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Fostering decarbonization through cheaper loans: rationale and practice

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There is growing evidence that firms with larger carbon footprints face higher borrowing costs. Ivanov et al. (2023) show that in the United States borrowing conditions, including interest rates, are more severe for brown firms following both the California cap-and-trade act and the Waxman–Markey act. Kacperczyk and Peydró (2024), using a global sample of firms, find that once banks commit to decarbonization, polluting firms receive less bank credit. Similar evidence is provided by Delis et al. (2024), Altavilla et al. (2023), Ehlers et al. (2022), and Reghezza et al. (2022). In bond markets, Zerbib (2019) and Baker et al. (2018), among others, document an additional return on brown relative to green corporate bonds.

These findings suggest that credit markets are beginning to internalize both physical and transition risks. However, this evidence remains largely reduced-form and partial. It typically treats climate risk as a firm-level characteristic, proxied by direct emissions, and focuses on its correlation with observed borrowing costs. Such an approach overlooks two key aspects. First, firms are embedded in complex input–output networks, where shocks originating in one sector propagate throughout the economy. Second, interest rates are not exogenously given risk premia, but equilibrium outcomes shaped by the interaction of production decisions, financing constraints, and default risk.

The brief builds on a structural general equilibrium model with green and brown firms (Lavia an Luciano, 2026) to show that these network effects are central. In particular, it argues that environmental exposure should be measured through a Leontief-based aggregation that captures both direct and indirect (supply-chain) emissions. This framework helps explain the behavior of U.S. banks around the Paris Agreement, highlighting how their credit conditions reflect not only firms' own emissions but also their position within production networks.

We conclude stressing that, from a policy perspective, these results imply that facilitating more favorable credit conditions for green firms, while accounting for the environmental characteristics of their entire value chain, is consistent with their lower risk exposure. Policies of this type would therefore not only be aligned with market-based risk pricing, but could also effectively support the transition toward a more sustainable economy.

Background: macro shock network effects and interest rates

Environmental risk (natural and transition) is one of the emerging risks that corporations find particularly difficult to manage, especially in the short run. Similar to wars and pandemics, this type of risk affects firms in the short term because most decisions regarding labor, investment, and intermediate goods cannot be adjusted once a shock occurs. Even if firms anticipate different scenarios ex ante, including catastrophic ones, they make irreversible decisions regarding production factors and inputs that cannot be adapted when severe shocks materialize. Consider the semiconductor crisis: orders had been placed well before deliveries failed to occur, and semiconductors could neither be easily substituted with alternative inputs nor reliably sourced from other producers. This rigidity, or irreversibility, generated widespread losses across the global economy, as it disrupted global value chains (see, for instance, Elliott and Golub, 2022).

In the presence of debt, shocks to value chains affect financiers and cascade further: if financiers are rational, they should take the inability of firms to pay debt back when setting the interest rate or the amount of their loans.

To study the equilibrium conditions in the presence of macro risks such as environmental or war ones, Como et al. (2026) built a model with rigidity and debt, which integrates a production network with its financing flows. Importantly, they make the credit conditions (interest rate) endogenous by describing not only the optimal behavior of firms and consumers, but also of their banks. They show that the interest rate asked to a specific firm depends not only on the shocks that can hit it directly, but also on the shocks that can reach it through the production chain, because they originally hit one of its suppliers, or a supplier of its suppliers, so on so forth. The total shocks hitting a firm therefore obtain by multiplying the original shocks to the population of firms by a matrix, which is the classical Leontief matrix.

Rational banks recognize that the probability of default for a given firm depends on the total shocks it faces, as defined above, and set interest rates accordingly. Therefore, both default outcomes and loan conditions crucially depend on the structure of the underlying network.

When default occurs, the magnitude of losses depends on the overall cost of debt, which is a weighted sum of the interest rates of suppliers and suppliers of suppliers, all along the value chain. This dependence is captured by a novel centrality measure, a "discounted" Bonacich centrality, which parallels the standard network centrality, but weights upstream sectors by their debt-adjusted Leontief matrix instead of weighting them according to their standard Leontief. For any given realization of the production shocks, the losses that a sector suffers are proportional to this centrality.

Environmental macro shocks and interest rates to green and brown firms

Focusing on environmental risk, in a second paper, Lavia and Luciano (2026) distinguish the firms belonging to the network based on their greenness and separate brown from green firms. Brown firms are subject to natural and transition risks, which affect productivity, green ones to natural only. These risks do not stop at the firm level. Because production uses intermediate goods, shocks propagate through input-output linkages. As standard in network models, the Leontief matrix provides the natural tool to

characterize this propagation: the primitive shocks to productivity are transformed into network-adjusted shocks that affect all downstream firms. Hence, a firm's effective exposure to environmental risk is determined not only by its own risk but also by that of its suppliers.

Banks are assumed to be residual claimants, and are therefore directly exposed to default risk, as in Como et al. (2026). The interest rate applied to any firm then depends on the distribution of its total shocks, namely the primitive ones affecting its own output and the ones inherited from its suppliers, be them natural or both natural and transition ones.

The model yields several implications. First, firm borrowing costs increase not only with direct transition or natural exposure but also with the exposures of upstream suppliers. Thus even green firms may face high interest rates if they are embedded in brown supply chains. Interest rates on brown firms are higher if the network is the same for brown an green firms, or if brown firms are more connected to brown and green to green.

Does this describe actual banks' attitudes?

In the second part of the paper, the authors bring the mechanisms highlighted by the model to the data by assembling a novel panel that combines U.S. firm-level balance sheet information and borrowing costs with sector-level carbon emissions from the Environmental Protection Agency and detailed input–output linkages from national accounts. Using carbon emissions as a proxy for exposure to environmental risk, they construct both a measure of direct emissions and a model-consistent measure of network-adjusted emissions that captures firms' inherited exposure to transition risk through production networks. The empirical analysis focuses on the United States over the period 2011–2023.

The empirical results deliver two main findings. First, exposure to carbon emissions is positively associated with firms' borrowing costs. When considered separately, both direct CO_2 emissions and network-adjusted emissions are associated with significantly higher interest rates. This evidence indicates that credit markets price climate-related risk and that firms operating in more emission-intensive environments face systematically higher financing costs.

Second, and more importantly, both direct emissions and network-adjusted emissions remain significant when the network measure is orthogonalized with respect to direct emissions. When direct CO_2 emissions are included together with the network exposure component, both coefficients remain economically large and statistically significant. This result shows that the network measure captures variation beyond firms' own emission levels.

These findings indicate that banks price carbon risk not only on the basis of sectoral emissions, but also in relation to firms' positions within production networks, in particular their exposure to carbon-intensive upstream suppliers. Consistent with the model, borrowing costs are associated not only with firms' direct emissions but also with the transition risk embedded in their supply chain exposure. However, this evidence remains correlational and does not, by itself, establish a causal relationship.

To address this issue, the authors further validate the mechanism by exploiting the entry into force of the Paris Agreement in 2016 as an exogenous shift in climate policy expectations. Using difference-in-differences and event-study designs, they show that borrowing costs increase disproportionately for

firms embedded in carbon-intensive production networks following the Agreement. The absence of differential pre-trends and the concentration of post-treatment effects in the network-based measure provide causal support for the interpretation that lenders revise credit pricing in response to anticipated transition risks transmitted through supply chains.

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Taken together, the theory and the empirical evidence show that climate transition risk is priced in credit markets primarily through production networks. Borrowing costs reflect not only firms' own environmental footprint, but, more fundamentally, their exposure to upstream carbon risk and their position within the supply chain. The empirical results therefore support the model's central prediction that transition risk operates as a systemic, network-amplified phenomenon rather than a purely firm-level attribute.

Policy implications

The theory summarized above grounds the following policy implication: favor milder credit conditions to green firms, and do that based on their whole chain greenness. Since we know that green firms are exposed only to natural risks, while brown can be hit both by them and transition ones, this is consistent with the fact that green firms are less risky.

More than that: the theory justifies specific aggregation measures of emissions, that rely on the Leontief matrix, to do that.

The empirical part shows that this policy has been applied in the US, over the period 2012-2023, and in particular following the Paris agreement.

Conclusions

The EU has taken important steps to promote compliance with the UN Guiding Principles on Business and Human Rights. Major interventions in the business sector include not only the Corporate Sustainability Reporting Directive (CSRD), which establishes principles for the accurate reporting of the environmental and social impacts of large firms, but also the Corporate Sustainability Due Diligence Directive (CSDDD), which aims to promote sustainable and responsible corporate behavior across firms' operations and value chains.

A key role in operationalizing ESG principles could be played by banks and financial intermediaries. These actors can ensure that more sustainability-compliant firms receive more favorable lending

conditions than less compliant ones. This approach has been advocated by the EU and implemented, particularly with regard to the environmental dimension, through green lending initiatives such as Invest EU, the activities of the European Investment Bank (EIB), the issuance of NextGenerationEU Green Bonds, and the involvement of local financial intermediaries.

This brief argues that such an approach is not only justified from a regulatory perspective, but also rational from the standpoint of banks. Green firms are indeed exposed primarily to physical (natural) risks, whereas brown firms face both physical and transition risks.

Furthermore, because firms operate within global value chains, an accurate assessment of "brownness" must appropriately account for direct suppliers, as well as suppliers of suppliers, their own suppliers, so on so forth, namely all indirect suppliers. When brownness is measured in terms of emissions, we provide an explicit method for calculating the total, direct and indirect, emissions of its value chain, which is not simply the sum of the individual emissions of its members.

Finally, the brief shows that in the United States, over the period 2012-2023, banks have supported the transition by offering lower interest rates to greener firms. Importantly, they have done so while accounting for value chain considerations, in line with the approach now promoted by the CSDDD.

References

Altavilla, C., Boucinha, M., Pagano, M., & Polo, A. (2023). *Climate risk, bank lending and monetary policy*. ECB Working Paper Series.

Baker, M., Bergstresser, D., Serafeim, G., & Wurgler, J. (2018). *Financing the response to climate change: The pricing and ownership of U.S. green bonds*. NBER Working Paper.

Como, G., Fagnani, F., Luciano, E., Milazzo, A., & Scarsini, M. (2026). *Rigidity and default in production networks*. SSRN Working Paper.

Delis, M. D., de Greiff, K., & Ongena, S. (2024). *Being stranded with fossil fuel reserves? Climate policy risk and the pricing of bank loans*. Financial Markets, Institutions & Instruments.

Ehlers, T., Packer, F., & de Greiff, K. D. (2022). *The pricing of carbon risk in syndicated loans: Which risks are priced and why?* Journal of Banking & Finance.

Elliott, M., & Golub, B. (2022). *Networks and economic fragility*. Annual Review of Economics, 14(1), 665–696.

Kacperczyk, M., & Peydró, J.-L. (2024). *Carbon emissions and the bank-lending channel*. ECGI Working Paper No. 991/2024.

Lavia, A., & Luciano, E. (2026). *The propagation of environmental risk through production networks: Borrowing cost effects*. SSRN Working Paper.

Reghezza, A., Altunbas, Y., Marques-Ibanez, D., Maddaloni, A., & Spaggiari, M. (2022). *The impact of climate change on the European financial system: Credit and market channels*. ECB Working Paper Series.

Zerbib, O. D. (2019). *The effect of pro-environmental preferences on bond prices: Evidence from green bonds*. Journal of Banking & Finance, 98, 39–60.