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Abstract

Green bonds have risen as an innovative instrument to fund sustainable projects. We discuss the role of the public sector in expediting green investments through green bonds issuance, based on a literature review. We find that the public sector has traditionally a key role in mitigating environmental uncertainties and in reducing green initiatives costs. In recent years, new financial market instruments such as green bonds were added it up to this public effort. Though the literature still do not find relevant yield differences between green and conventional bonds. However, there is already evidence that bonds with better environmental reputation (certified or with reliable issuers) have higher liquidity and demand, resulting in lower yields. Reliable green bond issuing can attract new long-term investors, who value environmental gains or pursue hedge against carbon assets fluctuations. We should note though that institutional investors still represent a small share of climate finance flows. As Governments and Multilateral organizations are relevant players in the green bonds market, additional research is needed to discuss the performance of public bonds and how these institutions can take advantage of their market conditions to de-risk green investments and attract private capital.

JEL classification: C610, G120, 0380, Q580

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1 Introduction

Since 2009, when the 15th Conference of the Parties (COP 15) to the United Nations Framework Convention on Climate Change (UNFCCC) took place in Copenhagen, climate finance has come to the forefront. This movement was followed by international climate agreements[1] that encouraged public and private financial resources mobilization to green investment and fostered the implementation of new financial tools. During this period, green bonds have risen as an innovative instrument to fund sustainable projects.

Since 2007, more than 3,000 green bonds were issued by Governments, Private and Multilateral organizations mobilizing more than US$ 500 billion (US$ 316 million in 2010 and US$ 257 billion in 2019[2]). The green bonds are fixed-income securities, usually certified by a third-party, to leverage resources in the capital market. The external certification guarantees that the proceeds are used for sustainable projects only, such as renewable energy, green buildings and clean transport. Green bonds play a relevant role for climate transition (Flaherty et al., 2017; Orlov et al., 2018). It provides an instrument to implement Sachs' (2014) idea of "intertemporal burden sharing". The cost of climate policies can be shared by current and future generations through debt finance. Thus, asset holders need to be induced to hold green bonds into their portfolio.

The green bonds solve investors' information constraints and can attract resources owned by private institutional investors. Institutional investors hold around US$ 120 trillion in assets (Bielenberg et al., 2016) but represent only 1.5% of the total climate finance (CPI, 2019). We already notice a movement in which several investors are improving their ESG practices or are aware of the financial instability risks of holding carbon-intensive assets (TCFD, 2017; Carney, 2015). Institutional investors can be crowded-in if public agents use its de-risk potential, especially in developing countries (IFA WG, 2017; OECD, 2018). Governments have a role in providing funding and in risk-bearing investments that exhibit higher externalities and uncertainties by reducing risk premia for such projects (Arrow & Lind, 1970; Mazzucato, 2018; Mazzucato & Semieniuk, 2018; Stiglitz, 1993). There is often uncertainty on environmental costs of projects which provides incentives for reducing the risk premia through

[1] In 2009, through the Copenhagen Accord, the international community agreed on financing US$ 100 billion per year for sustainable projects in developing countries. In 2010, the Cancun Agreement mobilized Governments to keep global temperatures well-bellow 2ºC above the pre-industrial level. This target was set to 1.5ºC in 2015 after the Paris Agreement.

[2] According with the Climate Bonds Initiative, https://www.climatebonds.net/

public investment (Arrow & Fisher, 1974). This is also true for the implementation of renewable energies, especially in developing countries, as the higher fixed and upfront costs - vis-a-vis fossil fuel projects - demand a public effort to support green investments (Ondraczek et. al, 2015; Sweerts et al., 2019; Hirth & Steckel, 2016; Waissbein et al., 2013; Schmidt, 2014).

This manuscript presents a comprehensive literature review to discuss the role of the public sector in fostering green investments through green bonds issuance. It brings additional theoretical and empirical references to recent research[3]. Given the positive externalities and financial market constraints associated with this activity, we analyze recent research in green bonds, green investment and public policy to bring this additional perspective to the green bonds academic debate. We group the literature in two sections. The section 2 discusses the role of the public sector in climate finance. We present the economic justification for public intervention when there is credit rationing, the instruments that can be used by governments in financial markets, and the specificities of advanced, developing countries and renewable energy investments. The Section 3 discusses green bonds recent performance and its role for public policy. We present an updated literature that analyzes green bonds, its specificities, market performance and application in policy. These sections are followed by a conclusion section.

2 The role of the public sector in climate finance

Although the role of the public sector in climate finance has increased, the great needs for climate finance demands additional credit sources also for private investment. The macroeconomics literature brings evidence that the credit dynamics is key for understanding investment and growth (Minsky, 1986; Faulwasser et al., 2018; Ajello et al., 2016; Gertler & Bernanke, 1989). Furthermore, imperfect capital markets, asymmetric information, moral hazard and adverse selection can explain credit costs and credit rationing given the relationship between borrowers and lenders and the existence of information constraints (Akerlof, 1970; Stiglitz & Weiss, 1981). Due to market imperfections, the Government may intervene in the credit market to reduce credit constraints and foster investment for certain type of projects.

[3]See Braga et al. (2020) and Heine et al. (2019).

Indeed, Governments are able to provide funding and fix market failures associated with costly information in credit markets (Stiglitz, 1994). When markets are missing and incomplete, the Government can also act as a risk-bearing agent (Mazzucato, 2018; Stiglitz, 1993). In financial activities, the public sector is able to guide private investments to high externalities projects, using tools such as guarantee of private obligations and direct Government lending (Flannery & Jackson, 1993; Jomo et al., 2016). Mazzucato & Semieniuk (2018) do an empirical research and find that public financial actors are more likely to invest in portfolios with higher technological risks, de-risking those investments and inducing technological paths in certain industries. Grant & Quiggine (2003) and Holmström & Tirole (1998) also bring empirical evidence that public sector's equity and bond issuing can reduce the risk premia and generate a liquidity premium in contrast to private agents. According to the Arrow-Lind Theorem, under uncertainty, projects with social benefits and with publicly born risks can have lower cost of risk-bearing as the State can distribute it across taxpayers (Arrow & Lind, 1970). However, we should note that the literature shows that the cost and capacity of risk-bearing depend on the country, type of project and sectorial specificities.

First, capital market imperfections and distinct risk perceptions impact the credit cost of different countries. Sweerts et al. (2019) estimate the weighted average cost of capital (WACC) for renewable energy projects in Africa and find that it varies from 8% to 32% in a sample of 46 countries (Sweerts et al, 2019). For better rated European countries, ECB (2019) shows that the capital cost varies in a range from 1.43% (France) to 4.53% (Greece) in 2017. For non-European countries, this range is even larger. According with the World Bank (2019): 25% of the countries have credit costs above 14% (African, Latin American and certain developing Asian countries) while only 9% of the countries follow the European pattern and have a credit cost below 4% (e.g., United States, Japan, South Korea and Israel). These differences are due to countries sovereign ratings. It impacts the public capacity in the capital markets to de-risk activities with high externalities.

Second, financial instruments should fit firms' life cycle and capital demand. The cost of capital depends on firm‘s asset prices and on the industry life cycle. Small, medium and start-up firms in innovative industries are frequently financially constrained and face a higher cost of capital (Hall & Lerner, 2010). Innovative small firms follow a financial growth cycle in which financial needs change as the business grows - from seed capital and venture capital to debt and

equity (Berger & Udell, 1998). When investment needs increase, firms switch to more costly sources, from internal to external finance, using first debt and then equity (Semmler, 2011). There is also evidence that the debt market (and bond market), instead of the equity market, explains better the investment behavior of firms (Philippon, 2019; Galleti & Ramsey, 2013; Semmler & Mateane, 2012).

Third, as to environmental investments, Fisher (1973) reviews the Arrow-Lind Theorem and finds that there is an uncertain cost of such projects that may affect the performance of investments. This uncertainty entails an adjustment of an investment's expected benefits and, as these costs are hard to measure and to identify, public policy should attempt to internalize them (Arrow & Fisher, 1974). For the specific case of renewable technologies implementation, empirical research shows that higher fixed capital costs and upfront costs for green investments tend to favor fossil fuel projects (Hirth & Steckel, 2016; Waissbein et al., 2013; Schmidt, 2014). Waissbein et al. (2013) shows it happens mostly for investment and financing costs. Hirth & Steckel (2016) discuss more specifically the financing costs and shows that the costs of renewable energy technologies are much more sensitive to the increase in credit costs than those of fossil fuel technologies. This difference is even greater in developing countries (Ondraczek et. al, 2015; Sweerts et al., 2019; Waissbein et al., 2013). It reinforces the need of public policy for investment de-risking.

However we should note that although the monetary cost of green investments can be high, recent trends show a decrease in its cost. The solar photovoltaic (PV) module prices have fallen by about 80% since the end of 2009, while wind turbine prices have fallen around 30 and 40% (IRENA, 2018). The global costs for renewable energy have decreased and tend to be lower than the fossil fuel cost of production[4]. Gimon & O'Boyle (2019) find that, for the US in 2018, 74% of the national coal supply is at risk as wind and solar suppliers can provide cheaper electricity. This price decrease is due to economies of scale and to the infinite supply of renewable energy sources but also due to public policy support aimed at reducing credit risk and guaranteeing the implementation of new technologies with high externalities and significant uncertainties.

Mazzucato (2015) sheds light on the role of the State in de-risking the implementation of radical innovation, not only by funding basic research but also by actively creating markets for these technologies. She argues that the green industry is still in an early technology stage, with high uncertainty, which

[4]See https://www.irena.org/Statistics/View-Data-by-Topic/Costs/LCOE-2010-2017

still demands a de-risking effort by the State. The Government of the United States, China and Germany, for instance, played an active role in reducing the cost of developing and commercializing wind and solar energy solutions. In 2017, Governments expenditures to implement renewable-based electricity were around US$ 143 billion, which represented 19% of the total investment employed in the electricity sector (IEA, 2018). Most public support was for solar and wind energy (80%). In Europe, around US$ 75 billion were spent in renewable energy subsidies in 2016 (European Commission, 2019). In the United States, explicit federal subsidies to renewable sources were US$ 15 billion in 2013 and US$ 6.7 billion in 2016, representing 46% of the total subsidies for the energy sector (EIA, 2018). Due to this incentive, the levelized cost of electricity (LCOE) for renewable energy is now from 2% to 9% lower than a similar non-subsidized investment in the country (Lazard, 2018). Thus, the literature and recent experience show that the public sector play a role in the implementation of green investment, mitigating environmental uncertainties and reducing costs associated with environmental projects.

3 Green bond's performance and public de-risking

For environmental projects, the public sector often pursue loan guarantees, new regulatory frameworks, risk insurance and the issuance and purchase of green bonds (Steckel & Jakob, 2018). Since 2007, more than 3,000 green bonds were issued by Governments, Private and Multilateral organizations mobilizing more than US$ 500 billion. Green bonds play a relevant role for climate transition (Flaherty et al., 2017; Orlov et al., 2018). It provides an instrument to implement Sachs' (2014) idea of "intertemporal burden sharing". The cost of climate policies can be shared by current and future generations through debt finance. Thus, green bonds have risen as an instrument to expedite climate transition.

However, some authors bring evidence that there is no yield differences between green and conventional bonds, i.e. there is a zero "green premium". Larcker & Watts (2019) analysis US municipalities bonds and find that same issuer's conventional and green bonds don't differ in terms of yields. Kuhn et al. (2018) find, for the UK bonds market, that, alike conventional bonds, the yields are driven by factors such as economic growth, risk, currency and the existence of a call option. Wanke (2017) discusses the recent positive correlation between long-term bond yields and oil prices and argues that oil price variations are an

important driver for every type of investment. Hyun et al. (2019) find that, on average, the green premium is close to zero. Some authors argue though that for certain types of bonds (like certified green bonds) you can find a premium.

This debate sheds light on the yield sensitivity of investors for green bonds. Several factors determine a bond yield, such as maturity, type of issuer, bond rating, the level of countries or issuers debt, market conditions at the time of the issuance and liquidity. We explore here the literature that discuss the impact of liquidity and investors preferences on the green bond yields, i.e. the impact of investors preferences for green securities which impact demand, prices and yields. Febi et al. (2018) find that green bonds are more liquid than conventional bonds and that the positive impact of low liquidity risks on spreads has become negligible in recent years. Several authors also find increasing yield differentials between green and conventional bonds. Baker et al. (2018) find that corporate and municipality green bonds in the US have been issued with a premium, with lower yields than conventional bonds: on average 6 bps lower. Nanayakkara & Colombage (2018) find a similar result for a global sample: 6.3 bps. Ehlers & Packer (2017) find, on average, a difference of 18 bps. Partridge & Medda (2018) build yield curves and find that the yield differences for green bonds have been increasing during time: in 2017, they find a difference of roughly 5 bp. Karpf & Mandel (2018) find a positive premium for green bonds but argue that it's not possible to infer the cause, if it's actually due to higher demand due to environmental preferences. Nevertheless, other authors show evidence that gren bonds demand and financial conditions can be impacted by preferences depending on the bond ESG reputation. The issuer environmental reputation or a bond third-party certification matters for the liquidity and yields, as it reduces informational asymmetries and avoids green washing.

Indeed, the type of issuer and the liquidity can impact yields. The nature of the issuer (if it's public or not) and whether the green bond is certified by a third-part or not matter for the yield, i.e. the green reputation of the bond allows lower yields. Bachelet et al. (2019) find empirical evidence that green bonds issued by institutional issuers are more liquid and have a negative premium. Moreover, private issuers of non-certified green bonds have less favorable characteristics, are less liquid and have a positive premium. Fatica et al. (2019) estimate the impact of being certified at almost 70 bps (versus 17 bps, which is the impact of self-reported green label). Li et al. (2019) find that certified green bonds have lower interest costs. Kapraun & Scheins (2019)

find that bonds listed in special green segments of securities exchange markets (Luxembourg or London Stock Exchange) trade at about 20 bps lower yields.

Other authors emphasize mainly the issuer profile and reputation as a driver for yield differentials. Gianfrate & Peri (2019) find that green bonds pay lower returns to investors, specially when they are issued by corporate issuers. Hachenberg & Schiereck (2018) find that yield differences between green and conventional bonds are mostly explained by the issuer industry (eg.: when it's government related) and by the existence of an ESG issuer rating. Ehlers & Packer (2017) find that green bonds have been priced with a premium at issuance: on average green bond yields are lower at 18 bps. However, the bonds rating matters for this difference. For AAA and AA rating bonds, this difference is around -10. For A to BBB bonds, this difference is around -40. Furthermore, Hachenberg & Schiereck (2018) find that A bonds are trade 4.87% tighter in terms of spreads than non-green bonds while they don't find a significant difference for other rating classes.

It has also been observed in the literature that green bonds attract long-term investors who value environmental gains. Flammer (2018) finds that firms that issue green bonds attract long-term oriented investors, guided by green portfolio selection criteria. Zerbib (2019) finds a significant but low premium related to investors' pro-environmental preferences in the bonds market. Indeed, investors demand in favor of green assets should matter for yield differences.

We should notice though that green assets are also attractive to investors searching for hedge opportunities against the financial instability risks associated with fossil fuels securities, as discussed by Carney (2015). Reboredo (2018) shows that the green bond market weakly co-moves with the fossil fuels markets which brings hedge and diversification opportunities to investors. Horsch & Richter (2017) also find that green bonds deliver diversification benefits as it shows low positive correlations with other mid and long-term corporate bonds and negative correlations with Treasury bonds, equities, and commodities prices. Indeed, the literature shows that green bonds solve information constraints that can attract new institutional investors concerned with ESG practices and can address financial risks of holding carbon-intensive assets.

A recent survey reported that only 14% of the investors believed that the supply of ESG fixed-income products is enough (RBC Global Assessment Management 2018). Bielenberg et al. (2016) argue that currently private investors accounts for up to half of total conventional infrastructure spending (from US$1 trillion to US$ 1.5 trillion a year): 65% from corporate actors and

the rest from institutional investors. The role of institutional investors is still low in climate finance. Although institutional investors currently hold around US$ 120 trillion in assets, they are responsible for only 1.5% of the climate finance flows (CPI, 2019). There is space to increase the role of institutional investors in climate finance.

Green bonds are an important instrument to attract those green investors or investors looking for protection against oil prices fluctuations. Market agents report that green bonds allow known institutional investors to gain exposure to climate-friendly assets (Venugopal, 2015). It has been also observed a diversification of the issuer's investors base (OECD, 2017b; World Bank, 2015). GIZ (2018) highlights the wide rage of investors attracted by the french sovereign green bond issuance. Moody's (2018) shows that, in France, foreign investors bought 63% of the total green bonds volume while their share in the total country sovereign debt is 55%. Climate Bonds Initiative (2018) presents the Poland experience and find that its sovereign green bond attracted new green investors representing 61% of its investors pool. Institutional investors can be even more attracted to those investments if public agents - with higher rating and credibility - use de-risking tools to increase investors returns (IFA WG, 2017; OECD, 2018).

For developing countries, there are additional challenges for the use of de-risking instruments in the green bonds market. In section 2, we showed that sovereign risk differentials and market structure matter to determine the WACC, usually higher in developing countries. Banga (2019) also lists market barriers that prevent developing countries from entering the green bonds market such as: the lack of knowledge, inappropriate institutional arrangements, minimum size requirements, the currency of issuance, and high transaction costs. Thus, the use of development banks as intermediary institutions for green bond management is recommended in order to solve existent constraints for developing countries in the green bonds market.

4 Conclusion

Green bonds have risen as an innovative instrument to fund sustainable projects, mobilizing more than US$ 500 billion since 2007. We review the recent literature to discuss the role of the public sector in fostering green investments through green bonds issuance. It provides a better overview of the use of bonds

as mechanism to ensure positive externalities and solve financial market constraints. This effort also brings additional theoretical and empirical references to recent research[5].

The literature shows that green bonds are an important instrument to share the costs of climate policies between current and future generations and implement governments climate transition policy. Indeed, the economic theory shows that Governments may intervene in the credit markets to reduce credit constraints and foster investments with high social benefits, uncertainty and risks. Recent research and policy experience demonstrante that it is particular true to environmental initiatives, with high externalities and uncertain costs. Advanced countries have already mobilized its public capacity to subsidize and fund the implementation of new green technologies, including the issuance of green bonds.

There is also a variety of literature discussing the green bonds market and its recent performance. While some authors do not find any yield difference between similar green and conventional bonds, others find a green premium. Recent evidence shows that green bonds have higher liquidity and pay lower yields specially when the bond has a positive reputation in the market. In particular, it happens when an issuer certifies the bond or has a positive ESG and credit reputation. Some authors also observe that green bond issuing attracts long-term investors who value environmental gains or look for safe assets against fossil fuels securities volatility. Indeed, issuers report an investors base diversification associated with green bonds issuance. However, the role of institutional investors in the climate finance flows is still low and demands a coordination effort to attract these resources.

Public de-risking of green assets, especially in developing countries, is a way of increasing its attractiveness. As Governments and Multilateral organizations are relevant players in the green bonds market, additional research is needed to discuss the performance of public bonds and how these institutions can take advantage of their market conditions to de-risk green investments and attract private capital.

[5]See Braga et al. (2020) and Heine et al. (2019).

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