

Central Bank Collateral as a Green Monetary Policy Instrument

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Abstract

Central banks can play an important role in the transition towards a climate-neutral economy. This paper discusses different green monetary policy instruments along the dimensions of feasibility of implementation and impact on the transition process. We identify the inclusion of “brown” collateral haircuts into a central bank’s collateralised lending framework as the most promising conduit of green monetary policy. The impact of such interventions on the real economy is then formally explored by extending a general equilibrium transition model to include a simple banking sector with central bank lending facilities and collateral adjustments. We find that both “brown” collateral haircuts and “green hairgrowth” increase carbon neutral investment while decreasing carbon intensive investment and emissions. Consequently, in addition to decreasing the exposure of the central bank balance sheet to climate-related risks, climate-based collateral adjustments have the potential of increasing the political feasibility of a timely transition to a carbon neutral economy by affecting emission levels. Despite “green hairgrowth” having a stronger effect on investment and emissions, “brown” collateral haircuts remain the recommended policy as the former is not necessarily “market neutral” and thus cannot be broadly applied across central banks.

Key policy insights

- “Brown” collateral constraints as green monetary policy is a feasible instrument that can be broadly implemented across different central bank frameworks and mandates.
- “Brown” collateral haircuts increase the financing costs and decrease the volume of carbon intensive investments.
- “Green hairgrowth” has a similar effect but is in conflict with market neutrality and, therefore, not as broadly implementable.
- The synergy of a price instrument and “brown” collateral constraints results in a significantly lower and potentially politically more feasible carbon tax.

Keywords: Green Monetary Policy, Brown Collateral Haircuts, Central Bank, Climate Mitigation

1 Introduction

Climate change takes place in a socio-economic context fraught with barriers and limitations that inhibit effective mitigation. Despite the increased frequency and intensity of extreme weather events associated with climate change and despite our ever-improving understanding of the consequences of inaction, politicians are still failing to enact adequate policy measures.

There is a substantial list of obstacles that either stand in the way of the introduction, or impede the functioning of traditional climate policy. The deep roots of fossil fuel usage in our socio-economic reality (Vaclav, 2010), structural characteristics of liberal democracies (Held and Hervey, 2009), credibility (Koch et al., 2016), short-termism (Fuss et al., 2018), high levels of public and private indebtedness (Mbaye and Badia, 2019), and a failure to adequately

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price climate risk from the financial sector (Campiglio, 2016), are among the key limiting factors. The pervasiveness and scale of these obstacles explain the current shortcomings of climate policy and dampen the prospects for ambitious policies going forward.

In light of these challenges, there has been increasing interest in building support for climate change mitigation beyond the conventional approach to climate policy. Following Mark Carney's seminal speech (Carney, 2015), increased attention has been devoted to the potential involvement of central banks in the green transition and, in particular, in maintaining financial stability in light of climate change. This paper offers a critical review of the instruments with which green monetary policy (GMP) can be conducted. After identifying the most promising instruments, we proceed to modelling and evaluating the potential impact of such measures on the real economy and consequently on the transition process. We consider GMP alongside conventional climate policy instruments like a carbon tax in a well-established transition model that allows for the evaluation of different policies for reaching an exogenously given climate target (Kalkuhl et al., 2012, 2013, 2015).

Disentangling what role central banks can play in the transition process in terms of mandates and their interpretations is not straightforward. Many central banks, like the US Federal Reserve, the Bank of England or the Bank of Japan, have their mandates centred around price stability, financial stability, and sometimes, maintaining employment. Other central banks engage in a much broader set of activities as seen in the industrial credit policies implemented by the People's Bank of China and Reserve Bank of India (Fukumoto et al., 2010; Bansal, 2017; Dikau and Volz, 2020). For example, the People's Bank of China, a founding member of the Network for Greening the Financial System (NGFS), has conducted both formal and informal green credit operations in an effort to support the development of green technology (PBC et al., 2016; Volz, 2018). While this type of central bank involvement might appear unconventional, Dikau and Volz (2020) find that 40% of central banks from the IMF's Central Bank Legislation Database have a provision to support government policy priorities. Given that 195 countries have signed the Paris Agreement and that many governments are prioritising 2050 net zero emissions, there is certainly scope for considering the implication of this "policy priority" for central bank mandates. However, there is also a strong case for a narrow mandate in maintaining credibility for the transmission of monetary policy (Goodhart, 2010). For this reason, many central bankers are in opposition to extensions and broader interpretations of mandates to include climate change mitigation. Out of this debate, currently, there is an emerging consensus that central banks cannot ignore climate change due to its effects on financial stability (NGFS, 2018, 2019, 2020; Bolton et al., 2020). Both the transitional and physical risks caused by climate change threaten the stability of the financial system in both the short, medium, and long term (Batten et al., 2016; Dafermos et al., 2018; Batten, 2018).¹ In the long-run, transition and physical risks are intertwined with the phase-out of fossil fuel-based industries and a transition towards renewable energy. As such, the goal of long-term financial stability exhibits a significant overlap with the goal of decarbonising the economy. This motivates our consideration of conventional climate policy like a carbon tax alongside GMP.

Central banks can get involved in a variety of ways. Passive measures involve the dissemination of information, developing standardised tools for evaluating risk, and coming up with a sound taxonomy for green assets (NGFS, 2019, 2020). Active measures, on the other hand, involve direct interventions by central banks, for example, through the buying and selling of securities based on their carbon intensity, or through differentiated credit policies based on the purpose of the loans. Whether such active measures should be implemented is an ongoing contentious debate, and one that goes beyond the scope of this paper (Tooze, 2019; Dikau and Volz, 2020). This paper aims to inform this discussion by exploring what such instruments might look like, how they could be implemented, and what their effects on the real economy might be.

Section 2 provides a discussion on the potential effects and feasibility of GMP instruments that are based on adapted versions of existing or past monetary policy instruments. We conclude that adapting the central bank collateralised lending framework for lending to commercial banks is a promising avenue for GMP. This involves differentiated collateral valuations (e.g. brown collateral haircuts) based on the transition risk associated with collateral that is being posted at the central bank. This instrument would be both effective in protecting central bank

¹ Transition risk refers to the implications of a potential stringent future climate policy, like a high carbon price, for the valuation of carbon-intensive assets. Physical risk refers to the potential losses to physical capital, agriculture, and labour, as well as heightened political and social instability caused by increased extreme weather events due to global warming.

balance sheets from potential losses due to transition risk and could be easily implemented into currently existing collateralised lending frameworks. In our modelling exercises, we find that, in terms of the effects of this instrument on the real economy, differentiated collateral valuations for central bank lending can change the investment patterns away from brown and towards green technology, which consequently leads to a reduction in emissions.

This paper also contributes to the literature on GMP by taking first steps in the direction of formally analysing green central bank policies in a transition model alongside conventional climate policy. We present results from this analysis in Sections 3 and 4, while more detailed descriptions of the model can be found in the Appendix (see Supplementary Material or SM).

Our main finding from the formal modelling exercises, as presented in Section 5, is that differentiated green and brown central bank collateral restrictions can reduce the level of the carbon tax needed to stay below 450 Gigatons of Carbon (GtC) of global emissions. This implies that there are positive synergies between reducing central bank balance sheet exposure to climate risk and emission reductions. Climate collateral adjustments could inadvertently lead to a transition involving a lower carbon tax.

2 Options for Green Monetary Policy

The toolbox of central banks includes both macro-prudential and monetary policy. In a conventional setting, central banks use monetary policy instruments to target short term interest rates (Bindseil, 2004), in order to influence macro variables like inflation, unemployment, or growth. Interest rate adjustments, however, while not necessarily neutral towards the structure of the economy, are not used in any targeted manner. For example, the lowering of interest rates might increase investment in the economy as a whole, but does so symmetrically for both green and brown investments. Therefore, this standard instrument of monetary policy does not appear to be well suited to deal with the problems originating in specific sectors of the economy. In the following, we discuss the feasibility of different GMP instruments, as well as how they might affect the structure of the real economy.

As emissions are created through a physical process, it is important to ascertain if an instrument has a strong pass through to the real economy and whether it has a directed effect, affecting green and brown investment asymmetrically. We also consider if the instruments are likely to have a neutral or complementary effect on growth and inflation. Finally, GMP should be feasible to implement by the vast majority of central banks. While some instruments might be effective and feasible under particular institutional settings, ideally, GMP should be (1) easy to practically implement and (2) congruent with the majority of central bank mandates. This would allow for a quick adoption of such instruments by central banks around the world.

Due to the increasing ineffectiveness of conventional monetary policy tools, such as interest rates and reserve ratio adjustments after the 2007 financial crisis, central banks have started employing additional “unconventional” policy measures in an effort to fulfil their mandates. Our approach here is to explore how these unconventional measures can be adjusted to take climate-related risks into consideration. Unconventional monetary policy can be split into two types of measures: balance sheet measures and forward guidance. Balance sheet measures consist of policy instruments that result in the expansion and contraction of the central bank’s balance sheet, whereas forward guidance is an attempt by central banks to influence expectations by credibly communicating future policy. Balance sheet measures can be further differentiated into four categories: direct quantitative easing (QE), direct credit easing (CE), indirect quantitative easing, and indirect credit easing (Fiedler et al., 2016). Direct quantitative easing refers to central banks directly purchasing high quality (low-risk) private and public assets. Direct credit easing is targeted asset purchases with the aim of countering illiquidity and improving credit conditions (Bernanke, 2009). Indirect quantitative and credit easing are measures by which the central banks influence long-term interest rates by lending at longer maturities. In addition, most central bank lending operations to commercial banks involve the posting of collateral at the central bank to secure the loan.

Because of the limited use of GMP, there is no empirical research to guide policy makers on its effects. This problem can be circumvented to some extent by drawing upon research on unconventional and targeted monetary policy instruments. In the proceeding subsections, we review some potential implementations of GMP and consider their feasibility and potential effects on the economy.

2.1 Direct Quantitative and Credit Easing

Direct quantitative easing (QE) was first introduced as a term by the Bank of Japan to describe monetary easing through large-scale asset purchases (Shirakawa, 2002). In our context, green QE would refer to targeted purchases of green assets. There is precedent for such targeted interventions in the form of the so-called direct credit easing (CE). The rationale for these targeted measures in the past has been to address short-falls in asset liquidity during periods of financial distress and to prevent the imminent collapse of particular markets (Cúrdia and Woodford, 2011). There is also evidence that these targeted interventions have an effect on the real economy and decrease financing rates for targeted assets (see Krishnamurthy et al., 2017). However, in the absence of financial distress in the green energy sector, targeted purchases of green assets are very likely to overstep the mandate of many central banks, as they would constitute a clear violation of the principle of “market neutrality”.²

2.2 Indirect Credit Easing

Indirect credit easing refers to actions on the part of central banks, that aim at reducing interest rates over a range of maturities by means of credit operations. In the years preceding the financial crisis, both the Federal Reserve Bank (FED) and the European Central Bank (ECB) successfully used large scale credit operations to restore bank credit supply. Since 2008, the ECB has provided cheap financing to credit institutions through Long Term Refinancing Operations (LTRO) and Targeted Long Term Refinancing Operations (TLTRO).³ There is substantial evidence showing that LTROs and TLTROs have had a positive effect on credit supply to the real economy (Darracq-Paries and De Santis, 2015; Andreeva and Garcia-Posada, 2019; Jasova et al., 2018; ECB, 2017; Benetton and Fantino, 2018; Bats and Hudepohl, 2019) and, while there is evidence of positive effects on GDP and inflation (Casiraghi et al., 2016; Boeckx, 2016), it is not unequivocal (Van der Kwaak, 2017).

Taking inspiration from the TLTRO program, green targeted refinancing operations (GTRO) could be designed by adjusting one or more of the following features of the framework. One could introduce differentiated rates for green and brown loans, green loan quotas with penalties, or green loan quotas with rewards. Using differentiated rates between green and brown refinancing operations would allow central banks to affect the relative financing cost of brown and green investments. A classification scheme like the EU Taxonomy (UNEP, 2018), for example, could be used to differentiate between green, brown, and neutral loans. Applying rewards or penalties to loan quotas achieved within a certain time period can be another way to incentivise banks seeking central bank credit to alter their lending practices. Penalties similar to those of the TLTRO-I, in which credit taken has to be repaid at an earlier date, could be applied to banks that fail to meet loan quotas. Conversely, a reward system could be employed in which banks that meet the quotas receive a preferential financing rate. Although both penalties and rewards act to incentivise banks to increase green loan volume, penalties might discourage institutions from using the central bank re-financing facilities in the first place. Borrowing from the TLTRO-II program, we suggest using GTRO that have a quota reward system which offers a preferential rate for banks that fulfil their loan quotas within the reference time period, where credit from the GTROs is earmarked for green loans. These tools can be operated alongside or without conventional monetary policy.

Though, theoretically, GTRO can contribute to an increase in green investment and the reduction of carbon emissions, credit market conditions might inhibit their successful implementation. How projects and investments are financed can play an important role in the effectiveness of targeted credit easing policies. Targeted refinancing operations might be more effective in the EU, where 70% of firms’ external funding is bank financed, as compared to the United States, where 80% is market funded (Cour-Thimann and Winkler, 2012).

While it is plausible that the success of TLTROs would carry over to GTROs, leading to changes in green and brown investment patterns, the market neutrality principle, that many central banks subscribe to, would make GTROs broadly infeasible. In addition, the strength of the transmission of the targeted refinancing operations to the real economy is somewhat reliant on the liquidity of the credit market, and the pass-through could be further dampened as green projects are more often financed through private equity, equity issuances, and asset financing as

² The principle of “market neutrality” refers to the goal of minimising the impact of central bank interventions on the relative prices in the economy (see, for example, Van’t Klooster and Fontan, 2020).

³ TLTROs offer credit to banks for loans specifically to non-financial corporations and households (with the exception of mortgages).

compared to the fossil fuel sector, which is largely financed through bonds and syndicated bank loans (Gaddy et al., 2017; Cojoianu et al., 2020, 2021).

2.3 Differentiated collateral valuation as a green monetary policy instrument

A more subtle approach to central bank involvement in the transition process can be derived from the collateralised lending frameworks used by most central banks. In order to access central bank liquidity, commercial banks must post collateral with the central bank. Highly rated collateral is taken at full value and, as assets become riskier, central banks apply haircuts to the asset's value. A haircut is a percentage reduction of an asset's market value. If a haircut is applied, commercial banks need to post more of the riskier asset in order to get equivalent liquidity. The instrumentalisation of the collateralised lending framework was intrinsic to the success of the ECBs LTRO programs, as they allowed collaterally constrained banks access to the fresh credit (ECB Bulletin, 2013).

Differentiated collateral valuation, based on the climate-related risks associated with the asset offered up as collateral, holds the promise of finding broad acceptance and of being easy to implement by central banks that want to include the consideration of climate-change-related risk into their operations. In particular, applying brown collateral haircuts to the valuation of assets posted as collateral, depending on their exposure to transition risk, would be in line with the principles underlying central bank collateral frameworks and would be practically feasible.

When it comes to the intention and purpose behind central bank collateral valuation schemes, it is often argued that such are in place for the protection of the central bank balance sheet (see, for example Issing (2005)). Balance sheet losses, via counterparty default are of primary concern to central banks, as losses can undermine the institution's credibility and ability to conduct monetary policy (McCaughrin et al., 2008; Bindseil et al., 2017a). Green and brown collateral should be treated differently, since the brown collateral is associated with additional transition risk.⁴ This treatment is in line with the "market neutrality" principle (Bindseil et al., 2017a), since applying a differentiated valuation simply takes into account the quality of the collateral posted against central bank loans. Just as any other money market actor, central banks would be applying collateral haircuts based on risk assessments – in this case transition risk assessments.

Brown collateral haircuts would also maintain the principles of risk equivalency, simplicity, and operational efficiency. The simplicity and operational efficiency of adding brown collateral haircuts to the collateral framework is to some extent contingent on the current framework structure. Namely, widening an existing framework and applying additional differentiation across the assets certainly adds complexity. While central banks are among the leading institutions studying the potential impacts of climate change and climate policy on the financial system⁵, due to the sheer scope of the endeavour, it might be necessary to outsource some of the information processing to third parties. The risk equivalency principle seeks to levelise the risk associated with different assets to the level that a central bank is prepared to take (Bindseil et al., 2017a). Brown collateral haircuts fulfil this principle, since the transition risk exposure of its collateral holdings is now being taken into consideration and can be optimised by the central bank.

Adjustments to the lending framework can also be seen as a policy measure. During the last financial crisis, central banks were quick and flexible in the adjustments to their collateral frameworks to increase financial and economic stability (Bindseil et al., 2017a). Many central banks adapted their collateral framework in light of underlying changes in the financial landscape (BIS, 2013; ECB Bulletin, 2013). In response to the global financial crisis, the collateral valuation scheme of the ECB was changed 74 times in the period 2008 to 2014.⁶ Climate-change-related risk represents a significant change in the financial landscape. Central banks can adapt to these changes by introducing brown collateral haircuts.

This instrument is also feasible in the sense that it can be broadly implemented across a wide range of central banks despite institutional and financial market differences. Though central banks across the world have different

⁴ Brown assets also threaten the entire financial system through future climate change damages. This represents an externality that by definition cannot be addressed in a market neutral way.

⁵ See the Bank of England's plans with regards to stress testing: <https://www.bankofengland.co.uk/speech/2020/andrew-bailey-speech-corporation-of-london-green-horizon-summit>.

⁶ For an overview of the literature on this topic, see Weber (2016).

institutional settings, mandates, and preside over widely differing financial markets, the use of collateral in their operations is ubiquitous. Schoenmaker (2021) finds that climate-based collateral adjustments do not hinder the implementation of monetary policy as they do not (1) narrow the list of eligible assets and (2) do not majorly disrupt the asset mix, currency denomination, and yield curve. Despite this, collateral frameworks differing in their uniformity⁷, width⁸, and implementation (earmarked vs pooled collateral)⁹ could play change the efficacy of brown collateral haircuts (BIS, 2013). Differentiated collateral frameworks can add an additional layer of complexity to risk management and require an internal or an external assessment of carbon exposures and associated risk. Market depth and institutional history are key determining factors in the width of a collateral framework. If the width represents a narrow slice of the overall economy, the effect of the policy might be limited. For example, the narrow collateral framework of the Reserve Bank of India would not allow for the diversity of collateral required to differentiate between green and brown assets. Therefore, the width of the collateral framework would need to be expanded in such settings. Whether central banks pool or earmark their collateral is not relevant for brown collateral haircuts if transition risk is evaluated on an asset-by-asset basis. However, pooled collateral frameworks might favour certain other methods of evaluation, such as the pooled climate risk method suggested by Oustry (2020) or a portfolio tilting method suggested by Schoenmaker (2021).

In practice, there are two ways to feasibly implement a collateral valuation based on carbon exposure. The first is to perform an independent assessment of the climate risk associated with the collateral. For the case of the ECB, the Single Supervisory Mechanism (SSM) is an institutional framework that can potentially house such assessments. The SSM conducts deep independent analysis of the banking system in the Eurozone, which requires developing a sound understanding of the risks on their balance sheets, and is therefore closely related to the task at hand. Alternatively, the carbon exposure data, as well as the associated implications for the collateral valuation, can be taken from trusted external sources. Currently, many central bank collateral valuation frameworks are based on the ratings provided by private rating agencies (Bindseil et al., 2017b). The recently created S&P Carbon Price Risk Adjusted Index Series offers a practical example of how asset valuations can be corrected for transition risk.¹⁰ Specifically for bonds, which are the asset most often used as collateral, Battiston and Monasterolo (2020) have created a promising framework for assessing how the transition can impact valuations. Central banks can then either apply haircuts to individual assets directly or, as proposed by Oustry et al. (2020), impose climate-related collateral requirements at the level of the institution seeking to borrow, requiring that the collateral *pool* provided by a bank matches some sustainability criteria.

The effects of such measures on the energy mix in the economy could manifest themselves through the collateral demand channel. A component of the demand for a collateral asset is its value in refinancing operations. The demand for an asset, and therefore its price, is reduced if a collateral haircut is introduced, because this decreases the utility of the asset as collateral at the central bank. Barthelemy et al. (2018) attributes movement of an asset's yield given new collateral constraints to a change in the liquidity premia. Similarly, while looking at the collateral policy changes enacted by the ECB, Corradin and Rodriguez-Moreno (2016) find that haircuts increase the yield on assets due to adjustment of the external finance premium. Therefore, brown collateral haircuts have the potential to increase the financing cost of brown firms, as the usefulness (as collateral) of the debt they issue decreases. We explore this channel in our modelling exercises.

In summary, brown collateral haircuts are broadly implementable across central banks both practically and in terms of mandate. Additionally, they can have a real effect on the investment patterns in the economy. For these reasons, we regard them as the most promising instrument for GMP.

⁷ Collateral frameworks can be uniform or differentiated. Under a differentiated framework, collateral and haircuts differ depending on the central bank operation, whereas uniform frameworks use the same structure across operations.

⁸ A narrow collateral framework only accepts a small set of high-quality assets as collateral, whereas a broad framework accepts a larger set of assets.

⁹ Central banks either pool all collateral together against liquidity or earmark assets for specific liquidity issuances.

¹⁰ A document describing the approach can be found at <https://www.spglobal.com/spdji/en/documents/education/education-considering-the-risk-from-future-carbon-prices.pdf>.

An interesting alternative to brown haircuts is green hairgrowth. This is a policy in which the collateral value of green assets is increased. This collateral valuation adjustment can reflect their superior quality in terms of their robustness to transition risk.¹¹ As the volume of green assets is substantially lower than that of brown assets, it could be that upon cutting the value of brown collateral, banks might have insufficient assets to acquire enough liquidity. The inability of central banks to supply sufficient credit to banks would be problematic during an economic contraction. Green hairgrowth might allow for an overall credit expansion that might be desirable in such periods. In the upcoming sections we abstract away from the difficult question of how the climate risk of an asset should be calculated and focus on modelling the effects of brown collateral haircuts and green hairgrowth on the investment patterns in the economy and on emissions. Since introducing green hairgrowth would, *ceteris paribus*, increase the overall amount of liquidity available to banks, it can have an additional supportive effect on the transition process as green capital accumulation happens faster. Despite its stronger effect, allowing for borrowing in excess of the face value of a loan has no precedent in central banking. Not only could this approach increase financial stability risk, but the favoured targeting of low-carbon assets does not adhere to the “market neutrality” principle. Given these caveats, the policy is not broadly implementable across central banks and it is a less favourable instrument than brown haircuts.

3 A simple approach to modelling central bank collateral constraints

As a starting point we use a simple formulation of central bank collateral constraints based on the industrial organisation approach to financial intermediation (Freixas and Rochet, 2008; VanHoose, 2017), as taken by Lessmann and Kalkuhl (2020). A key function of intermediation is to pool financial resources and make them available for productive investments. We model this by a representative financial intermediary whose business is to gather deposits D and offer loans L_j to different sectors. Here, we differentiate loans for green g , brown b , and final goods y sectors. The intermediary pays an interest rate on deposits of r_d to households and receives differentiated rates r_j based on loan type. The intermediary can fund loans through three sources: deposits from households, interbank borrowing M , or central bank credit CB . They are obliged to pay an interest rate r_m on all funds borrowed on the interbank market and an exogenously set rate of r_c on all credit borrowed from the central bank. The central bank rate is set as a parameter with a value low enough, such that it will, under normal circumstances, always be lower than the deposit and interbank rate, so as to incentivise financial intermediaries to take credit from central banks. Management of the intermediation of loans and deposits are costly due to personnel cost, screening, and monitoring (Calice and Zhou, 2018). In order to operate, the financial intermediary must pay these costs given by the function $C(D, L)$. The financial intermediary’s objective is to maximise profits subject to funding constraints as seen in Equations (1-4).

$$\max \pi^{Bank} = r_g L_g + r_b L_b + r_y L_y - r_m M - r_d D - r_c CB - C(D, L) \quad (1)$$

$$L = M + D(1 - \alpha) + CB \quad (2)$$

Equation (2) represents the accounting balance as all loans L must be equal to the sum of interbank funds, central bank funds, and deposits less the reserve ratio α .

The method used to describe central bank credit and collateral constraints is a simplified version of that used by Hilberg and Hollmayr (2011), who include two separate types of banks and collateralised assets. The financial intermediary’s ability to borrow funds from the central bank is constrained by the type of loans they can post as collateral as described by Equation (3).

$$(L_g \mu_g + L_y \mu_y + L_b \mu_b) \omega = CB \quad (3)$$

¹¹ In the long term, one would expect green assets to be associated with less risk, due to the lack of exposure to transition risk. This is reflected in the recent study by Kempa et al. (2021) in which the author finds that the borrowing cost for renewable energy firms is higher in the short term, but lower in the long term, as compared to fossil-fuel-related firms.

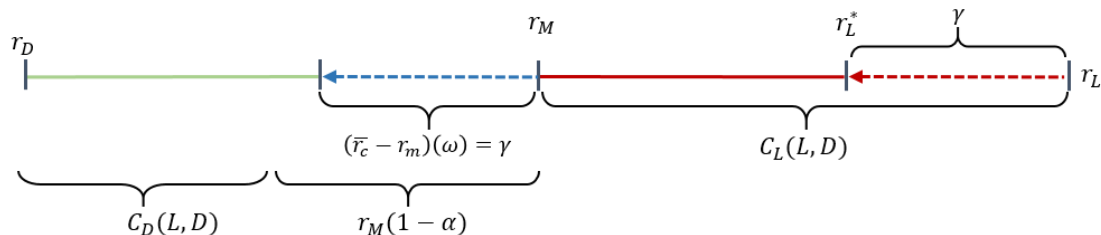


Figure 1: Interest rate spread with central bank credit.

The central bank makes credit available proportional to the amount of deposits and interbank loans held by an intermediary. This ratio of central bank funds to deposits and interbank loans is set exogenously with the parameter ω . Through Equations (2 and 3), the amount of central bank credit ultimately becomes constrained by the deposits D , and interbank credit M , that the bank is able to attract.

$$L = L_g + L_b + L_y \quad (4)$$

Additionally, the different types of collateral posted by banks is subject to the haircuts μ_b , μ_y , and μ_g . Since brown loans have a high carbon exposure and are, therefore, exposed to transition risk, the central bank adds a haircut $\mu_b \leq 1$ that reduces the value of brown loans posted as collateral by financial intermediaries. Working in the opposite fashion as brown haircuts, green hairgrowth, $\mu_g \geq 1$, increases the value of green collateral posted with the central bank.¹² If loans are directed towards the generation of green energy, their collateral value is increased.

To reflect a meaningful central bank policy, the rate r_c , which the central bank sets exogenously, will always be less than the interbank and deposit rates. This is the case as in order to motivate borrowing for the purpose of conducting monetary policy, central banks must offer an interest rate lower than that from alternative sources. The dynamics of how the interest rates are determined are shown in Figure 1 and follow from the first order conditions for the financial intermediaries problem (see Appendix 6.2, SM), which are found by maximising Equation (1) with respect to L_g, L_b, L_y, D under the constraints (2-4). Without central bank credit, $\omega = 0$, the loan rate r_L is entirely determined by the interbank rate r_M and the management cost of loans $C_L(L, D)$. With the introduction of central bank credit, the rate charged on loans is reduced from r_L to r_L^* by the amount γ . The size of γ is a product of the central bank rate r_c and ω (Figure 1). As the proportion of central bank credit rises, the amount of funds required from the interbank market decreases and hence the costs are reduced, leading to a lower required rate of return from loans. The second component of γ is the spread between the interbank and the central bank rate. The larger the spread between the two rates given a certain ω , the larger the cost saving on credit funding for loans, hence the reduction of the rate charged for loans.

When financial intermediaries can distinguish between loan types it is possible to affect differentiated interest rates by applying differentiated haircuts to collateral. In the model described by Equations (1-4), credit is asymmetrically collateral-constrained based on the purpose of the loan. If a loan is directed towards a process which does not produce carbon, i.e. the generation of green energy or the production of final goods, it is taken at face value, whereas only a fraction of the face value $(1 - \mu_b)$ of loans allocated to fossil fuel extraction and fossil fuel energy generation counts towards central bank credit collateral. The haircut reduces the value of brown loans for financial intermediaries, as this type of loan limits their access to cheap central bank funding. Therefore, in order to persuade financial intermediaries to continue to issue brown loans, the brown sector must pay higher interest rates, which, as we see later, is only viable at lower levels of brown energy production and fossil fuel extraction relative to the rest of the economy. Adding central bank credit (CB) to the banking sector reduces both the lending rate for green and brown loans, however applying a haircut on brown loans ($\mu_b < 1$) results in a less pronounced reduction of brown interest rates (cf. Appendix 6.2, Figure 5, SM). Applying these haircuts asymmetrically to different loan varieties results in unique interest rates. Due to the haircut $\mu_b < 1$, the central bank credit effect on brown interest rate γ_b is

¹² Unless otherwise stated, assume μ_y to be equal to 1.

smaller than that on the green rate γ_g . As such financial intermediaries require a higher interest rate for brown loans r_b^* than for green loans r_g^* .

Given green hairgrowth (i.e. increases in the value of green collateral), $\mu_g > 1$, the central bank credit effect on green interest rates is amplified. As the parameter for green hairgrowth μ_g increases, so too does the negative effect of central bank credit on the interest rate. The green interest rates, r_g , therefore decreases with green hairgrowth.

4 Policy analysis

The previous section suggests that collateral haircuts can be a tool for central banks to affect the interest rates charged by commercial banks, and to differentiate interest rates for brown and green investments. This section links our model of central bank credit and differentiated collateral haircuts to an established climate policy model (Kalkuhl et al., 2012, 2013, 2015), extended to include a banking sector as seen in Lessmann and Kalkuhl (2020). The model features enough sector detail to describe how economic activity gives rise to greenhouse gas emissions, and how

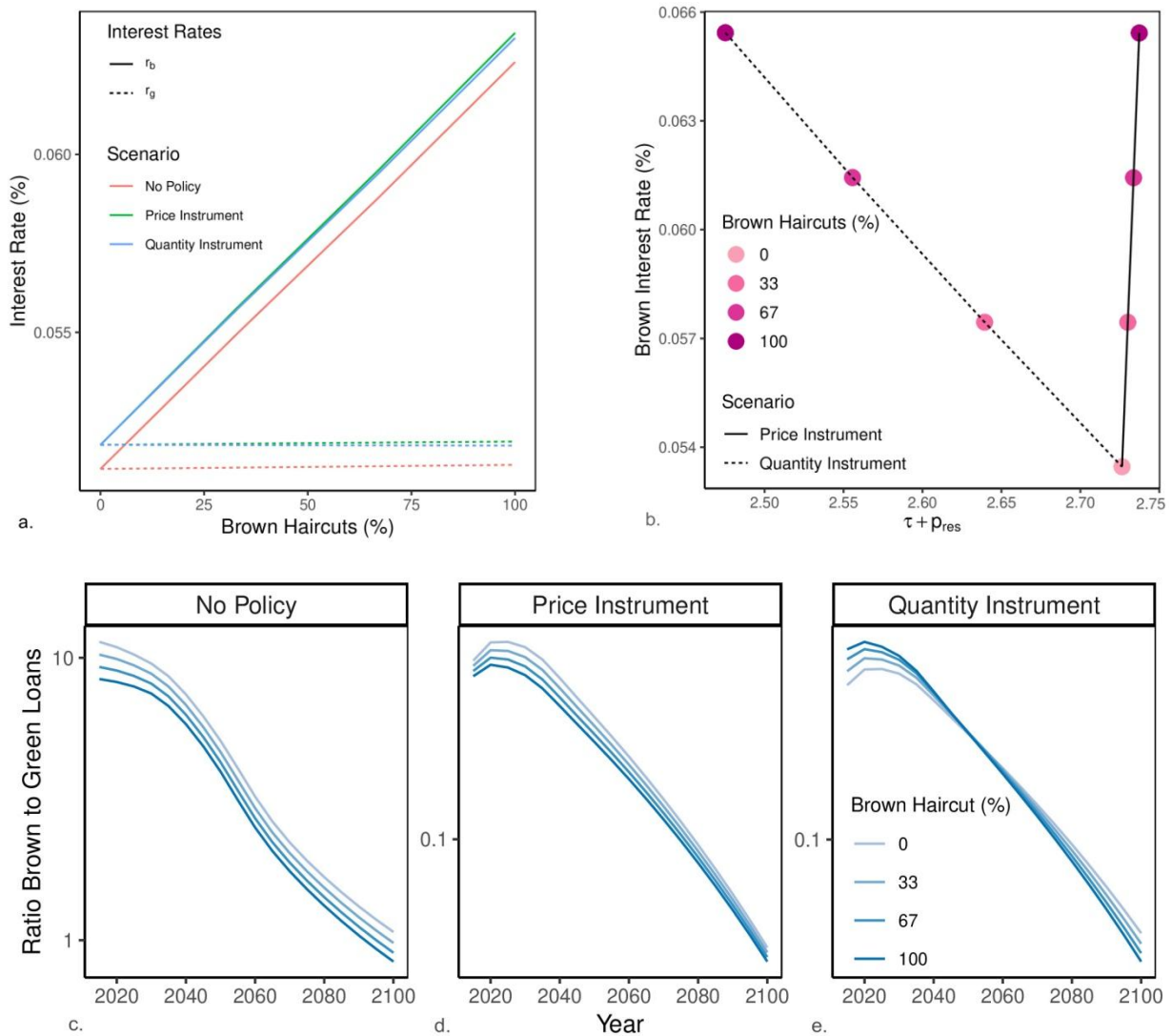


Figure 2: Panel (a) shows the linear increase of brown interest rates across different policy scenarios given an increase in brown collateral haircuts. (b) With a quantity policy, brown haircuts result in a lower net marginal resource cost because of the reduced optimal tax τ . This effect is not present with a price instrument due to the fixed nature of the carbon tax τ . Panels (c-e) illustrate the change in green and brown loans (investment) under different policy regimes given higher brown haircuts. Under a no-policy scenario, there is a steady decrease in the brown to green loan ratio indicating a shift in investment towards a carbon neutral economy. The effect is substantially more pronounced with either a price or quantity instrument indicating the necessity of a carbon price.

climate policy can steer the economy towards lower emissions.

The economy in the climate policy model consists of consumer households, firms, banks and a government. The household sector describes the decision of consumers to either purchase a consumption good, or save their income for later use by storing it in a deposit account. Firms are distinguished by sector into the consumption goods sector and four energy sectors specialised in (1) fossil resource extraction, (2) generating energy from fossil resources, (3) renewable sources, and (4) nuclear power. The banking sector provides capital to all firms, while the government oversees and steers all activities in the economy using a set of policy instruments, here a tax or cap on emissions. In the Appendix (SM), we provide a sketch of the structure of the economy (Figure 4) as well as a detailed mathematical description (Section 6.1).

Model experiment design

Brown collateral haircuts decrease brown investment. Similarly, inflating the collateral value of green loans (green hairgrowth) should increase the demand for green loans, partially substituting for brown loans. We investigate the effects of central bank collateral frameworks in the following model experiments.

Brown haircuts: The first experiment tests brown haircuts in a variation of the collateral valuation for brown loans, ranging from the default of valuing brown collateral at face value, to the extreme case of a 100 percent haircut rate, such that brown loans are rejected as central bank collateral.

Climate policies: In the second experiment we compare how collateral haircuts affect two climate policy instruments: a quantity instrument (cap on cumulative emissions) and a price instrument (carbon tax). We apply the same haircuts on brown loans and explore (a) how haircuts and climate policy interact, (b) the difference for the two types of climate policy, and (c) possible complementarities between central bank collateral policy and conventional climate policies.

Green hairgrowth: Finally, we explore green hairgrowth, i.e. increasing the value of green collateral as the converse instrument to brown haircuts, in our third experiment. We vary the value for green collateral from taking its collateral at face value up to valuing green collateral at twice its face value. We consider effects of green hairgrowth with and without climate policy.

4.1 Brown haircuts

Figure 2a, confirms our theoretical considerations in Section 3: a reduced valuation of loans to brown sectors when posted as central bank collateral drives up the interest rate that is subsequently charged for such loans. This drives a wedge between the differentiated interest rates for brown loans versus loans to green sectors or goods production, putting an approximately 1% premium on the interest rate for brown relative to green loans, when brown collateral is rejected (100% haircut rate). We also see that the interest rate spread is almost exclusively due to a rise in the rate on brown loans, indicating that reducing fossil fuel use is harder than ramping up clean energy generation. Capital accumulation (not shown) in the green and brown sectors mirrors the changes in interest rate: while capital accumulation in the fossil extraction and fossil energy sectors declines, full haircuts raise the renewable energy capital stock by more than 10%.

The differentiated interest rate has a profound effect on how loans are provided to the economy. Without climate policy, our economy is mainly supported by energy generated fossil fuels, and hence brown loans are a multiple of green loans. Figure 2c shows the ratio of green versus brown loan volumes, which is about 10-fold in 2020, gradually declining as fossil fuels become scarcer and more expensive over the course of the century, while energy from renewable sources becomes more competitive as its productivity is improved by technological learning. This relative effect is most pronounced in early years, indicating that a redirection of the economy is immediately effective. Diverting investment away from the fossil industry has the expected effect on emissions as well. In 2160, CO₂ emissions are down by 129 GtC from 2706 GtC when we compare no haircuts to full haircuts. However, cumulative emissions show only a decline by 0.5%. Brown collateral haircuts by themselves are therefore no substitute for climate policy in the modelled economy. We will return to Figure 2 (panels d and e) in our discussion of climate policies in the next section.

4.2 Brown haircuts with conventional climate policy

This section explores the role of brown haircuts with conventional climate policies. We study the interaction of climate policy and brown haircuts in modelling experiments with two alternative climate policy instruments. The first is a quantity instrument that mandates the government to keep cumulative emissions below a given emissions budget of 450 GtC. The government will endogenously determine a price on carbon which achieves the quantity target in an optimal way.¹³ The second instrument is a price instrument fixing the carbon price by imposing a carbon tax on the use of fossil fuels in fossil energy generation. The carbon tax is set to the values of the optimal carbon price in the quantity instrument case without haircut, such that at the 0 percent haircut rate, the two instruments are identical.

Introducing climate policies shifts the interest rates paid on loans for the brown and green sectors upward compared to the no (climate) policy scenario (Figure 2a). We attribute the higher interest rate level to the scarcity that arises from climate policy: with carbon pricing, use of the fossil resource that is now taxed is reduced. Subsequently lower economic activity in general implies a higher marginal productivity, which puts upward pressure on interest rates.

For similar reasons, interest rates are higher when the climate policy is implemented via a price instrument (compared to the quantity instrument solution). For a price instrument, the increased interest rate for brown loans adds to the overall price of fossil energy, whereas the quantity instrument allows the carbon price to adjust downward, such that the brown haircut may substitute for part of the carbon tax.

To understand this difference in how collateral haircuts affect price and quantity policies, consider that the unit cost of fossil energy (c_f) are determined by the cost of capital (given by the interest rate $r_{t,b}$) as well as the cost of resource, which is made up by resource price and carbon tax ($p_{t,r} + \tau_r$). The exact formula also takes into account how well more capital can substitute for a lack of resource (and vice versa, given by the elasticity parameter σ) and what the relative importance of the two inputs is (share parameter β).

$$c_f(r_b, p_{t,r} + \tau_{t,r}) = \left(\beta^\sigma r_b^{1-\sigma} + (1 - \beta)^\sigma (p_{t,r} + \tau_{t,r})^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \quad (5)$$

A fixed price policy pins down the carbon tax ($\tau_{t,r}$). Central bank policy that causes a rise in the interest rate $r_{t,b}$ subsequently raises the unit costs of fossil energy in addition to the fixed carbon tax. Carbon tax and collateral haircuts both add to unit costs in the weighted sense given by Equation (5). Figure 2b illustrates the effects for different haircut rates. When higher haircut rates raise the interest rate r_b at a fixed carbon price, the relationship is almost perfectly vertical. The slightly positive slope of the relationship reflects an increase in the resource price p_R , which we attribute to higher costs in the resource extraction sector, as here, likewise, the costs of capital are increased due to the brown haircut.

In contrast, a fixed quantity is implemented by the government via a price on carbon $\tau_{t,r}$ that keeps cumulative emissions below the target at the least welfare cost. Hence, when central bank policy raises the unit cost of fossil energy via $r_{t,b}$, the price on carbon $\tau_{t,r}$ will adjust such that cumulative emissions remain the same. Here, climate policy and central bank policy are (imperfect) substitutes such that, under a quantity policy, $c_f(r_b, p_R + \tau_{t,r})$, it remains approximately the same.¹⁴ In Figure 2b, this substitution effect corresponds to the negative slope in the relationship of the two dimensions of unit cost ((average) cost of brown capital and (average) resource price).

¹³ The objective function maximised by the government coincides with that of the household sector and therefore the carbon price of the government is optimal in terms of social welfare.

¹⁴ As the quantity target (carbon budget) is cumulative, timing is flexible and a different timing of emission may be optimal – which is indeed what we find.

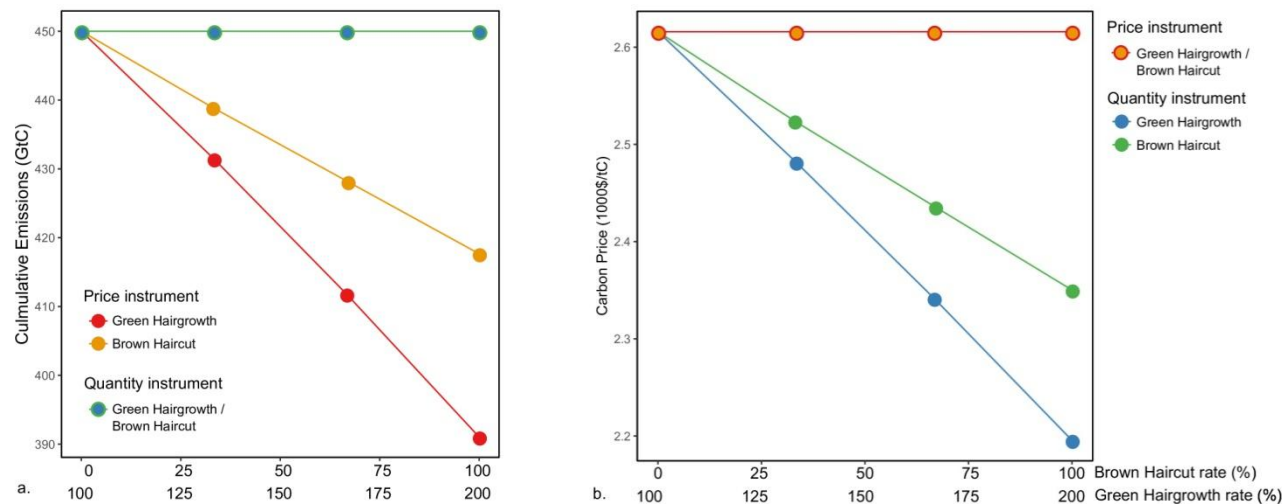


Figure 3: Panels (a) and (b) contrast the difference between brown haircuts and green hairgrowth given a carbon price or quantity instrument for climate policy. In panel (a), collateral policies act as an additional cost to the price instrument further reducing the amount of emissions in the atmosphere. Whereas combined with a quantity instrument (b), climate collateral adjustments keep emissions constant (a) but reduce the carbon price.

By putting a price on carbon, climate policy has a decisive effect on the allocation of loans. With carbon pricing, the volume of loans is in sharp contrast to the no policy case with the majority of loans now going to green sectors (Figure 2c-d). Beginning with green loans at double the volume of brown loans in early years, the ratio falls further until the end of the century when their volume is tenfold the brown loan volume. This is the same for both instruments. Again, the effect of haircuts is different for the two climate policy instruments. With a price instrument (Figure 2d), brown haircuts work to reduce the ratio of brown to green loans at every point in time. Higher costs of capital add to the unit cost of fossil energy, hence haircuts have a very similar effect on loans as the carbon tax.

In the case of quantity instrument, brown haircuts raise the loans ratio in the first half of the century – an effect that is offset by a decrease of the loans ratio in the second half. Figure 2d shows this decrease in early years versus the increase of the ratio later. In absolute numbers the volume of brown credit over the course of the century remains virtually the same with slight shifts only in the intertemporal allocation of haircuts shifting loans to earlier time periods. It is the nature of the fixed cap instrument that it ensures the same overall carbon budget, i.e. the instrument limits the use of fossil resource. A change in the cost of capital as brought about by the haircuts will affect the relative prices of the inputs to fossil energy generation (resource and capital) with only slight effects on how fossil energy is produced. The overall demand for brown capital is therefore barely affected. And without a substantial drop in fossil energy generation, there is only little room for additional renewable energy, and consequently the increase in green loan demand remains small.

4.3 Green hairgrowth

An alternative to reducing the valuation of brown collateral is to increase the value of green collateral, which could be termed green hairgrowth. Indeed, model experiments where we vary green hairgrowth rates for the two climate policy instruments analogous to the previous section reveal that the effects on interest rates are similar to those of brown haircuts. An increase in green hairgrowth results in lower green and higher brown interest rates. Consequently, the volume of brown loans is reduced while the volume of green loans is increased.

We contrast the interaction of a central bank green collateral hairgrowth policy with climate policies in Figure 3. The interaction has two dimensions: the effect on cumulative greenhouse gas emissions, which measures the environmental effectiveness of central bank intervention (left panel), and the effect on the price on carbon (right panel), which we take as a measure of the pressure put on the economy by climate policy.

The first lesson is that – along these two dimensions – hairgrowth and haircut policies work in very similar ways. As discussed in the previous section (Section 4.2), any central bank policy that raises the brown loan rate will add to

the effects of the carbon tax and subsequently trigger additional emissions reductions. Haircuts and hairgrowth policies both show this effect (Figure 3a). We can see, however, a stronger effect on emissions from green hairgrowth, and a closer inspection of the model results that this is driven by a larger interest spread between r_b and r_g in the hairgrowth scenario. Quantity policies put a cap on emissions, hence the constant line at 450 GtC is no surprise.

But even if central bank policies cannot affect the overall emissions of a quantity policy, both brown haircut and green hairgrowth policies provide a different kind of relief for the economy. With quantity policies, the increased brown loan rates can partially substitute for carbon pricing, as evident from the decline of the average carbon price in Figure 3b. Here it is that, by definition, the price policy does not react to the central bank policy.

Of course, a government that is aware of these effects may very well choose to adjust its price policy downward in response to central bank intervention. A central bank collateral policy can thus work in support of climate policy. Whether the support amounts to a strengthening of an existing price policy, or whether it takes some of the (carbon pricing) pressure off the economy, depends on the climate policy instruments and the government's response to central bank policy.

5 Conclusion and Policy Implications

The development and deployment of low-carbon technologies is central to the mitigation of climate change. This requires a substantial mobilisation of investment through climate policy. Climate risks, both physical and transitional, threaten both financial and economic stability. In this paper, we discussed different GMP instruments along the dimensions of their feasibility, as well as their potential impacts on the real economy. We identified a particularly promising instrument – brown collateral haircuts based on carbon exposure – and provided some details on how the collateralised lending frameworks of central banks currently work and on how they can be adjusted along the dimension of carbon exposure. In terms of the effects of this instrument on the real economy, our modelling suggests that differentiated collateral valuation based on carbon exposure can impact the investment patterns in the real economy to benefit green investments, ultimately resulting in less emissions. In that sense, a policy mix of a carbon tax and GMP can allow governments to reduce the size of the optimal carbon tax, making a timely transition to a carbon neutral economy more politically feasible.

Central bank mandates and their interpretations can pose barriers to active targeted GMP such as Green Targeted Refinancing Operations or Green Quantitative Easing. Climate risk collateral adjustment policies can be thought of as a measure that simply accounts for the differences in risk associated with high-carbon and low-carbon assets. This measure protects central banks against downside balance sheet risk, while, at the same time, fostering financial stability. In current central bank collateralised lending frameworks, assets are valued differently according to their respective credit ratings. A natural extension of this policy would be to incorporate transition risk by applying haircuts and hairgrowth to the respective collateral based on carbon intensity. This would require central banks to (1) perform an independent assessment or (2) mandate third parties to conduct an assessment of transition risk exposures. This approach supports the central bank goal of financial market stability and does not imply direct targeted support or penalisation of any one sector. Even though green hairgrowth, as an instrument, has a stronger effect on emissions than brown haircuts (due to the additional overall central bank credit that enters the economy), allowing for borrowing in excess of the face value of a loan has no precedent in central banking and might be difficult to reconcile with the “market neutrality” principle. Therefore, brown collateral haircuts are more institutionally feasible and can be more broadly applied across diverse central banks.

Our numerical analysis suggests that by differentiating between green and brown collateral when lending to commercial banks, central banks can contribute to climate change mitigation. Brown collateral haircuts and green collateral hairgrowth can reduce the borrowing rates for green loans and increase those for brown loans, which ultimately changes the investment pattern in the real economy in favour of green investments. Apart from reducing the exposure of central banks' balance sheets to climate risk, differentiated collateral valuations have a complementary synergistic effect with conventional carbon pricing which leads to additional emission reductions. In the presence of brown collateral haircuts, the economy can stay below a certain emissions threshold with a lower carbon price.

Our modelling is stylised in nature and the following important limitation applies. The modelling exercise is rooted in a real economy setting, which precludes the study of inflation dynamics. An extension to nominal variables

would, in particular, allow for the consideration of negative consequences or constraints associated with GMP and the expansion of the money supply.

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