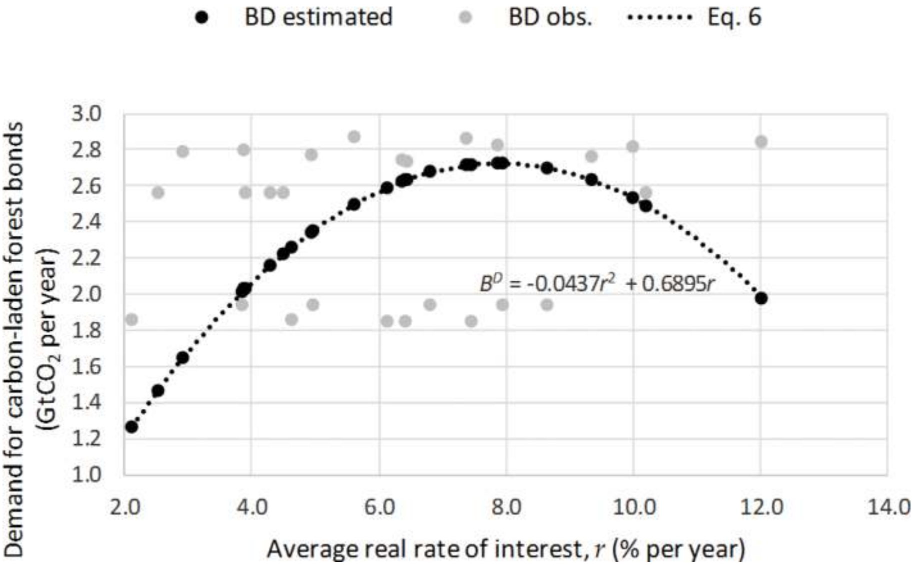

Figure 4. Demand for forest bonds.

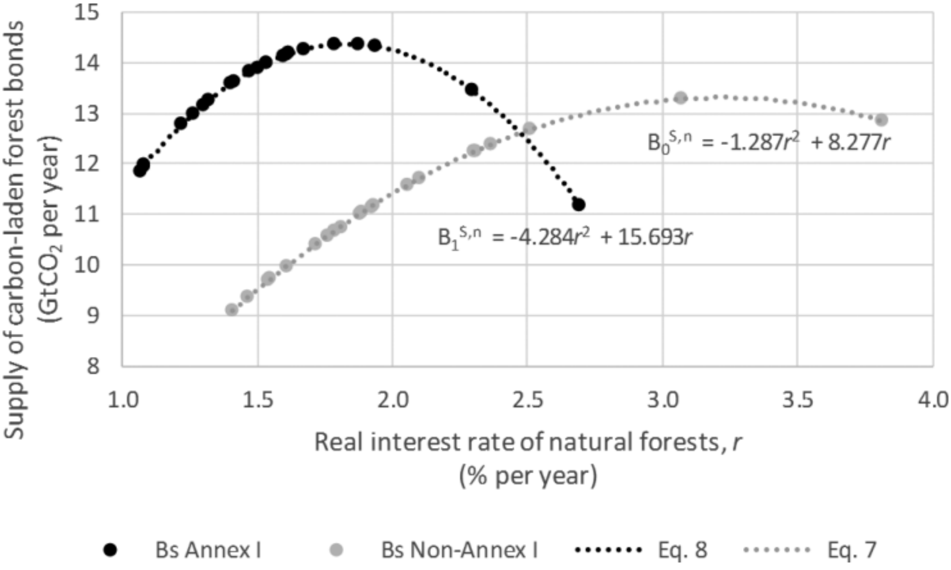

Figure 5. Supply of *natural* forest bonds by Non-Annex I and Annex I emission sources.

In **Figure 5**, the supply of *natural* forest bonds unexpectedly increases with the rate of interest as far as it reaches a maximum of 3.22% per year in Non-Annex I countries ($dB_0^{S,n}/dr = 0$) and 1.83% per year in Annex I countries ($dB_1^{S,n}/dr = 0$). From there on, it then behaves as expected, just like it does with respect to *unnatural* forest bonds. As **Figure 6** shows, the supply of unnatural forest bonds goes down as the rate of interest goes up. Yet, in either natural or unnatural forest stands, the supply of forest bonds in Non-Annex I countries changes more *slowly* with (is more *inelastic* to) the interest rates, whereas it does it *faster* (more *elastic*) in Annex I countries.

Next, a scenario analysis, carried on in **Table 6**, finds the optimal rate of interest on the world's market for loanable forest funds that meets, for every scenario described in Section 5.2, the objective-function established by Eq. (17). The results from **Table 6** allow for the estimation of Eqs. (18) and (19), depicted in **Figure 7**, which not only set down the finance boundaries for a forest bond market but also show the optimal path of the real rate of interest on forest bonds in the long run.

$$B^{D^*} = 1.3293 + 0.1982r^* \tag{18}$$

$$B^{S^*} = 154.35 - 31.4842r^* \tag{19}$$

From **Table 6**, Eqs. (18) and (19), the demand for forest bonds equals the supply when $r^* = 4.90\%$ per year. This amounts, in **Table 6**, to scenarios 3 and 6, which, as expected from **Table 1**, had to actually yield the same results. Next, by setting Eqs. (18) and (19) equal to zero, the optimal range for r^* is found to be $-6.707 < r^* < 4.934$, within which a financial market for forest bonds might really come to existence. However, negative values for r^* mean a supply of bonds so larger than

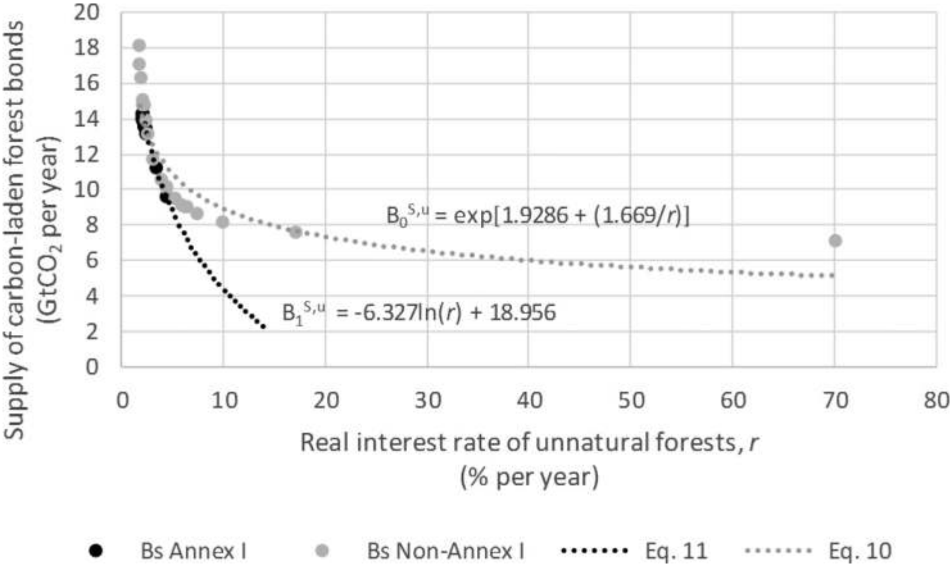

Figure 6. Supply of *unnatural* forest bonds by Non-Annex I and Annex I emission sources.

	B_k^{S*}		B_j^{S*}				
	Natural forests ($k = n$)	**Unnatural forests ($k = u$)**	**Non-Annex I ($j = 0$)**	**Annex I ($j = 1$)**	B^{S*}	B^{D*}	r*
	Eq. (9)	**Eq. (12)**	**Eq. (14)**	**Eq. (15)**	**Eq. (13)** **Eq. (16)**	**Eq. (6)**	
Scenarios	**$GtCO_2$ yr^{-1}**	**$GtCO_2$ yr^{-1}**	**$GtCO_2$ yr^{-1}**	**$GtCO_2$ yr^{-1}**	**$GtCO_2$ yr^{-1}**	**$GtCO_2$ yr^{-1}**	**% per annum**
5	4.360	20.410	22.673	2.097	24.770	2.097	4.112
1	0.959	20.033	22.148	-1.156	20.993	2.145	4.262
3	-16.303	18.633	19.389	-17.059	2.330	2.330	4.900
6	-16.303	18.633	19.389	-17.059	2.330	2.330	4.900
4	-110.302	15.302	2.694	-97.694	-95.000	2.694	7.094
2	-1×10^{10}	-41.575	-2.31×10^{9}	-7.69×10^{9}	-1×10^{10}	-7.83×10^{7}	42369.708

Notes: (a) Calculations performed in GAMS-IDE version 24.7.1 (March 2016). (b) Negative figures mean carbon emissions, whereas positive values mean carbon removals.

Table 6. Scenarios and optimal rates of interest on forest bonds (r^{*})^{a,b}.

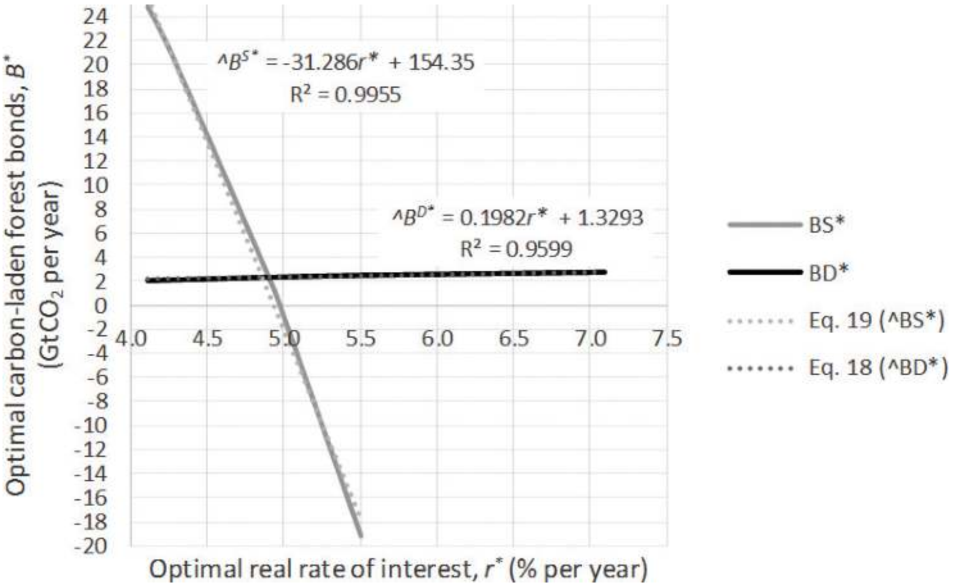

Figure 7. Optimal real rate of interest on long-term forest bonds (forest perpetuities).

the demand that the costs to remove emissions would outstrip the benefits, thereby yielding negative returns.

As long as the value found for r^* falls outside this optimal range, some scenarios (like scenarios 2 and 4 of **Table 6**) are likely to keep any market for forest bonds from thriving. Whereas scenario 2 encloses a *biophysical* restriction, so that emissions removal is assigned to *unnatural* forests only, scenario 4 takes on a *geographical* restriction, requiring that only Non-Annex I countries seek for emissions reduction by forest sinks. Clearly, none of these restrictions favours forest finance.

In other scenarios (1 and 5), although biophysical and geographical restrictions do not impair forest finance, they lower the rate of interest on forest bonds as compared with that of unrestricted scenarios (3 and 6). The lowest rate of return (r^* = 4.112% per year) occurs in scenario 5, whose *geographical* restriction allows for emissions reduction by only Annex I countries. A lower rate of return (r^* = 4.262% per year) also comes out of the *biophysical* restriction of scenario 1, in which only natural forests are committed to emissions reduction.

6. Conclusion

In light of the results of the LFF model, displayed in **Table 6**, the Kyoto Protocol resembles scenarios 2 and 5, in which forestry-CDM allowed for *unnatural* forests only to take part in emissions removal, required from Annex I binding countries. As shown in **Table 6**, the biophysical restriction of scenario 2 is more stringent to forest finance than the geographical restriction of scenario 5. They respectively yield the unrealistically highest (42,369.708% per year) and the lowest (4.112% per year) rate of interest on forest bonds. In between, the Paris Agreement has formally called in Non-Annex I countries and natural forests (REDD+) to assist in reducing emissions. When neither biophysical nor geographical restrictions are in place, the LFF results (scenarios 3 and 6 in **Table 6**) show that demand and supply of forest bonds would even off (2.33 GtCO2 per year), and the rate of interest on them would lie between the extremes yielded by scenarios 2 and 5. Although this would favour carbon finance, natural forests would behave as carbon sources (emitting BS(k = n) = 16.303 GtCO2 per year) rather than sinks. Nonetheless, if too a heavy burden is placed upon REDD+ and upon the carbon sink role of natural forests (scenario 1), this biophysical restriction would be less stringent to a forest bond market than the geographical restriction under which Non-Annex I countries would solely commit themselves to emissions reduction (scenario 4). As shown in section 5.3, scenario 4 yields a rate of interest on forest bonds (r^*= 7.094% per year) that exceeds the acceptable upper bound (r^*= 4.934% per year). This is, though, a likely scenario, provided that Annex I countries, as argued in Section 2, withdraw the Paris Agreement (see Footnote 13).

Moreover, in all scenarios, unnatural forests are required more emissions removal than natural forests ($B^S{}_u > B^S{}_n$). Non-Annex I countries issue more forest bonds—that is, demand more carbon removal stocks—than Annex I countries do ($B^S{}_0 > B^S{}_1$). All this suggests that, since deforestation is high in Non-Annex I countries, they are driven to offset carbon emissions by demanding carbon removal stocks from unnatural forests, whereupon BS(u) > BS(n) in **Table 6**. Therefore, according to the LFF model outcomes, the efforts of the Paris Agreement towards forest conservation (REDD +) point to scenarios 1 and 5, in which emission reductions by natural forests are positive ($B^S{}_n > 0$) and the rates of interest on forest bonds are lower (respectively, r^*= 4.262 and r^*= 4.112% per year). Higher rates of return/interest mean less forest conservation and more forest offset (plantations).

Although this outcome appears to disagree with the static one in **Figure 1**, it dynamically means that, in a carbon-storing economy, conservation amounts to an excess supply of carbon money (forestland), whereas deforestation corresponds to an excess demand for carbon stocks. Whenever deforestation outstrips conservation, the rate of interest is supposed to go up, because the actual supply of forestland (carbon money) is not enough to meet the demand for commodities (carbon stocks) throughout the economy [51]. Then, the consumption of carbon stocks is currently discouraged, thereby increasing the demand for forest bonds (upcoming supply of forest stocks). Conversely, when conservation is expected to outbalance deforestation, the rate of interest is supposed to go down. Since there is too much forestland (carbon money) in relation to the demand for carbon stocks, the supply of forest stocks is currently withheld, thereby increasing the supply of forest bonds (upcoming demand for forest stocks).

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