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## Banking barriers to the green economy

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# Banking barriers to the green economy[§]

PRELIMINARY AND INCOMPLETE

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In the race against climate change, financial intermediaries hold a key role in rapidly redirecting resources towards greener economic activities. However, this transition entails a dilemma for banks: entry of innovative and green firms in polluting industries risks devaluating legacy positions held with incumbent clients. As a result, banks exposed to such losses may be reluctant to finance innovation aiming to reduce polluting activities such as green house gas emissions. In this paper, we formalize potential banking barriers to investments in green firms that threaten the value of legacy contracts by affecting collateral pledged by incumbent clients to banks as well as probabilities of default. We show that the more homogeneous and concentrated the banking system is in a given industry, the fewer new innovative firms will be granted loanable funds. We further exploit data on credit allocations in Belgium between 2008 and 2018, to investigate the empirical relevancy of such barriers in polluting industries with larger exposures to green technology disruption. The results indicate that the market structure of the banking system may be key to facilitating a green economic transition highlighting the need for policies to address the role of brown legacy positions and heterogeneous bank business models.

**Keywords: Financial intermediation, innovation, barriers, climate change**

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# 1 Introduction

*A new, sustainable financial system is under construction. It is funding the initiatives and innovations of the private sector and amplifying the effectiveness of governments' climate policies—it could even accelerate the transition to a low-carbon economy. Unfortunately, like virtually everything about the response to climate change, this new sustainable financial system is not developing fast enough for the world to reach net zero.*

Mark Carney,
Governor, Bank of England.

Across the world, governments are in a race against time to stop runaway climate change.[1] However, a rapid transition away from fossil-fuel energy into environmentally friendly technologies may entail substantial economic costs: (1) a sudden substitution of energy sources would be restricted in supply and expensive at the margin; (2) there could be a sudden repricing of carbon-intensive assets (i.e., stranded assets), which are financed in large part by debt.[2]

Given the stakes and the risks at hand, the question arises on whether credit markets are impeding the pace of transition to a greener economy. In general, climate change offers ambiguous opportunities to financial intermediaries: on the one hand, legacy positions in polluting ('brown') industries may prevent incumbent investors from promoting entry to innovative ('green') firms as these new firms could threaten the credit value of their clients; on the other hand, demand for green technology has become so strong that investments in the right innovation may produce large returns in case of success.

In this paper, we analyze banks' strategic lending behavior in presence of *green* externalities. First, we extend the corporate finance model of Holmstrom and Tirole (1997) to study the effect of an investor's legacy portfolio on her decision to extend credit to new firms (or projects) when these firms (or projects) may adversely affect the value of the investors' original portfolio. The sources of externalities originate from the fact that new projects (e.g., green technology) may either increase the probability of default or degrade the value of the collateral related to legacy projects (e.g., brown technology).[3] Second, we analyze how the banking market structure affects the rationing of new projects as a function of the distribution of banks' legacy positions to green technology disruption. Finally, we exploit data on credit allocations in Belgium between 2008 and 2018, to investigate the existence of such rationing barriers in polluting industries with larger exposures to green technology disruption and more homogeneous banking portfolios.

**Overview of the model, data and results** To investigate our research questions, we model a competitive banking sector where each bank inherits a legacy position. A new firm has a positive NPV investment

[1] In its *Green Deal* proposal made in April 2020, the European Commission stated:"*The EU will be climate neutral in 2050 [...] Reaching this target will require action by all sectors of our economy, including investing in environmentally-friendly technologies.*". See `https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en`

[2] In 2016, more than two thirds of EU financed fossil-fuel activities came from debt, of which 55% was originated by banks which in total contributed to 43% of total EU funding to fossil-fuel firms (Gros et al., 2016).

[3] For instance, a recent report by the National Bank of Belgium on real estate credit market states that energy efficiency is a determining factor for both collateral value and probability of defaults of mortgage loans (NBB, 2020).

project that threatens the value of legacy positions either through lowering the collateral value or by increasing the probability of default of legacy positions. We study the role of heterogeneity in the exposure of banks to this externality. A key role in our analysis is the magnitude of the externality on the bank with the lowest legacy position, and thus the banking market structure. Our model predicts that new firms are rationed when (i) the NPV of its project is lower than the minimum externality it generates, or (ii) they have insufficient cash to overcome this minimum externality. New firms internalize the externality and leave part of the revenue to the bank to compensate for the loss on its legacy assets.

Using sectoral data on credit allocations in Belgium between 2008 and 2018, we find that sectors exposed to green technology disruption as measured by the distance between the sector's emission performance relative to a European benchmark, see greater credit growth at the extensive margin for young innovative firms (age less than 5 years) the more heterogeneous the banking market structure is, i.e., when the lowest legacy position in the banking market is rather low. We do not find a similar role of banking market structure and legacy positions for the financing of other firms both at the extensive and intensive margin.

**Policy implications** The results from this paper talk to a number of ongoing policy debates. First, by highlighting the role of legacy positions in a bank's incentives to finance innovation, our paper shows the need for banks which are free of brown assets in order to promote entry of green firms. Public 'green banks' initiatives such as the UK Green Investment Bank or the New York Green Bank could therefore be key to reduce barriers to entry for more energy-efficient firms. Second - and perhaps more importantly - our results on the role of the banking system structure suggest that introducing legacy free banks would also induce incumbent banks to extend credit to innovative firms which they would have rationed otherwise. This effect gets more pronounced the more incumbent banks share homogeneous legacies. As a result, the total capacity of credit provisions to green technology gets compounded beyond the individual capacities of green banks to include all banks in the system.

**Literature review** Our work contributes to two streams of literature. The first one considers the role of banks in fostering innovation and economic growth. In general, the level of development of a financial system directly impacts economic growth. However, which orientation of the financial system dominates has been long debated (Beck and Levine, 2002). A major finding from this literature is that banks become less adequate to finance innovation as GDP increases compared to stock markets (Cihak et al., 2013; Gambacorta et al., 2014; Beck, 2009; Popov, 2018). In the case of high tech intensive innovation, Hsu et al. (2014) use a large cross-country analysis and find that similar industries exhibit different levels of innovation depending on whether they rely on equity markets (higher) or credit markets (lower).

Several mechanisms have been put forward to establish why banks may be ill suited to finance advanced (high-tech) innovation. First, banks may be less capable of screening early stage technologies. Ueda (2004) argues that this may explain why innovative technology firms with little collateral are financed by venture capital. Second, banks may find it costly to promote new technology when they have already acquired expertise on mature technology. Minetti (2011) shows in this context that banks may exhibit technological conservatism: when acquiring information is costly, banks favor firms with mature technology in order to preserve the value of their acquired expertise. Third, the intangible nature of advanced technology innovation makes such project harder to collateralize (Carpenter and Petersen, 2002; Hall and Lerner, 2010). Finally, the structure of the banking system may also direct banks' decision to finance innovation. In a model that combines a financial market and a product market, Cestone and White (2003) find that financial entry deterrence is most important when competition in financial markets is most limited. In the same vein, Cetorelli and Strahan (2006) combine theoretical predictions and empirical tests to show that concentrated banking markets increase barriers to potential entrants in local US markets. Exploiting the effect of interstate branching deregulation in the US, Cornaggia et al. (2015) finds that banking competition increases the financing of private innovation, also preventing private firms from being acquired by large public ones. With respect to this literature, our paper shows that the capacity to promote innovation is affected by the interplay between structure of the banking system and the distribution of legacy exposures to the externalities of innovation.

The second strand of the literature relates to the relationship between climate change and financial markets and, in particular, the role of finance in accommodating the transition away from carbon emissions. In a cross-country, cross-industry panel analysis, de Haas and Popov (2019) find that equity-based economies transit faster towards low-carbon emissions and innovate more in terms of energy efficiency as measured by the number of green patents filed when compared to credit-based economies. Dasgupta et al. (2002) review early works showing environmental news sensitivity of stock markets with gains from good news and losses from bad ones. The authors further suggest that banks may prevent loans to firms exposed to adverse environmental liability. In more recent work, Bolton and Kacperczyk (2020) show the existence of a carbon-risk premium from investors in the US stock market. Focusing on syndicated loans, Delis et al. (2019) find that banks started to impose higher costs on credit for fossil fuel firms exposed to climate policies, after 2015. Our paper contributes to this corpus of research by highlighting the role of the banking system structure and the effect of legacy assets of industries subject to large levels of emissions: by preventing the financing of entry and innovation in industries most exposed to green technology externalities, the banking system effectively slows the necessary transition to a low-carbon economy.[4]

Finally, our setting is also related to the role of policy makers in directing financing towards sustainable and environmentally friendly innovation. Acemoglu et al. (2012, 2016) study optimal policies in terms of taxes and subsidies in order to induce innovation towards cleaner technologies. Our results highlight the need to design an incentive compatible financing environments in conjunction with tax and subsidy policies. As such, some emission outcomes can be addressed by effectively promoting competition and diversity among the banking and alternative sources of funding for green innovation.

[4]We are not the first to study how legacy positions in a banks' portfolio drive new lending dynamics. Giannetti and Saidi (2019) for example show that lenders that are prominent providers of credit to an industry in distress are more likely to initiate new loans to (i) downstream firms (in order to boost sales of the distressed (upstream) industry) and (ii) upstream firms (as the suppliers' financial health and continued provision of inputs and other products are important for the performance of downstream distressed firms).

**Outline of paper** The remainder of the paper is organized as follows. Section 2 introduces a monopoly banking system model to study whether innovative firms are rationed or not, while Section 3 studies a competitive banking system model. Section 4 presents our empirical analysis using sector-level data from Belgium. Sections 5 offers policy implications. Section 6 concludes.

## 2 Monopoly banking system

Consider a monopoly bank who is the only source of external finance in the economy. We investigate how legacy positions stemming from previously granted loans may affect lending decisions towards loan applications by new firms. To capture this, we first discuss the general lending decision of the monopoly bank in presence of moral hazard on the part of the firm. Afterwards, we turn to lending decisions towards a new firm in the presence of externalities on legacy positions. Our goal is to understand how legacy positions may affect credit rationing strategies by the monopoly bank towards new firms.[5]

### 2.1 Lending decision in absence of externalities

To understand the bank's profits from lending, we employ a setup as in Holmstrom and Tirole (1997) or Tirole (2010).

**Firm's project** Consider a firm applying for a loan to the monopoly bank for a project with the following characteristics. The firm has no cash at hand, but has collateral (i.e., machines or buildings) with value $C$, that it brings to the project. Next to this collateral, the firm needs a loan of amount $I$ to invest into an indivisible project. When successful, the project yields $R$ whereas it yields zero when unsuccessful. Independent of failure, the project further always gives back the collateral $C$. When the project fails, the bank grabs the collateral of value $C$.[6] The bank's capacity for rent extraction is limited by the following moral hazard problem. When the entrepreneur (i.e., firm) works, its success probability is $P_H$. It is $P_L$ when the entrepreneur shirks. The entrepreneur enjoys private benefits from shirking $B$. We assume that the project has a positive NPV when the entrepreneur behaves. In contrast, the NPV is negative in case the entrepreneur shirks. That is

$$P_H R - I > 0 > P_L R + B - I.$$

**Bank's lending decision and profits** The bank should make sure that the following two constraints are fulfilled. The first is the *incentive compatibility* constraint ($IC$). It implies that the entrepreneur should at least expect to receive as much by working than by shirking:

$$(IC): P_H R_E \geq P_L R_E + B, \text{ or } \; R_E \geq B/(\Delta P),$$

[5] In our analysis, we focus on negative externalities because we think these are most relevant in our setting. However, this does not imply we exclude the possibility of positive externalities, i.e., cases where new firms would increase the collateral values of bank's legacy positions or decrease their default probabilities. We briefly discuss this at the end of Subsection 3.3.

[6] We discuss and relax these assumptions at the end of the Section.

where $R_E$ is the payment received by the firm when successful (this encompasses a compensation for the collateral being brought to the project by the entrepreneur), and $\Delta P = (P_H - P_L)$. In case the $IC$ constraint is not fulfilled, the bank knows the firm will shirk such that the bank would realize losses by granting the loan.

The second constraint is the firm's *individual rationality* ($IR$) constraint. This implies that the entrepreneur should be willing to bring his or her collateral to the project, i.e.,

$$(IR): P_H R_E \geq C, \text{ or } \; R_E \geq C/P_H.$$

In other words, the firm should in expected terms not make losses when bringing its collateral to the project. This holds whenever $R_E \geq C/P_H$.

Since the bank is the only source of external finance, the bank will extract as much rents as possible subject to the $IC$ and $IR$ constraints faced by the entrepreneur. To determine the bank's profit, we need to compare both constraints and determine which is the most binding. Two cases exist depending on whether $C/P_H$ is larger or smaller than $B/(\Delta P)$. Let $\tilde{C} \equiv (BP_H)/(\Delta P)$. We have:

1. When $C \geq \tilde{C}$, the $IR$ constraint binds. The profit of the monopoly bank then becomes:

   $P_H(R + C - C/P_H) + (1 - P_H)C - I = P_H R - I > 0.$

   This profit is strictly positive given that the NPV of the project is positive. The firm's profit then equals zero.

2. When $C \leq \tilde{C}$, the $IC$ constraint binds. In this case, the entrepreneur always makes positive profits since the bank needs to leave money on the table to prevent the entrepreneur from shirking. This implies that $R_E = B/(\Delta P)$. The entrepreneur's profits then equals $P_H(B/(\Delta P)) - C$. The monopoly bank's profit then becomes

   $P_H(R + C - B/(\Delta P)) + (1 - P_H)C - I = P_H R - I - (P_H B/(\Delta P) - C) = P_H(R - B/(\Delta P)) - I + C > 0.$

   The latter is positive as long as $C \geq \underline{C} \equiv \; I - P_H(R - B/(\Delta P))$.

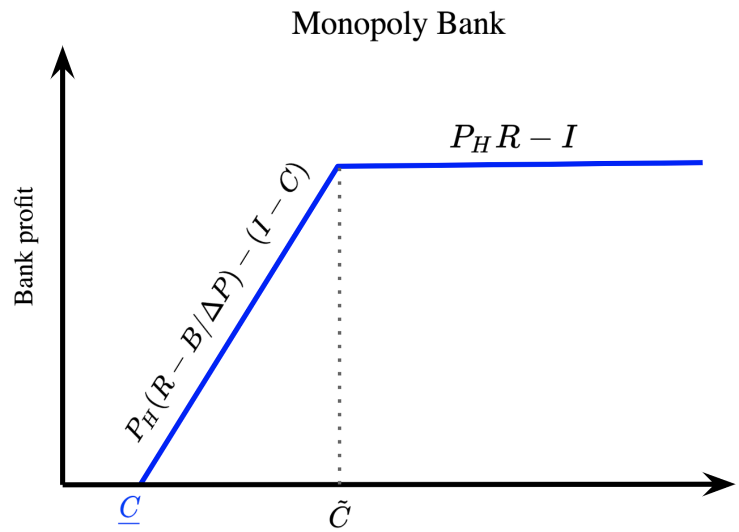
As a result, we observe that the bank grants the loan if the firm has collateral that exceeds $\underline{C}$. Proposition 1 summarises the results for the lending decision of a monopoly bank in absence of externalities. Figure 1 illustrates the profit function of the monopoly bank from extending the loan to the firm as a function of $C$.

**Proposition 1.** *In absence of externality, a monopoly bank enjoys positive rents that depend on the magnitude of collateral pledged as long as $\underline{C} \leq C \leq \tilde{C}$. If $C \geq \tilde{C}$, its profits equal the NPV and are independent of $C$. For values of $C < \underline{C}$, the bank does not make positive profits and does not lend.*

### 2.2 Lending decision in presence a negative externality

We now consider the following situation: a firm approaches the monopoly bank requesting funding for an innovative project whose successful implementation would entail a devaluation of the bank's portfolio of legacy loans. This would be the case for example of a construction company implementing a novel

Figure 1: Monopoly profits from bank extending a loan to a firm in absence of externality, as a function of the collateral pledged by the firm $C$




energy-efficient technology. Should this technology enter the market, it could adversely affect incumbents using polluting technology by increasing their probability of default (e.g., loss of market shares) or the collateral they have pledged to the bank (e.g., devaluation of energy-inefficient machines or buildings).

To keep exposure simple, we proceed by considering two firms: firm 1 is the incumbent energy-inefficient company who has already been granted a loan by the monopoly bank under the conditions stated in Section 2.1 (i.e., collateral pledged by firm 1 is such that: $C_1 \geq \underline{C}$); firm 2 is the firm requesting a new loan related to an energy-efficient project.

Firm 2 approaches the monopoly bank for external finance. Let us for now focus on the collateral externality brought by firm 2's project.[7] A characteristic of firm 2's project is therefore that when implemented, it generates a negative externality on the value of the collateral of firm 1. That is, the collateral value of the machines brought into firm 1's project drops by $\Delta C$.[8] Assuming that the bank cannot pass on this loss to the entrepreneur, the bank's expected profits on firm 1 will than drop by $\Delta C$.[9]

**Firm 2's project** Firm 2 approaches the monopoly bank to obtain funding for a project that requires a total investment of $I$. For sake of simplicity and without loss of generality, we assume the firm has cash at hand $A < I$ but no collateral. Similar to Section 2.1, the monopoly bank faces a moral hazard problem regarding entrepreneur of firm 2. When the entrepreneur of firm 2 works, its success probability is $P_H$. It is $P_L$ when the entrepreneur shirks. When successful, the project yields $Z$. The entrepreneur enjoys

[7] We discuss the case of externality on firm 1's probability of default at the end of the Section.

[8] For simplicity and tractability, we assume that the externality on firm 1 occurs independently of the success of firm 2. The simple fact of financing firm 2 already generates the externality on firm 1. We further assume that the success probabilities of the two firms are independent from each other.

[9] We relax this assumption at the end of the Section.

private benefits from shirking $B$. We assume that the project has a positive NPV when the entrepreneur behaves. In contrast, the NPV is negative in case the entrepreneur shirks. That is

$$P_H Z - I > 0 > P_L Z + B - I.$$

Notice that by allowing $Z$ to be different from $R$, we capture the possibility of different investment opportunities for firm 2 relative to firm 1.[10]

**Bank's lending decision and profits** In order to induce the entrepreneur of firm 2 to work and to participate, the bank should make sure that the IC and IR constraints of firm 2 are simultaneously fulfilled. Similar to the previous section, we have:

- The IC constraint is as follows:

  $$(IC_2): P_H Z_E \geq P_L Z_E + B, \text{ or } \; Z_E \geq B/(\Delta P),$$

  where $Z_E$ is the payment received by the entrepreneur of firm 2 when successful. This implies that the entrepreneur should at least expect to receive as much by working than by shirking.

- The IR constraint is as follows:

  $$(IR_2): P_H Z_E \geq A, \text{ or } \; Z_E \geq A/P_H.$$

  The $IR_2$ constraint implies that the entrepreneur in expected terms should at least get $A$ back from participating in the project.

In absence of externality, the monopoly bank's decision follows Proposition 1 with cash $A$ in lieu of collateral. We now analyze the role of the negative externality of firm 2 which the bank takes into account when deciding on whether firm 2 will be credit rationed or not. In fact, the granting of a loan to firm 2 leads to a drop in the collateral value of firm 1 by $\Delta C > 0$.

When lending to firm 2, the bank's profit on firm 1 is reduced by $\Delta C$ if the bank cannot pass on this loss to firm 1. To see this, recall that the profit of the monopoly bank in the absence of the externality equals $P_H(R + C - C/P_H) + (1 - P_H)C - I$ when $C \geq \tilde{C}$. Keeping $C/P_H$ constant (i.e., no pass-through to firm 1), the profit of the monopoly bank in the presence of the externality drops to $P_H(R + C - \Delta C - C/P_H) + (1 - P_H)(C - \Delta C) - I = P_H R - I - \Delta C > 0$.[11] Similarly, when $C \leq \tilde{C}$, the profit in the presence of the externatility on firm 1 drops to $P_H(R + C - \Delta C - B/(\Delta P)) + (1 - P_H)(C - \Delta C) - I$ when $C \leq \tilde{C}$. In sum, the monopoly bank's profit on firm 1 drops by $\Delta C$ whenever the bank had granted a loan to firm 1.

This implies that the individual rationality constraint of the bank now considers the joint profit maximization on lending to both firms. Put differently, the monopoly bank will only want to grant a

[10] Without loss of generality, we assume that both entrepreneurs have the same private benefit B.

[11] The assumption of no pass-through to firm 1 is not crucial for our analysis. Even if the bank would have complete pass-through and thus act as a debtholder, the bank would still face the negative externality when firm 1 fails. We elaborate on this later in the Section.

loan to firm 2 whenever it makes profits which are larger than $\Delta C$. Otherwise, the bank prefers to forego lending to firm 2 as it would undermine the profits it makes on firm 1.

As before, the monopoly bank needs to make sure that firm 2's constraints (i.e., $IR_2$ and $IC_2$) are fulfilled. We need to consider two cases.

1. $P_H Z - I - \Delta C < 0$. In this event, firm 2 is rationed independent of its level of cash at hand A. The reason is that the externality that firm 2 generates on the collateral value of firm 1 (and thus the bank's profits on firm 1) make this a negative NPV project. In the absence of this externality, firm 2 would not be credit rationed. Because of the bank's legacy position, firm 2 now becomes credit rationed.

2. $P_H Z - I - \Delta C > 0$. In this case, the project is a positive NPV project even after accounting for the negative externality on firm 1. We then need to analyze which constraint binds to determine the bank's lending decision and profits. Let $\hat{A} \equiv (BP_H)/(\Delta P)$.

   - When $A \geq \hat{A}$, the IR constraint of firm 2 binds. As a result, the profit of firm 2 then equals zero and the net extra profit of the monopolistic bank on firm 2 then becomes:

   $$P_H(Z - A/P_H) - (I - A) - \Delta C = P_H Z - I - \Delta C > 0.$$

   - $A \leq \hat{A}$, firm 2's IC constraint binds. The entrepreneur's profits then equals $(P_H B)/(\Delta P) - A$. The monopolistic bank's profit becomes

   $$P_H(Z - B/(\Delta P)) - (I - A) - \Delta C.$$

   The latter is positive whenever $A \geq I - P_H(Z - B/(\Delta P)) + \Delta C \equiv \bar{\bar{A}}$. The implication is that firms with $A \leq \bar{\bar{A}}$ are credit rationed, while some would have been granted funding in the absence of the legacy position.

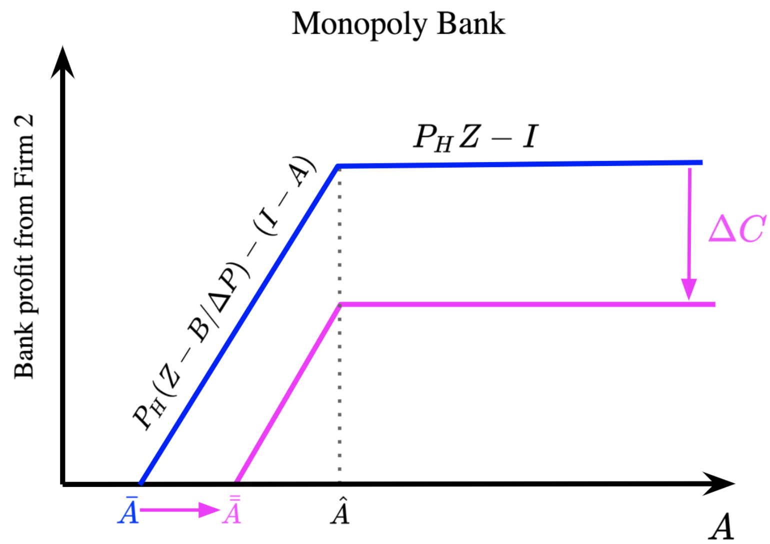
Proposition 2 summarises the results for a monopoly bank's lending decision to a new project in presence on negative externality between the new project and the bank's legacy of pledged collateral.

**Proposition 2.** *In presence of an externality $\Delta C > 0$ on an existing firm's project (firm 1), the monopoly bank decides to credit ration another firm's project (firm 2) if*

- $\Delta C > P_H Z - I$
- *When $\Delta C \leq P_H Z - I$, firm 2 is credit rationed if $A \leq \bar{\bar{A}}$ where $\bar{\bar{A}}$ increases monotonously with $\Delta C$*

Figure 2 further illustrates the bank's profit from funding the firm's new project in presence of externality. The purple line shows the profits of the bank as a function of $A$. It shows that firms with $A \leq \bar{\bar{A}}$ are constrained since the bank cannot realize positive profits from lending to them. For firms with $\bar{\bar{A}} \leq A \leq \hat{A}$, the bank realizes positive profits which are increasing in A. They are however lower with $\Delta C$

Figure 2: Monopoly profits from bank extending a loan to a firm in presence of externality $\Delta C$, as a function of the amount of cash brought by the firm $A$




compared to the situation without legacy position in firm 1. Finally, when $A \geq \hat{A}$, the bank realizes the entire NPV of the project net of the externality generated on firm 1 (i.e., the bank's net profit of granting a loan to firm 2 is lowered with $\Delta C$ – the difference between the blue and purple line). Note that when $\Delta C$ is larger than the NPV of the project, the purple line shifts so much down that the bank would make negative profits by extending the loan. In that case, it rations firm 2 independent of its amount of cash at hand.

## 3 Competitive banking system

Previous results assume that conditional on granting the loan, the bank was extracting all the remaining rents. We now study a competitive banking system where all the bargaining power is transferred to the firm. Below, we show that previous results are independent of the banking system structure, except when the distribution of the possible gains from trade among banks and firms is heterogeneous which then allows us to derive empirical predictions.

### 3.1 Homogeneous banks

To understand the impact of the externality, we first establish banks' incumbency positions that are homogeneous.

**Lending decisions and profit in absence of externalities.** Assume that each bank had a firm requesting to fund a project similar to Section 2.1. In a competitive setting, we now have to consider the individual rationality constraint ($IR_B$) faced by the competitive bank on top the of the IR and IC constraints on the firm's side. To grant a loan, the bank needs to fulfill the following constraint:

$$(IR_B): P_H(R_B + C) + (1 - P_B)C \geq I, \text{ or } \; R_B \geq (I - C)/P_H.$$

Where $R_B$ is the payment made to the bank by the firm on top of the collateral C. When analysing the full set of constraints, we observe that:

- Both individual rationality constraints ($IR$ and $IR_B$) are satisfied whenever $R_E + R_B \leq R$, or $I \leq P_H R$. This condition is independent from collateral and is fulfilled given that the project has positive NPV.

- The firm's incentive compatibility constraint and the banks individual rationality constraint ($IC$ and $IR_B$) are satisfied whenever $R_E + R_B \leq R$, or $C \geq \underline{C} \equiv I - P_H(R - B/(\Delta P))$

Similar to Proposition 1, loans are granted when the firm pledges collateral $C$ larger than $\underline{C}$. However, given the change in bargaining power, the firm now appropriates all profit which accounts for $P_H R - I$. In sum, we now have a homogeneous banking sector where banks do not make profits, but where all banks have a similar incumbency position and exposure to a possible externality.

**Lending decisions and profit in the presence of negative externalities.** Let us recover the setting where firm 2 requests a loan to fund an innovative (e.g., energy-efficient technology) project which entails a devaluation of incumbent firms' collateral (e.g., energy-inefficient machines). Banks are so far assumed to be homogeneous. They therefore have the same legacy of granted loans, which uniformly exposes them to the negative externality.

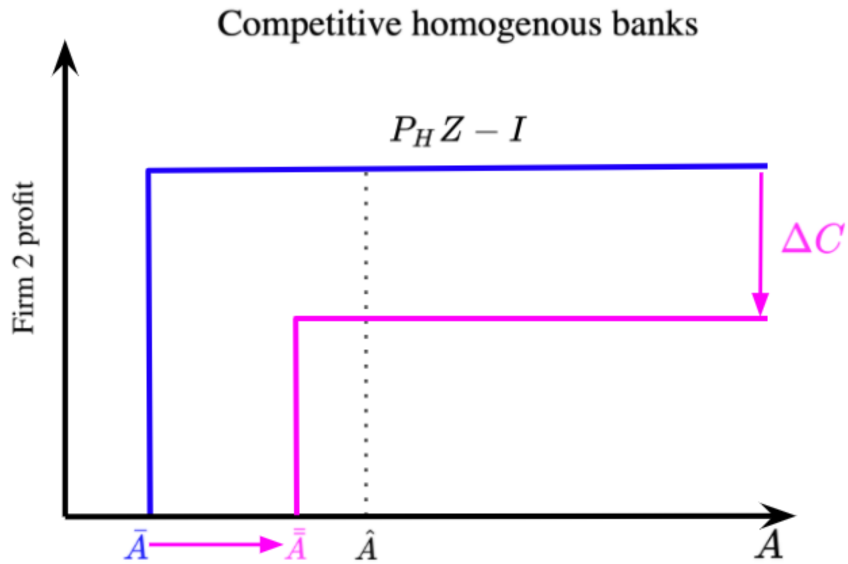
When there is a negative externality $\Delta C$ on the legacy position of banks, the individual rationality constraint of the bank changes: $IR_B = Z_B \geq \frac{I+\Delta C-A}{P_H}$. Intuitively, a bank only wants to engage firm 2 when it is also compensated for the negative impact on its incumbency position (i.e., impact on collateral). This is rational given that each bank knows that all other banks face the same condition. We then obtain the following set of constraints combinations:

- When $A \geq \hat{A}$, the $IR$ of firm 2 binds. We have that $Z \geq Z_2 + Z_B = \frac{A}{P_H} + \frac{I+\Delta C-A}{P_H}$ which yields $Z \geq \frac{I+\Delta C}{P_H}$. Firm 2's profit is then determined by $P_H Z - (I + \Delta C)$.

- When $A \leq \hat{A}$, the $IC$ binds. We have that $Z \geq Z_2 + Z_B = \frac{B}{\Delta P} + \frac{I+\Delta C-A}{P_H}$ which yields $A \geq I + \Delta C - P + H(Z - \frac{B}{\Delta P}) \equiv \bar{\bar{A}}$. As a result, if $A \geq \bar{\bar{A}}$, firm 2's profits are determined by $P_H Z - (I + \Delta C)$. If $A < \bar{\bar{A}}$, the firm is credit rationed. In absence of negative externality, a firm with $\bar{A} \leq A < \bar{\bar{A}}$ would have been granted the loan.

Note that, in this bargaining power setting (i.e., all rent goes to firm), the entering firm endogenizes the negative externality and leaves part of the revenue to the bank to compensate for the loss $\Delta C$. Even when obtaining external finance, profit opportunities are reduced for innovative firms in case of homogeneous legacy of competitive banking. Proposition 3 summarises the rationing result and Figure 3 illustrates the profit of firm 2 as a function of $A$.

Figure 3: Firm profits from competitive bank extending a loan in presence of homogenous externality $\Delta C$, as a function of the amount of cash brought by the firm $A$



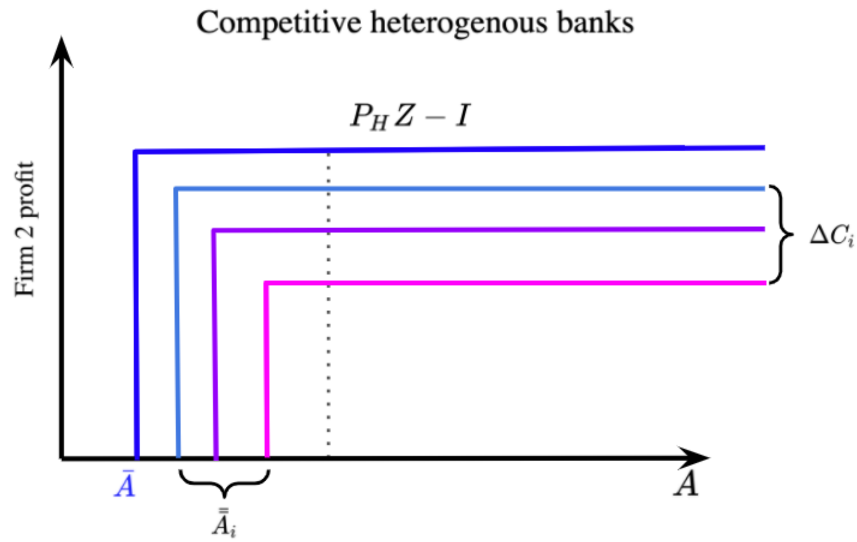

**Proposition 3.** *In presence of a homogeneous externality $\Delta C > 0$ , a competitive bank decides to ration the new firm's project if $A < \bar{\bar{A}}$ where $\bar{\bar{A}}$ increases monotonously with $\Delta C$. In absence of a homogeneous negative externality, a firm with $\bar{A} \leq A < \bar{\bar{A}}$ would have been granted the loan.*

### 3.2 Heterogenous banks

In the previous, we assumed homogeneous banks. We now consider banks with different legacy positions. Banks may face heterogeneous legacy positions for various reasons. A direct one may stem from banks having different market shares related to the same externality. Another one occurs even when banks have equal market shares but $\Delta C_i$ is different across banks, for example because they employ different collateral requirements, or accept collateral with different loadings on the negative externality. In what follows, we are agnostic about the reason behind their different legacy positions and capture it through $\Delta C_i$ for each bank $i$ in the banking system.

If banks have heterogenous legacy positions, they face different devaluation shocks related to the negative externality brought by firm 2 (i.e., $\Delta C_i$ for each bank $i$ in the banking system). For simplicity, we assume that banks as well as firm 2 are perfectly informed about all bank's legacy positions. In this case, the extent of rationing faced by firm 2 will be determined by the bank with the lowest externality: $i^* = \min_i\{\Delta C_i\}$. The distance between $\bar{A}$ and $\bar{\bar{A}}_{i^*}$ determines the values of A for which firm 2 is rationed due to the negative externality, while $\Delta C_{i^*}$ determines the reduction in the profit of the entering firm. Notice that firm 2 now only needs to internalize the smallest negative externality. Furthermore, in the absence of any other friction, banks $i \neq i^*$ are willing to extend a loan to firm 2 for $A \geq \bar{\bar{A}}_{i^*}$ even though this reduces the overall profits on their legacy positions and the new firm. The reason is that these banks know that

Figure 4: Firm profits from competitive bank extending a loan in presence of heterogeneous externalities $\Delta C_i$, as a function of the amount of cash brought by the firm $A$




firm 2 is able to get a loan from bank $i^*$ and would face this reduction in overall profits independent of whether they or another bank extends the loan to firm 2.

Proposition 4 summarises the rationing result and Figure 4 illustrates the profit of firm 2 as a function of $A$ and $\Delta C_i$.

**Proposition 4.** *In presence of heterogeneous externalities $\Delta C_i$, firm 2's project is credit rationed if $A < \bar{\bar{A}}_{i^*}$ where $i^* = \min_i\{\Delta C_i\}$, that is, $i^*$ is the bank with the lowest exposure to the negative externality. When $A \geq \bar{\bar{A}}_{i^*}$, any bank is willing to fund firm 2's project.*

### 3.3 Discussion

We close the theoretical part of this paper by discussing five points: the empirical implications of our results, the nature of the collateral our model implies, the extension of our results to include negative externalities on the probabilities of default of incumbent firm in the absence or jointly with the effects over collateral, and the case of positive externalities.

**Empirical predictions.** Armed with our theoretical results, we can formulate testable predictions.

1. An increase in exposures to technological shock should lead to more credit rationing. This implication derives from Propositions 2 and 3.

2. An increase in heterogeneity of exposures to technological shock should lead to less credit rationing. This implication derives from Proposition 4.

**Nature of collateral.** Our analysis regarding firm 1 and firm 2 makes an important distinction between the nature of the own funds a firm brings into the project. While firm 1 brings inside collateral C (i.e., assets it owns such as machines), firm 2 brings cash A to the project. In the absence of an externality, this inside collateral could be seen as 'quasi-cash' as it is risk-free. However, due to the externality, an important distinction between inside collateral and cash or outside collateral (e.g., the owner's house or government bonds) can be made. While cash or outside collateral is not subject to the externality and keeps its value independent of the entry of firm 2, inside collateral becomes risky due to its exposure to firm 2's new project. This implies that cash and inside collateral are not perfect substitutes to the extend they have different exposure to shocks.[12]

Our model assumes that the monopoly bank absorbs the negative shock on collateral when firm 1 is successful, i.e., the bank is junior to the entrepreneur. Alternatively, we could assume the bank is a senior claimholder such that the negative externality is only important if firm 1 fails. This would be equivalent to consider only the relevance of collateral in case the project fails (as e.g., Stiglitz and Weiss (1981)). Even in that case, the externality on collateral (compared to cash) remains relevant as the bank is always affected when it needs to grab the collateral when firm 1's project fails.

**Externality on probability of default** Our model considers externalities on collateral values. Other externalities are possible that lead to qualitatively similar insights and conclusions. For example, the financing of firm 2's project could increase the probability of default of firm 1, say by $q$. This could, for example, stem from direct competition between the two firms. Taking the same setup as in Subsection 2.1, the implication woudl then be that that a monopoly bank would face a reduction in profits on firm 1 of $qR_B$. Put differently, $qR_B$ plays a similar role as $\Delta C$ in our main analysis. Similar conclusions hold for a homogeneous banking sector when the financing of firm 2's project leads to an identical impact on the probability of default of the portfolio held by each bank. When considering competitive heterogeneous banks, the extent of rationing faced by firm 2 is again determined by the bank with the lowest externality, i.e., bank $i^* = \min_i\{qR_{Bi}\}$.

**Externality on collateral** *and* **probability of default** The discussion above modelled each externality separately. We now briefly discuss what happens when both externalities occur simultaneously. Without going into the details, we can say that the externalities reinforce each other. Intuitively, an increase in default probability together with a drop in collateral value gives the monopoly bank a bigger shock as it makes it more likely to receive the lower valued collateral.

**Positive externalities.** Our analysis so far assumed negative externalities on legacy positions. In some cases, positive externalities may occur. An example outside climate change would be a new infrastructure project that generates positive externalities on property values in the area or decreases the probability of default of incumbent firms due to increased demand. In such cases, the bank with the largest

[12] The literature on collateral often considers that collateral has a lower value to the lender than to the borrower. Our analysis does not depend upon this heterogeneity in valuation, assumes that collateral has equal value to both lenders and borrowers.

legacy position would benefit most from financing this infrastructure project, and credit rationing would be determined by that position.

## 4 Data and empirical analysis

In this section, we investigate whether there is evidence of rationing or discrimination against entry of new firms in the presence of negative externalities on banks' legacy portfolio related to polluting activity. Our data relates to the Belgian economy. Despite its size, Belgium presents itself as an interesting application for two reasons. First, it is an economy which mainly relies on banks to provide funding to the private sector (NBB, 2018). According to de Haas and Popov (2019), bank-based economies are less likely to transit to low carbon emission. Testing our theory on Belgian data could therefore identify the economic channels behind this result. Second, Belgium is largely exposed to climate risk, in particular, due to its large share of energy-inefficient buildings (NBB, 2020). Belgium recently committed to a climate change plan which involves a reduction of 30% of greenhouse gas emissions by 2030 as well as a boost to energy-efficiency of 26% by the same deadline (European Union, 2018).

### 4.1 Data

We combine two data sources to investigate our research questions. First, we obtain data from the Belgian corporate credit registry maintained by the National Bank of Belgium. This data set contains at the bank-firm level all annual loan exposures to non-financial firms in Belgium over the period 2008 to 2018. The banks are established in Belgium and licensed by the NBB. This concerns both (i) branches incorporated under foreign law established in Belgium as well as (ii) banks incorporated under Belgian law. In order to tie our results to the theoretical framework, we aggregate the micro-level data at the sector-level. Second, we gather information on yearly green house gas (GHG) emissions per value added for each industrial sector in European economies from the Eurostat environmental database (covering the same time span). These two data sources allow us to construct measures of credit growth (both intensive and extensive margins), risk of negative externalities of the legacy portfolio and bank credit market structure.

### 4.2 Empirical framework

According to Proposition 4, for a given threat of externalities in an industry, we should expect less lending growth to new firms the more homogeneous the credit market structure of that industry is. In order to test this assertion, we consider the following regression framework:

$$y_{s,t} = \alpha\Delta^m_{s,t-1} + \beta\Delta B4_{s,t-1} + \gamma\Delta^m_{s,t-1} \times \Delta B4_{s,t-1} + \boldsymbol{\zeta}'\boldsymbol{x}_{s,t-1} + \delta_s + \delta_t + \varepsilon_{s,t} \quad (1)$$

where $y_{s,t}$ is a metric capturing various definitions of lending growth in sector $s$ from $t-1$ to $t$, $\Delta^m_{s,t}$ measures the threat to legacy assets in sector $s$ at time $t$, $\Delta B4_{s,t}$ quantifies the heterogeneity in legacy positions and $\boldsymbol{x}_{s,t}$ is a set of control variables. We elaborate on these variables below. Proposition 4 suggests that $\gamma$ is positive.

We define four measures of $y_{s,t}$. First, let $(Credit\ growth\ new\ loan\ firm\ age\ 5)_{s,t}$ denote the flow of new credit at time $t$ to firms younger than 5 years of age that did not hold any bank credit at time $t-1$ over the total outstanding stock in sector $s$ at $t-1$. This concept of credit growth directly speaks to our theoretical framework and captures the extent to which banks start funding new/young firms that previously did not rely on bank credit. $(Credit\ growth\ new\ loan\ firm\ age\ 10)_{s,t}$ is defined in a similar way, except that it expands the scope to firms of age less than 10 years (and thus also includes more established firms). Both credit concepts capture exclusively the extensive margin. In addition, let $(Credit\ growth\ rolling)_{s,t}$ denote the flow of credit at time $t$ to firms in sector $s$ which hold a bank credit at both time $t-1$ and time $t$ (over the total outstanding stock to sector $s$ at $t-1$). This growth variable thus reflects growth in the intensive margin and covers all firms in the economy. To account for the fact that a large fraction of Belgian bank credit relates to loans with a fixed amortization scheme (which mechanically affects the intensive margin of credit growth but does not reflect economically meaningful dynamics), we define $(Credit\ growth\ rolling\ adjusted)_{s,t}$ which is stripped from periodical installments.

We assess the potential for a negative externality by measuring the GHG emission performance of an industry compared to a European benchmark. A technological distance is then computed as the difference between the GHG emission per value added in a Belgian industry and a European wide emission benchmark. We consider two benchmarks: the median and mean value in the distribution of emissions of said sector across EU countries. Formally, we define $\Delta^m_{st}$ as the distance in gas emission per value added between the sector $s$ in Belgium at time $t$ and the benchmark $m \in \{\text{median, mean}\}$ in sector $s$ at time $t$ across Europe. A sector $s$ far away from the technological frontier (as captured by the median or mean value) will have a large positive $\Delta^m_{s,t}$ which entails a larger threat to its legacy assets in that sector $s$. Put differently, the externality of new loans on legacy assets within that sector $s$ increases in $\Delta^m_{s,t}$.

To measure the level of heterogeneity of legacy positions of banks, we construct a simple measure of market share distance between banks. To that end, we first note that Belgium has a very concentrated banking sector, with 4 banks providing jointly up to 90% of aggregate credit to non-financial firms.[13] Given that context, we compute $\Delta B4_{s,t}$ which measures the difference between the highest and the lowest market share among the four major banks for a given industry $s$ at a given time $t$. We take the $t-1$ values to make sure that the market shares are predetermined. Intuitively, the higher $\Delta B4_{s,t}$, the more heterogeneous legacy positions are in the spirit of Proposition 4 with $\Delta B4_{s,t} = 0$ implying that all banks are equally exposed.

### 4.3 Descriptives

Table 1 reports summary statistics of our data. Several patterns are worth highlighting. First, as stated above, Belgium has a concentrated credit market dominated by four major banks as reflected by the large Herfindahl-Hirschman index (HHI) across all sectors. Despite these high concentration measures, $\Delta B4_{s,t}$ reveals material heterogeneity in sector presence between these four banks (some sectors are served by a single bank whereas in other sectors the active banks are equally important). Second, both

[13] BNP Paribas Fortis, ING, Belfius and KBC (listed in random order).

distance measures $\Delta^{m}_{s,t}$ reveal that Belgium, across sectors, does not systematically outperforms or fall behind the EU average/median. Table 4 additionally presents sector level statistics on absolute emissions per added-value for each sector in Belgium and the respective European benchmarks. Finally, the credit growth measures reflect material variation, both at the intensive and extensive margin.

[ Include Table 1 ]

### 4.4 Results

According to Proposition 4, we expect lending to new firms to grow less in an exposed industry if legacy positions are homogeneous. We therefore hypothesize a positive interaction term $\gamma$ in Equation 1 between the technological distance and the market share distance among the big four banks.

Column (1) in Table 2 corroborates the predictions from our theoretical framework: for a given threat to legacy positions in sector $s$, a more heterogeneous presence of banks in sector $s$ leads to more new credit supplied to new/young firms. To appreciate the size of this mechanism, consider a sector $s$ for which $\Delta^{mean}_{s,t-1} = 50$. From Table 1, this would be a sector which slightly underperforms the EU benchmark, and is in between P75 and P95. Consider two different credit market structures in sector $s$. In set-up $A$, all banks are equally active in this sector at time $t-1$ (in which case $\Delta B4_{s,t-1} = 0$). In set-up $B$, only one bank is active in sector $s$ at $t-1$ (in which case $\Delta B4_{s,t-1} = 1$). Albeit extreme, both scenarios are empirically relevant. Comparing set-ups A and B, we observe that the interaction of an asymmetric credit market structure and threat of stranded assets leads credit growth to new firms accounts for 50 basis points ($= 50 \times 0.0001 \times 100 b.p.$) higher than in the homogeneous credit market. Column (2) further underscores that this mechanism is only relevant for the very young firms (when including older firms between age 5 and 10, the result no longer holds). Moreover, columns (3) and (4) confirm these results when introducing the median as the technological benchmark ($\Delta^{median}_{s,t-1}$) instead of the mean ($\Delta^{mean}_{s,t-1}$).

[ Include Table 2 ]

Our framework only delivers a clear prediction for credit growth to new firms that previously did not rely on bank credit. Hence, we should not expect the mechanism to hold when we focus on the intensive margin. To that end, column (1) in Table 2 broadens our scope to include firms that were previously borrowing and provides a falsification test as $\gamma$ is no longer significant. Column (2) complements this result when we correct for amortization schemes. Finally, column (3) and (4) further confirm aforementioned results for $\Delta^{median}_{s,t-1}$.

[ Include Table 3 ]

## 5 Policy implications

Many banks have high exposures to carbon-intensive industries whose business models may not fit into the transition to a low-carbon economy. Proposition 2 formalizes how these legacy positions in a bank portfolio impedes funds from being channeled to green firms. Various policy measures can help to breach the source of this barrier at the bank level. First could be the promoting of new (green) institutions that do not have legacy positions (i.e., for these institutions, $\Delta C = 0$). Relevant examples include the UK Green Investment Bank, or the Green credit department of ICBC China. Moreover, to the extent these initiatives are public (or quasi-public), their mandate potentially does not require them to factor in the impact of $\Delta C$ (i.e., their behaviour is not governed by our framework). Second, focusing on incumbent institutions, policymakers have voiced the possibility of leveraging macro prudential policies (ECB, 2019; European Union, 2018). Such policies work by introducing an additional implicit/explicit cost $\Delta M$, where $\Delta M$ either (i) increases if the bank persists in lending to brown firms or (ii) drops when it lends to low-carbon firms. Bank behaviour can then be steered by driving the sign of $\Delta C - \Delta M$, where banks prefer to lend to green firms if $\Delta C < \Delta M$. Examples include (i) a risk-weight reduction (addition) in the prudential framework for banks' exposures to green (brown) assets, (ii) lower (higher) required reserve rates for portfolios skewed toward greener, less carbon-intensive assets (brown, carbon-intensive assets), (iii) dedicated disclosure requirements, (iv) climate-related stress testing, etc. Evidently, the feasibility of such measures hinges on a proper taxonomy (a classification of economic activities and the conditions under which economic activities can be considered sustainable) to sort between green and brown firms. Such work is underway at the European Commission.

Perhaps more important to the current concerns of policymakers are the implications of our results to the banking system structure. In fact, while Proposition 2 formalizes institution-level lending behaviour, Proposition 3 and Proposition 4 show that the market structure of the banking system plays a crucial role in determining the extent of credit provisions to innovative firms. In particular, the existence of spillovers may positively amplify the effectiveness of limited interventions. Recall that, according to Proposition 3, in a banking system where banks have equal stakes in legacy assets, banks can complicitly promote the same rationing policy towards disruptive firms. That is because all banks suffer equally from the entry of one single firm. In contrast, once legacy positions become heterogeneous, as in Proposition 4, the presence of banks with less or no exposuret to asset devaluations promotes credit provisioning. Foremost, the devaluation of legacy assets materialises irrespective of the loan originator. Therefore, once the entry of a disruptive technology is certain (i.e., banks cannot collude to prevent it), losses will materialise irrespective of the stakes. Accordingly, all banks in the system become theoretically likely to extend credit to disruptive projects using this same technology.

Overall, this set of results suggest that having a single bank with no legacy position (e.g., a green bank with no brown assets) enter the credit market would subsequently induce incumbent banks to lend to innovative firms which they would have rationed otherwise. Aggregate banking provision of credit directed to disruptive technologies would therefore be amplified beyond the credit capacity of the legacy-free bank, potentially encompassing the whole banking system.

# 6 Conclusion

In this paper, we showed the existence of barriers to entry for innovative firms in the form of credit rationing by banks with legacy positions. Banks decide to ration firms when their projects threatens to devalue their legacy portfolio, either via collateral value drop or increase in probabilities of default. In the context of climate change, this setting corresponds to banks delaying the transition to a carbon-neutral economy by limiting entry of green firms (e.g., firms with more energy-efficient technologies) in industries where they hold large stakes. In particular, the paper shows the key role of the banking market structure: on the one hand it can act as a main driver of barriers to green innovation by new firms when banks have homogeneous exposures, on the other hand it can accelerate credit supply by all banks with the entry of legacy-free banks.

Our empirical investigation employs bank credit and emissions data at industry level for Belgium over the period 2008-2018. Our preliminary findings suggest that in industries subject to a larger threat on legacy assets, younger firms face greater credit rationing when the banking market structure is homogeneous in that industry.

Our theoretical model and empirical analysis feature a number of limitations. The theoretical model makes a number of abstractions such as the presence of other financing sources, other sources of market frictions, or industry and banking dynamics. While these are relevant, our stylized model has the objective to identify possible key drivers that may hinder the financing of new green technological innovations, and propose a number of policies that may undo these barriers. Our current empirical analysis relies upon industry level data for Belgium. Natural next steps relate to external validity and the use of more granular lender industry or lender-firm data.

# 7 Tables

Table 1: Summary Statistics

| Variable | Obs | Mean | Std | p05 | p25 | p50 | p75 | p95 | Min | Max |
|---|---|---|---|---|---|---|---|---|---|---|
| CREDIT GROWTH | | | | | | | | | | |
| Credit growth rolling | 197 | -0,0009 | 0,0756 | -0,1153 | -0,0239 | 0,0003 | 0,0265 | 0,1101 | -0,4472 | 0,2368 |
| Credit growth rolling adjusted | 197 | 0,0315 | 0,0768 | -0,0911 | 0,0049 | 0,0326 | 0,0604 | 0,1386 | -0,4448 | 0,2680 |
| Credit growth new loan firm age 10 | 197 | 0,1076 | 0,8107 | 0,0000 | 0,0190 | 0,0411 | 0,0659 | 0,1233 | 0,0000 | 11,4065 |
| Credit growth new loan firm age 5 | 197 | 0,0297 | 0,0296 | 0,0000 | 0,0107 | 0,0222 | 0,0411 | 0,0811 | 0,0000 | 0,1716 |
| # new loans | 197 | 790,3 | 1057,6 | 0,8 | 63,0 | 423,0 | 1009,0 | 3196,2 | 0,0 | 4836,0 |
| # new loans firm age ≤ 10 | 197 | 380,5 | 491,0 | 0,0 | 23,0 | 194,0 | 456,0 | 1582,8 | 0,0 | 2219,0 |
| # New loans firm age ≤ 5 | 197 | 234,9 | 311,8 | 0,0 | 13,0 | 115,0 | 280,0 | 977,2 | 0,0 | 1485,0 |
| CREDIT MARKET STRUCTURE | | | | | | | | | | |
| Herfindahl-Hirschman index | 197 | 2754 | 1368 | 1806 | 2102 | 2389 | 2768 | 6075 | 1500 | 10000 |
| $\Delta B4$ | 196 | 0,2479 | 0,1672 | 0,0601 | 0,1537 | 0,2045 | 0,2914 | 0,5506 | 0,0000 | 1,0000 |
| EMISSION LEVEL DATA | | | | | | | | | | |
| Emission level ($CO_2/VA$) | 197 | 657,6 | 1238,7 | 4,3 | 31,8 | 93,9 | 617,5 | 3625,9 | 0,0 | 5537,1 |
| Distance mean ($\Delta_{s,t}^{Mean}$) | 197 | -161,8 | 1095,0 | -1928,5 | -19,3 | -5,8 | 21,0 | 1472,1 | -5656,0 | 2259,5 |
| Distance median ($\Delta_{s,t}^{Median}$) | 197 | 65,3 | 833,3 | -1223,4 | -1,9 | 7,6 | 53,9 | 2157,6 | -2711,8 | 2907,5 |

Notes: (Credit growth rolling)$_{st}$ denotes the change in the stock of lending to sector $s$ between $t-1$ and $t$ among firms which hold a bank credit in both periods over the stock of lending to sector $s$ at time $t-1$. (Credit growth rolling adjusted)$_{st}$ is similar to (Credit growth rolling)$_{st}$, except that it controls for predetermined amortization schemes of fixed installment loans which mechanically affects credit growth. (Credit growth new loan firm age 10)$_{st}$ and (Credit growth new loan firm age 5)$_{st}$ captures growth of new loans to firm which did not hold a bank credit at time $t-1$ of age less than 10 and 5 years, respectively. (# new loans)$_{st}$ is a count variable of the number of new loans to firms with no bank credit per sector. (# new loans firm age ≤ 10)$_{st}$ and (# new loans firm age ≤ 5)$_{st}$ counts the number of new loans to firms with no bank credit and less than 10 (5) years of age at time $t$, respectively. (HHI)$_{st}$ represents the Herfindahl-Hirschman index (where all banks are included in its computation. $\Delta B4_{st}$ measures the difference between the highest and the lowest market share among the four major banks for a given industry $s$ at a given time $t$. (Emission level)$_{st}$ captures the GHG emissions per value added of sector $s$ at time $t$. ($\Delta_{s,t}^{Mean}$) ($\Delta_{s,t}^{Median}$) denotes the difference between the Belgian emission level of sector $s$ at time $t$ and the EU mean (median) for that sector at time $t$.

Table 2: Baseline results I

| | *Dependent variable* | | | |
|---|---|---|---|---|
| | Credit growth new loan firm age 5 | Credit growth new loan firm age 10 | Credit growth new loan firm age 5 | Credit growth new loan firm age 10 |
| Covariates | (1) | (2) | (3) | (4) |
| $\Delta B4_{s,t-1}$ | 0.023 | 2.835$^{***}$ | 0.024 | 2.896$^{***}$ |
| | (0.023) | (0.646) | (0.023) | (0.640) |
| $\Delta^{mean}_{s,t-1}$ | 0.00003 | −0.001 | | |
| | (0.00003) | (0.001) | | |
| $\Delta^{mean}_{s,t-1} \times \Delta B4_{s,t-1}$ | 0.0001$^{**}$ | −0.0004 | | |
| | (0.0001) | (0.002) | | |
| $\Delta^{median}_{s,t-1}$ | | | 0.0001 | -0.002 |
| | | | (0.00004) | (0.001) |
| $\Delta^{median}_{s,t-1} \times \Delta B4_{s,t-1}$ | | | 0.0002$^{***}$ | −0.001 |
| | | | (0.0001) | (0.002) |
| Observations | 196 | 196 | 196 | 196 |
| Controls | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes |
| Sector FE | Yes | Yes | Yes | Yes |
| $R^2$ | 0.490 | 0.486 | 0.507 | 0.493 |
| Adjusted $R^2$ | 0.370 | 0.365 | 0.391 | 0.374 |
| Residual Std. Error (df = 158) | 0.023 | 0.647 | 0.023 | 0.643 |

Notes: $^{*}$p<0.1; $^{**}$p<0.05; $^{***}$p<0.01. Dependent variables (Credit growth new loan firm age 10)$_{st}$ and (Credit growth new loan firm age 5)$_{st}$ capture growth of new loans to firms which do not hold a bank credit at time $t-1$ of age less than 10 and 5 years, respectively. The covariate $\Delta B4_{st}$ measures the difference between the highest and the lowest market share among the four major banks for a given industry $s$ at a given time $t$. $\Delta^{Mean}_{s,t}$ ($\Delta^{Median}_{s,t}$) denotes the difference between the Belgian emission level of sector $s$ at time $t$ and the EU mean (median) for that sector at time $t$ and captures the threat to legacy assets in that sector. Controls include the HHI index $(HHI)_{s,t-1}$, sectoral emissions $((CO_2/VA)_{s,t-1})$ and interactions $(HHI)_{s,t-1} \times (CO_2/VA)_{s,t-1}$, $(HHI)_{s,t-1} \times \Delta B4_{s,t-1}$ and $\Delta B4_{s,t-1} \times (CO_2/VA)_{s,t-1}$.

Table 3: Baseline results II

| | *Dependent variable* | | | |
|---|---|---|---|---|
| | Credit growth rolling | Credit growth rolling adjusted | Credit growth rolling | Credit growth rolling adjusted |
| Covariates | (1) | (2) | (3) | (4) |
| $\Delta B4_{s,t-1}$ | $-0.192^{***}$ | $-0.194^{***}$ | $-0.184^{***}$ | $-0.187^{***}$ |
| | (0.068) | (0.069) | (0.069) | (0.069) |
| $\Delta^{mean}_{s,t-1}$ | $-0.0001$ | $-0.0001$ | | |
| | (0.0001) | (0.0001) | | |
| $\Delta^{mean}_{s,t-1} \times \Delta B4_{s,t-1}$ | 0.0002 | 0.0002 | | |
| | (0.0002) | (0.0002) | | |
| $\Delta^{median}_{s,t-1}$ | | | -0.0001 | -0.0001 |
| | | | (0.0001) | (0.0001) |
| $\Delta^{median}_{s,t-1} \times \Delta B4_{s,t-1}$ | | | 0.0002 | 0.0002 |
| | | | (0.0002) | (0.0002) |
| Observations | 196 | 196 | 196 | 196 |
| Controls | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes |
| Sector FE | Yes | Yes | Yes | Yes |
| $R^2$ | 0.338 | 0.344 | 0.326 | 0.333 |
| Adjusted $R^2$ | 0.182 | 0.190 | 0.168 | 0.177 |
| Residual Std. Error (df = 158) | 0.068 | 0.069 | 0.069 | 0.070 |

Notes: $^{*}$p<0.1; $^{**}$p<0.05; $^{***}$p<0.01. Dependent variable (Credit growth rolling)$_{st}$ captures growth of lending to sector $s$ between $t-1$ and $t$ among firms which hold a bank credit in both periods. (Credit growth rolling adjusted)$_{st}$ controls for predetermined amortization schemes. The covariate (B4 Distance)$_{st}$ measures the difference between the highest and the lowest market share among the four major banks for a given industry $s$ at a given time $t$. $\Delta^{Mean}_{s,t}$ ($\Delta^{Median}_{s,t}$) denotes the difference between the Belgian emission level of sector $s$ at time $t$ and the EU mean (median) for that sector at time $t$ and captures the threat to legacy assets in that sector. Controls include the HHI index $(HHI)_{s,t-1}$, sectoral emissions ($(CO_2/VA)_{s,t-1}$) and interactions $(HHI)_{s,t-1} \times (CO_2/VA)_{s,t-1}$, $(HHI)_{s,t-1} \times \Delta B4_{s,t-1}$ and $\Delta B4_{s,t-1} \times (CO_2/VA)_{s,t-1}$.

# A Industry emissions

Table 4: Industry Emission Statistics

| Nace | Industry Name | Avg. Emission Belgium | Avg. Emission Europe Mean | Avg. Emission Europe Median |
|---|---|---|---|---|
| A | Agriculture, forestry and fishing | 4716 | 2779 | 2327 |
| B | Mining and quarrying | 2454 | 1413 | 651 |
| C | Manufacturing | 709 | 670 | 613 |
| D | Electricity, gas, steam and air conditioning s... | 2956 | 6780 | 4499 |
| E | Water supply; sewerage, waste management and r... | 736 | 2260 | 1941 |
| F | Construction | 120 | 156 | 111 |
| G | Wholesale and retail trade; repair of motor ve... | 48 | 64 | 52 |
| H | Transportation and storage | 573 | 1199 | 877 |
| I | Accommodation and food service activities | 105 | 66 | 58 |
| J | Information and communication | 23 | 19 | 12 |
| K | Financial and insurance activities | 12 | 25 | 9 |
| L | Real estate activities | 4 | 15 | 5 |
| M | Professional, scientific and technical activities | 31 | 35 | 22 |
| N | Administrative and support service activities | 68 | 74 | 54 |
| O | Public administration and defence; compulsory ... | 46 | 50 | 36 |
| P | Education | 27 | 35 | 27 |
| Q | Human health and social work activities | 44 | 43 | 37 |
| R | Arts, entertainment and recreation | 114 | 54 | 47 |
| S | Other service activities | 92 | 70 | 48 |
| T | Activities of households as employers; undiffe... | 105 | 139 | 38 |

Notes: List of industries and their average emissions. Yearly emission levels are computed in Green House Gas emissions per value added (grams/euros) at the sector level. Values are averaged between 2008 and 2018

## References


ACEMOGLU, D., P. AGHION, L. BURSZTYN, AND D. HEMOUS (2012): "The environment and directed technical change," *American Economic Review*, 102, 131–66.

ACEMOGLU, D., U. AKCIGIT, D. HANLEY, AND W. KERR (2016): "Transition to clean technology," *Journal of Political Economy*, 124, 52–104.

BECK, T. (2009): "The econometrics of finance and growth," in *Palgrave Handbook of Econometrics*, Springer, 1180–1209.

BECK, T. AND R. LEVINE (2002): "Industry growth and capital allocation:: does having a market-or bank-based system matter?" *Journal of Financial Economics*, 64, 147–180.

BOLTON, P. AND M. KACPERCZYK (2020): "Do investors care about carbon risk?" Tech. rep., National Bureau of Economic Research.

CARPENTER, R. E. AND B. C. PETERSEN (2002): "Capital market imperfections, high-tech investment, and new equity financing," *The Economic Journal*, 112, F54–F72.

CESTONE, G. AND L. WHITE (2003): "Anticompetitive financial contracting: The design of financial claims," *The Journal of Finance*, 58, 2109–2141.

CETORELLI, N. AND P. E. STRAHAN (2006): "Finance as a barrier to entry: Bank competition and industry structure in local US markets," *The Journal of Finance*, 61, 437–461.

CIHAK, M., A. DEMIRGUC-KUNT, E. FEYEN, AND R. LEVINE (2013): "Financial Development in 205 Economies, 1960 to 2010," *Journal of Financial Perspectives*, 1, 17–36.

CORNAGGIA, J., Y. MAO, X. TIAN, AND B. WOLFE (2015): "Does banking competition affect innovation?" *Journal of financial economics*, 115, 189–209.

DASGUPTA, S., B. LAPLANTE, H. WANG, AND D. WHEELER (2002): "Confronting the environmental Kuznets curve," *Journal of Economic Perspectives*, 16, 147–168.

DE HAAS, R. AND A. POPOV (2019): "Finance and carbon emissions," Tech. rep., ECB Working Paper.

DELIS, M. D., K. DE GREIFF, AND S. ONGENA (2019): "Being stranded with fossil fuel reserves? Climate policy risk and the pricing of bank loans," *Climate Policy Risk and the Pricing of Bank Loans (April 21, 2019). Swiss Finance Institute Research Paper.*

ECB (2019): "Financial Stability Review 2019," .

EUROPEAN UNION (2018): "Regulation (EU) 2018/1999 of the European Parliament and of the Council on on the Governance of the Energy Union and Climate Action," .

GAMBACORTA, L., J. YANG, AND K. TSATSARONIS (2014): "Financial structure and growth," *BIS Quarterly Review March.*

GIANNETTI, M. AND F. SAIDI (2019): "Shock propagation and banking structure," *The Review of Financial Studies*, 32, 2499–2540.

GROS, D., P. R. LANE, S. LANGFIELD, S. MATIKAINEN, M. PAGANO, D. SCHOENMAKER, AND J. SUAREZ (2016): *Too late, too sudden: Transition to a low-carbon economy and systemic risk*, 6, Reports of the Advisory Scientific Committee.

HALL, B. H. AND J. LERNER (2010): "The financing of R&D and innovation," in *Handbook of the Economics of Innovation*, Elsevier, vol. 1, 609–639.

HOLMSTROM, B. AND J. TIROLE (1997): "Financial intermediation, loanable funds, and the real sector," *the Quarterly Journal of economics*, 112, 663–691.

HSU, P.-H., X. TIAN, AND Y. XU (2014): "Financial development and innovation: Cross-country evidence," *Journal of Financial Economics*, 112, 116–135.

MINETTI, R. (2011): "Informed finance and technological conservatism," *Review of Finance*, 15, 633–692.

NBB (2018): "Annual report 2018," .

——— (2020): "Climate change related transition risk associated with real estate exposures in the Belgian financial sector," Tech. rep., National Bank of Belgium Financial Stability Report.

POPOV, A. (2018): "Evidence on finance and economic growth," in *Handbook of Finance and Development*, Edward Elgar Publishing.

STIGLITZ, J. E. AND A. WEISS (1981): "Credit rationing in markets with imperfect information," *The American economic review*, 71, 393–410.

TIROLE, J. (2010): *The theory of corporate finance*, Princeton University Press.

UEDA, M. (2004): "Banks versus venture capital: Project evaluation, screening, and expropriation," *The Journal of Finance*, 59, 601–621.

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