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Combining financial and ecological sustainability in bank capital regulations

Hye-jin Cho
Sciences Po, Reims, France
Othmar M. Lehner
Hanken School of Economics, Helsinki, Finland, and
Rachatar Nilavongse
Tallinn University of Technology, Tallinn, Estonia

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Abstract

Purpose – With the macroprudential approach, systemic risk is explained by a general equilibrium (GE) model. However, since on-balance-sheet and off-balance-sheet (OBS) risks are structurally segmented, for example annually or periodically on financial statements, the GE model might need further integration with OBS risks including ecological shocks.

Design/methodology/approach – This study develops a theoretical two-period model with consumption, investment and loans, which further includes carbon emissions to distinguish between loans for "green" or "brown" firms to enhance the perspective of ecological sustainability.

Findings – The paper shows how the environmental, social and governance (ESG) factors might be of relevance in the standard bank capital regulatory structure. In dealing with ecological sustainability, a new methodological framework with the green K-index introduces penalties to be paid in the capital structure related to ESG factors. The model is enhanced for screening green or brown firms related to impact investing. The integrated view of financial stability and ecological sustainability further illuminates how a wide cross-sectoral resilience of a green K-index measure for the economy might be achievable.

Research limitations/implications – A stock-flow consistent model with balance-sheet methods raises the question whether all necessary variables and parameters can be computed in practice. Compared to the agent-based model (ABM), this model additionally lacks inputs from agents' behaviour, thus non-rational decisions, which may be relevant in practice. More generally, by adopting a balance-sheet structure, the model shows a coherent framework with relevant variables. The methodology of the GE model with OBS has not been scholarly explored and thus is presented for discussion rather than generalisation. The GE model with OBS provides a new interpretation of systemic risk and interbank relations with a consideration of ecological aspects. Its economic implication contributes to contemporary banking theory as well as to the sustainability discussions in the larger financial sector.

Practical implications – Banks and investors can more carefully measure the ecological risks in their loan portfolios and make better informed decisions leading to a better sustainability of the financial markets.

Originality/value – This study develops a theoretical GE model with off-balance-sheet risks. The model adds green regulation enhancing the capital regulation framework relevant to sustainability. This, in turn, enhances the role of banks in a coherent economic framework for loan decisions towards a much greener finance.

Keywords Banking, General equilibrium, Off-balance-sheet risks, Systemic risks, Impact investing, Green finance

Paper type Conceptual paper

Introduction

The minimum capital requirement is a necessary condition for banking-sector stability to raise the quality, consistency and transparency of the capital base. In addition, the environmental, social and governance (ESG) opportunity is a recent issue required to achieve ecological sustainability. In this article, following up on the ESG portfolio risk considerations

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in Brandstetter and Lehner (2015), a model is developed that intends to reduce procyclicality to the financial shocks and promote the countercyclical buffer within the aim of ecological sustainability.

The question why financial intermediaries provide important and defining services to the economy has few answers from Bernanke (1983), Blinder and Stiglitz (1983), Boyd and Prescott (1986), Townsend (1983). Concretely, to understand the role of banks in aggregate economic activity, banks in general equilibrium (GE) in Bernanke and Gertler's (1985) model, mitigate private information asymmetry. That is to say banks, as an economic factor, directly allocate economic recourses, not in merely financial veils. The model present by Gorton and Winton (1995) shows the socially optimal level of stability of the banking system. Through this paper, based on the model of banking in GE, we illuminate optimal allocation related to sustainability in the economy since the regulator not only prefers more capital in the system, but also implements robustness in the economy for preventing panics and maintaining confidence. Ecological risks may well be the cause of large shocks that may cause major disruptions in financial markets but are so far are either under-priced or, more often, even overlooked.

Related to the behaviour of investors, the ESG risks and opportunities provide managerial incentives for firms. First, investors decide on socially responsible investments (SRIs) with greater persistency than conventional fund investors as changes in ESG factors typically are more long-term oriented (Brandstetter and Lehner (2015). Additionally, Bollen (2007) claims that investors' decisions to invest in or withdraw from SRI funds seem less affected by past negative performance compared to the decisions of conventional fund investors. Second, there seems to be a considerable merit in investing with consideration for ESG. In a survey of regulatory background in Renneboog *et al.* (2008), SRI assets, reached $2.3 trillion in 2005, representing about 10% of total assets under management in the US (SIF, 2001) and SRI assets in Europe amounted to $1.4 trillion in 2005, representing 10–15% of European funds under management (Eurosif, 2006). That is not to say that concepts of corporate social responsibility (CSR) and SRI are far from clear cut and widely discussed in the scholarly literature. Dorfleitner *et al.* (2007, 2012) for example drive forward our behavioural as well as economic understanding of investors in the ESG sphere for example by looking at social blindness or at the altruistic versus rational behaviour of agents with risk aversion. Finally, asset valuation with ESG opportunities and risks in mind raise the issue how social returns might enhance fundamental values in the economy, and whether investors are willing to pay a premium for firms aiming for social and/or environmental returns.

In the final report on the EU taxonomy (2020), related to sustainable finance, the screening criteria for 70 climate mitigation and 68 climate change adaptable activities are mentioned. Reviewing financial sustainability related to those sustainable issues in the Basel III system, the risk coverage framework (Binder and Lehner, 2020) intends to capture all material risks by using a counterparty credit risk formula weighted on the external rating of the counter party. Indeed, exposure measures are promising to enhance unpredicted sustainable issues, i.e. on-balance sheet, repurchase agreements and security finance, derivatives and off-balance-sheet items. In the paper, rather than enlarging the risk contagion, related factors and risk scopes are detected without overstatement by using the GE model and deposit attached to the optimised equity capital (OEC). To explain risk coverage, by proving correlation of OEC upon the previous deposit level, the paper aims to ensure that banking-sector-capital requirements take account of the macro-financial environment in which each substantial economic entity operates in a resilient system that also prepares for ecological shocks.

Ecological risks may correlate off-balance-sheet (OBS) risks, which in turn increases the systemic risk in the financial sector. In our paper, we distinguish between loans for "green" or "brown" firms and we introduce the minimum equity requirement for brown loans, which represents a green capital regulation. This particular macroprudential tool can be used to dampen the effects of ecological risks on OBS risks. Particularly, we compute the green K-index that measures the systemic risks in the financial sector. Based on our model simulations, as the minimum requirement for brown loans rises the green K-index drops and this result indicates a decrease in the systemic risk level. Our green capital regulation therefore can enhance ecological sustainability and financial stability.

The paper is structured related to financial decisions of economic agents as follows. The first section will present the GE model with OBS risks in a two-period model. The second section deals with ESG risks and opportunities, which are solved in the consumer problem. By introducing green capital, the third section presents the optimal capital structure in the firm's profit maximisation problem funded by commercial banks. The fourth section considers money multiplier effects by green capital, which is balanced by central banks. The final section summarises the implication of the right incentive for preventing systemic risks measured by the green K-index minimum equity requirement with green capital.

General equilibrium model with OBS risks

Insofar as systemic risk is concerned, firms, households, central banks and commercial banks face risks, which are highly linked to each other. Seen from this point of view, the banking industry and the monetary policy have particular relevance to systemic risk. On-balance-sheet risks may be defined in a fourfold manner: credit risk, market risk, liquidity risk and systemic risk. Assets of banks have credit risk and market risk. Credit risk is the risk that a borrower will default on any type of debt by failing to make required payments. Market risk is the risk of losses in positions arising from movements in market prices. In the case of liquidity risk, there are two major situations. One is the emergency capacity of banks. When an illiquidity event takes place, an affected bank typically must borrow funds at interest rates exceeding those paid by other institutions. The other situation is about the stability of the banking system in case of inducing a large number of depositors to seek withdrawals.

In conjunction with Freixas and Rochet (1999) and Krugman (2006), the model shows direct relevance to circulate securities and deposits. In the paper, the balance-sheet concept is upgraded by evaluating the value of economic entities and by considering the profit to support financial entities. Capital circulation is presented in Figure 1. Green regulation supporting ecological sustainability is connected to bank capital regulation.

We would say liquidity risk in regard to demand deposit is on the balance-sheet risks of banks. Credit, market and liquidity risk are portrayed but systemic risk is negative externality or an adverse spillover effect stemming from transaction in which they were not

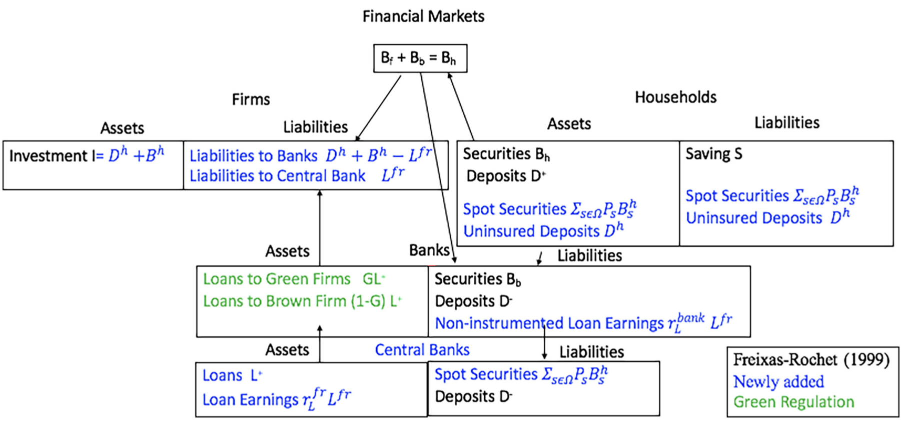


Figure 1.
Financial decisions of economic agents compared to Freixas and Rochet (1999)

participants. Distinguished from credit risk containing sovereign risk (political risk), and counterparty risk (unincorporated entities' risk exposed to financial risk, usually referring to governments, national banks), systemic risk is the risk of collapse of an entire financial system or the entire market, as opposed to risk associated with any individual entity, group or component of a system. Kaufman and Scott (2003) define "systemic risk" as below:

> Systemic risk refers to the risk or probability of breakdowns in an entire system, as opposed to breakdowns in individual parts or components, and is evidenced by co-movements (correlations) among most or all the parts. (p. 371)

Two-period model with consumption, investment and loans

Household sector

In this part, the two-period model addresses household decisions such as consumption, savings, assumed to have cash-in-advance and labour supply is exogenous. Firms maximise profits and directly maintain capital, securities and bonds with the same cash flows. Overall, the capital structure of the Modigliani-Miller theorem in the absence of taxes, bankruptcy costs and asymmetric information, are applied to measure the value of firms. To some extent, central bank holds capital with profit and balance-sheet returns in circulation for the purpose of assuring financial stability and ecological sustainability.

The main purpose of the model is to explore optimal solutions about the problem of households, firms, banks and regulation bodies. The two-period model $(t = 0, 1, 2)$ with a unique physical good initially is owned by consumers in the economy in which a continuum of *ex ante* identical agents is each endowed with one unit of goods at the period $t = 0$, and this good is to be consumed at each period of $t = 1$ and $t = 2$. The consumer chooses her consumption profile $(C_1,\ C_2)$ and the allocation of her savings S^h between bank deposits D^h and securities $\sum_{s\epsilon\Omega} P_s B_s^h$, in a way that maximises her utility function μ under her budget constraints:

$$
\begin{aligned}
&\text{Max } \mu(C_1\ C_2)\\
&C_1 + \sum_{s\epsilon\Omega} P_s B_s^h + D^h + S^h - \sum_{s\epsilon\Omega} P_s B_s^h - D^h = W_1\\
&C_2 = \Pi_f + \Pi_b + (1+r)\sum_{s\epsilon\Omega} P_s B_s^h + (1+r_D)D^h + (1+r_h)S^h\\
&-(1+r)\sum_{s\epsilon\Omega} P_s B_s^h - (1+r_D)D^h
\end{aligned}
\tag{1}
$$

where W_1 represents her initial endowment of the consumption good, $\Pi_f\ + \Pi_b$ for respectively profits of the firm and of the bank (distributed to the consumer-stockholder at $t = 2$). B^h denotes securities, D^h is bank deposits, S^h denotes for savings, $r,\ r_D,\ r_h$ are interest rates paid by securities, deposits and savings. For each future state of the world $s\ (s \in \omega)$, one can determine the price P_s the contingent claim that pays one unit of accounts in states and nothing otherwise.

The consumer has a well-defined set of desires ("preference"), which can be represented by a numerical utility function. In addition, we assume that consumer chooses optimally, in the sense that they choose the option with the highest utility of those available to them. Firstly, the consumer chooses her consumption profile $(C_1,\ C_2)$ and allocates her savings S^h to bank deposits D^h or securities B^h. If real assets $S^h - \sum_{s\epsilon\Omega} P_s B_s^h - D^h$ are non-negative, it implies real assets are sufficient to support household economy. Secondly, the consumer maximises her utility function μ, which is assumed to be increasing and concave.

The paradigm related to impact investing (Lehner *et al.*, 2018) will be addressed in this part. Impact investing breaks the traditional concept that capital is finance-only limited. Traditionally, the GE model in banking assumes putting initial cash-in-advance and measures the capital. Impact investment deals the capital flow with "socially responsible investments" or "sustainable finance." It is often referred to as the "blended value."

In the following Table 1, the three categories of impact investment by Brandstetter and Lehner (2015): traditional, impact-first and thematic are used as structuring elements. The first category relies on fundamental paradigms such as the cash-in-advance constraint. Second, impact-first investments are integrated into traditional optimisation tools with financial trade-off stemming from social or environmental needs but may be offset by gains in these areas. Tradable green securities for example are dealing with climate risks and uncertainty risks. Third, thematic impact investment creates a commercial growth opportunity based on innovations tackling environmental and social needs and may lead to market-rate or market-beating returns.

Households choose $(C_1,\ C_2,\ S_1,\ S_2,\ R_1)$ taking prices $(W_1,\ W_2)$ as given. Formally, if we consider the 4-factor model containing banks as banks have the special financial structure having deposits as liabilities and loans as assets, we need to have a different mindset from the generally accepted accounting principles about debit and credit accounts. The GE diagram is similar with the balance sheet. Distinguishably, the money flow in the paper starts at the bank transaction which is "deposits and borrowings" as liabilities and "claims to corporate" as assets. Then, deposits of household are the amount to be accumulated in banks. Conveniently, securities rather than deposits of household are categorised as riskier investments.

Technically, households operate household economy related to banks regardless of consumption for today or tomorrow such that the first order condition of the utility function $\mu^{'}(C_1\ C_2) = 0$ is denoted as time indifference about consumption preference. That is, households operate household economy related to banks regardless of consumption for today or tomorrow. We conclude consumption choice is not affected by return of initial savings r_1 at the frame of banking money flow related to household. Hence, we get the choice of consumption $C_1 = (W_1 - S_1) + (S_1 - \sum_{1\epsilon\Omega} P_1 B_1^h + D_1)$:

ESG method	Methodology	Contents
Traditional	Cash-in-advance	$0 < D^h \leq W_1$ The paper is based on the cash-in-advance constraint (Clower, 1967). Each consumer or firm must have available cash before they can buy goods
Impact-first investment	Price of security h under uncertainty	$\sum_{s\epsilon\Omega} P_s B_s^h$ (Respectively $\sum_{s\epsilon\Omega} P_s B_s^f$, $\sum_{s\epsilon\Omega} P_s B_s^b$) implies the price of securities by the absence of arbitrage opportunities. A bank issues (or buys) a security h (interpreted as a deposit or a loan) characterised by the array $B_s^h(s\epsilon\Omega)$ (resp. B_s^f, B_s^b) of each payoff in all future states of world
Impact-first investment	Preference of savings	The household has preference to increase the budget to collect savings S^h and affected by risk levels of securities, deposits and real assets. Savings S^h is the sum of securities $\sum_{s\epsilon\Omega} P_s B_s^h$, deposits D^h and real assets $S^h - (\sum_{s\epsilon\Omega} P_s B_s^h - D^h)$
Thematic impact investment	Interior solution	The consumer's problem has an interior solution only when interest rates equal $r = r_D$

Table 1. The environmental, social and governance (ESG) opportunity in the consumer's optimal problem

$$\begin{aligned} &\text{Max } \mu(C_1, C_2) = 0 \\ &C_1 + \sum_{1\epsilon\Omega} P_1 B_1^h + D_1 = W_1 \\ &R_1 + C_2 + (1+r)\sum_{1\epsilon\Omega} P_1 B_1^h + (1+r_1)D_1 - (1+r) - \sum_{2\epsilon\Omega} P_2 B_2^h - D_2 = W_2 \end{aligned} \tag{2}$$

As noted before, time indifference about consumption such that $\mu'(C_1\ C_2) = 0$ is the same condition regardless of real assets, whether it is contained in savings or not. The choice related to precautionary spending is not affected by the interest rate r_1 for initial savings. In addition, the same condition is applied for real assets, namely whether is contained in savings or not. By the end, the aggregation value of securities and deposits is such that $\sum_{1\epsilon\Omega} P_1 B_1^h + D_1$. Evidently, this condition appears in this banking model when we ignore real assets, which are mostly stable in the household economy and can be interpreted as the largest portion of expense and the intangible asset producing future benefits. Therefore, since real assets are contained in savings, we can explain how much of household economy is possibly affected by the allocation of securities and deposits.

Production sector

The firm chooses its investment level I and its financing through real assets $\sum_{s\epsilon\Omega} P_s B_s^h + D^h$, liabilities to banks $\sum_{s\epsilon\Omega} P_s B_s^h + D^h - L^{fr}$, or liabilities to the central bank L^{fr} in a way that maximises its profit:

$$\begin{aligned} &\text{Max}\Pi_f(P_f) \\ &\Pi_f = f(I) + r_f\left(\sum_{s\epsilon\Omega} P_s B_s^h + D^h\right) - r_L^{\text{bank}}\left(D^h + \sum_{s\epsilon\Omega} P_s B_s^h - L^{fr}\right) - r_L^{fr} L^{fr} \\ &I = S^h = D^h + \sum_{s\epsilon\Omega} P_s B_s^h \end{aligned} \tag{3}$$

where f is denoted as the production function of the representative firm, r_f as the premium of firm's real assets, r_L^{bank}, r_L^{fr} as interest rates on bank loans and the central bank loans, respectively, B^{fr} as securities of the central bank and L^{fr} as loans claimed by the firm to the central bank. For each future state of the world s $(s \in \omega)$, one can determine the price P_s of the contingent claim that pays one unit of accounts in a state s and nothing otherwise. The investment level is denoted by I and S^h for savings. Eventually, P_f has an interior solution only when $r_f = r_L^{\text{bank}} = r_L^{fr}$.

The model provides firms' borrowing compositions. The borrowing composition of firms imparted dynamics with the preference to maintain real assets $\sum_{s\epsilon\Omega} P_s B_s^h + D^h$. Regardless of equilibrium, firms prefer loans from the central bank (so called as bonds) than commercial banks. Among the D^h and $\sum_{s\epsilon\Omega} P_s B_s^h$, firms may prefer to have D^h because of financial stability and preference about certainty. In their economic existence, banks have a responsibility to operate the dynamics of the debt-to-equity ratio D/E and maintain the economic entity of real assets $D + E$ in the economy. If we assume that multiplier μ exists, then $\mu(D^h + B^h) > D^h + B^h - L^{fr} > L^{fr}$. This assumption reflects the preference for real assets over government bonds (lower interest rate on a bond than a loan) and over loans because of the interest rate differences.

Adding the intermediate sector, we can define the global pollution η as below:

$$Y_t = \eta(H_t)^{1-\alpha}\left(\sum_{s\epsilon\Omega} P_s B_s^h + D^h\right)^{\alpha} \tag{4}$$

where total capital $\sum_{s\epsilon\Omega} P_s B_s^h + D^h$ is allocated, then global pollution H_t is allocated to green capital and brown capital, proportionally by a green ratio G_t and a brown ratio $(1 - G_t)$.

Two types of entrepreneurs – green and brown firms

There are entrepreneurs operating a green firm making low-carbon emissions who maximise profits subject to:

$$f(I) = \; Y_t = \eta(H_t)^{1-\alpha}\left(\sum_{s\epsilon\Omega} P_s B_s^h + D^h\right)^{\alpha} G_t \tag{5}$$

and a borrowing constraint:

$$D^h + B^{fr} \leq G_t L^{fr} \tag{6}$$

There are entrepreneurs operating a brown firm making high-carbon emissions who maximise consumption subject to

$$Y_t = \eta(H_t)^{1-\alpha}\left(\sum_{s\epsilon\Omega} P_s B_s^h + D^h\right)^{\alpha} (1 - G_t) \tag{7}$$

and a borrowing constraint:

$$D^h + B^{fr} \leq (1 - G_t) L^{fr} \tag{8}$$

Commercial banks

A commercial bank chooses its supply of loans to firms $D^h + B^{fr} + L^{fr}$, its demand for deposits D^h and the borrowing $B^{fr} - L^{fr}$ in a way that maximised its profit:

$$\begin{aligned} &\text{Max } \Pi_b(P_b) \\ &\Pi_b = r_L^{\text{bank}}\left(D^h + \sum_{s\epsilon\Omega} P_s B_s^h - L^{fr}\right) - r_{L_{fr}}\left(\sum_{s\epsilon\Omega} P_s B_s^{fr} - L^{fr}\right) - r_D D^h \end{aligned} \tag{9}$$

where r_L^{bank}, $r_{L_{fr}}$ are interest rates on bank loans and central bank loan, D^h denotes for bank deposits, B_s^h denotes for securities and B_s^{fr} denotes for securities of the central bank and L^{fr} is loans claimed by the firm from the central bank.

Central bank

The central bank maximises the profit by choosing its supply of loans L^+, its demand for deposits D^- and the issuance $\sum_{s\epsilon\Omega} P_s B_s^b$.

$$\begin{aligned} &\text{Max } \Pi_b(P_b) \\ &\Pi_b = r_L L^+ + r\sum_{s\epsilon\Omega} P_s B_s^b - r_D D^- L^+ = \sum_{s\epsilon\Omega} P_s B_s^b + D^- \end{aligned} \tag{10}$$

The central bank chooses its investment level I and its financing through real assets $D^h + \sum_{s\epsilon\Omega} P_s B_s^h$, liabilities to commercial bank $D^h + \sum_{s\epsilon\Omega} P_s B_s^h - L^{fr}$ or liabilities to the central bank L^{fr} in a way that maximises its profit:

$$\text{Max}\,\Pi_f$$

$$\Pi_f = f(I) + r_f\left(D^h + \sum_{s\epsilon\Omega} P_s B_s^h\right) - r_L^{\text{bank}}\left(D^h + \sum_{s\epsilon\Omega} P_s B_s^{fr} - L^{fr}\right) - r_L^{fr} L^{fr} \tag{11}$$

$$I = S^h$$

where f denotes the production function of the representative firm. r_f is the premium of firm's real assets. r_L^{bank}, r_L^{fr} are interest rates on bank loans and bank central bank loan, D^h denotes for bank deposits, B_s^h denotes for securities, B_s^{fr} denotes for securities of the central bank, L^{fr} is loans claimed by the firm to the central bank. For each future state of the world s $(s \in \omega)$, one can determine the price P_s of the contingent claim that pays one unit of account in state s and nothing otherwise. I is the investment level and S^h denotes for savings. The price vector of firms denoted as P_f has an interior solution only when $r_f = r_L^{\text{bank}} = r_L^{fr}$.

General equilibrium

GE is characterised by a vector of interest rates $(r, r_D, r_h, r_f, r_L^{\text{bank}}, r_L^{fr})$ and three vectors of demand and supply levels $(C_1, C_2, D^h, \sum_{s\epsilon\Omega} P_s B_s^h)$ for the consumer,

$(I, \sum_{s\epsilon\Omega} P_s B_s^h, D^h, L^{fr})$ for the firm, $(L^{fr}, \sum_{s\epsilon\Omega} P_s B_s^h, D^h, \sum_{s\epsilon\Omega} P_s B_s^{fr})$ for the bank and $(D^h, \sum_{s\epsilon\Omega} P_s B_s^h, L^{fr})$ for the central bank. Each agent behaves optimally (i.e. his or her decisions solve P_h, P_f or P_b).

It is clear in this model (See Table 3) that the only possible equilibrium is such that all interest rates are equal $r = r_L = r_D$.

By adding the financial intermediary agent such as commercial banks and central banks (in Tables 4 and 5), ESG risk management practically combines sustainability and the responsibility of investment. That is to say, compared to classical banking model in GE, the capital regulation related to ESG risk management is clarified within the bank scope as above.

Green capital regulation

Green capital regulation summarises feasibility of borrowings, optimal parametrisation by a green parameter and balance-sheet equality constraint (see Figure 2 below). Precisely, borrowings

Table 2.
A bank balance sheet for green regulation

Assets	Liabilities
Loans to Green Firms $\stackrel{\text{def}}{=} K_{\text{green}} = G_t(D^h + B^{fr} - L^{fr})$	Deposits D^h
Loans to Brown Firms $(1 - G_t)(D^h + B^{fr} - L^{fr})$	Borrowing $B^{fr} - L^{fr}$

Table 3.
Each market clearing

$I = S$ (good market)
D^h (Firm)–D^h (Firm) + D^h (Household) – D^h (Household) + D^h (Bank) – D^h (Bank) (Deposit market) L^{fr} (Firm)–L^{fr} (Firm)– L^{fr} (Bank) + L^{fr} (Bank) + L^{fr} (Central Bank)–L^{fr} (Central Bank) (Credit Market) B_s^h (Firm) – B_s^h (Firm) + B_s^h (Household) –B_s^h (Household) + B_s^{fr} (Bank) – B_s^{fr} (Bank) + B_s^{fr} (Central Bank) – B_s^{fr} (Central Bank) (Financial market)

will consist primarily to be feasible as of 1- β for each loan term where β is a green parameter and initial deposits are assumed to be 1, such that $D_0 = 1$. To see how this formula works in practice, loans to green firms (see Table 2) denoted as K_{green}, $G_t(D^h + B^{fr} - L^{fr})$ are optimised when balance-sheet equality constraint is $D^h - B^h - \textit{Optimised Equity Capital}\ (OEC_n)$ is bounded. In defining the optimal solution, infinity of a green parameter β formulates 0 of deposits, borrowing and OEC at infinity.

A clear understanding of the arguments contained in Hart and Jaffee's (1974) properties for the feasible and efficient set assumed that the initial equity capital is zero (i.e. $K = 0$). We may answer it is possible that the intermediary's equity is zero in the substantial degree of leverage (high liabilities to equity ratios $\left(\frac{\text{Equity Capital}}{D^h+B^{fr}+L^{fr}}\right)$. Eventually, green capitals K_{green} implement optimal capital regulation, as shown in Figure 2 below.

Just as standard capital regulation is applicable in approximating the optimal capital, so the green capital regulation has the same optimal capital after screening of borrowers. As in Kahane (1977), we assume the equity is positive ($K_{\text{green}} > 0$), so that the opportunity set does not pass through the origin (i.e. the vector of deposit D, borrowing B, OEC is zero give an infeasible solution). Then theoretical superior limit for deposits is defined by deposits:

Table 4. General equilibrium (GE) with green firms

Firms		Households	
Assets	Liabilities	Assets	Liabilities
Real Assets $D^h + B^h = I$	Liabilities to Banks $D^h + B^h - L^{fr}$ Liabilities to Central Bank L^{fr}	Securities B^h Deposits D^h Real Assets $S^h - (B^h + D^h)$	Savings S^h

Table 5. General equilibrium (GE) with green firms continued

Commercial banks		Central bank	
Assets	Liabilities	Assets	Liabilities
Loans to Green Firms $\stackrel{\text{def}}{=} K_{\text{green}} G_t(D^h + B^{fr} - L^{fr})$	Deposits D^h	Claims to corporate L^{fr}	Securities B^{fr}
Loans to Brown Firms $(1 - G_t)(D^h + B^{fr} - L^{fr})$ ESG risk management	Borrowing $B^h - L^{fr}$	Borrowing to banks $B^h - L^{fr}$	

n	Deposits	Borrowings	Optimized Equity Capital
n=0	$D_0 = 1$	-	
n=1	$D_1 = (1 - \beta - K_{green})$	$B_1 = (1 - \beta)$	$OEC_1 = K_{green}$
n=2	$D_2 = (1 - \beta - K_{green})^2$	$B_2 = (1 - \beta)(1 - \beta - K_{green})$	$OEC_2 = K_{green}(1 - \beta - K_{green})$
n=3	$D_3 = (1 - \beta - K_{green})^3$	$B_3 = (1 - \beta)(1 - \beta - K_{green})^2$	$OEC_3 = K_{green}(1 - \beta - K_{green})^2$
...	...	...	...
n=k	$D_K = (1 - \beta - K_{green})^K$	$B_k = (1 - \beta)(1 - \beta - K_{green})^{k-1}$	$OEC_k = K_{green}(1 - \beta - K_{green})^{Kgreen-1}$
...	...	...	...
n→∞	$D_\infty = 0$	$B_\infty = 0$	$OEC_\infty = 0$
	Total Deposits $D = \frac{1}{K_{green}+\beta}$	Total Borrowings $B = \frac{1-\beta}{K_{green}+\beta}$	Total optimized equity capital $\frac{K_{green}}{K_{green}+\beta}$

Source(s): Calculated by the authors

Figure 2. Green capital regulation

$$\text{Deposits} = \sum_{n=0}^{\infty}(1 - K_{\text{green}} - \beta) = \frac{1}{K_{\text{green}} + \beta}$$

Theoretically, the superior limit of the equity capital by the firm is measured as the OEC such that $K_{\text{green}} \times \text{Deposit} = \frac{K_{\text{green}}}{K_{\text{green}}+\beta}$. Additionally, the theoretical superior limit of total borrowings in banks is borrowings such that $(1-\beta) \times \text{Deposits} = \frac{1-\beta}{K_{\text{green}}+\beta}$.

The geometric series of capitals in Figure 2 presents borrowings at stage k, which are defined by a function of deposits at the precedent stage. Supposedly, bank size is given such as Gorton and Winton (1995). That is to say, OEC at stage k is a function of the deposits at the precedent stage such that $\text{OEC}_{k_{\text{green}}} = K_{\text{green}} \times D_{k_{\text{green}}-1}$. Hence, if the OEC depends on the initial deposit, then the terminal condition is liquidation of bank deposits. Therefore, the OEC depends on the previous deposits in the case of no liquidation.

Clearly, deposits insurance cost also increases because deposit insurance depends on the size of deposits. Deposits at stage k are the difference between additional borrowings and the OEC $D_{k_{\text{green}}} = B_{k_{\text{green}}} - \text{OEC}_{k_{\text{green}}}$. To say the least, the composition of banks' balance sheets has no impact on other agents in the same way as the theorem of Modigliani-Miller.

To sum up, a green capital regulation is a new and innovative bank capital regulation. The green capital regulation can be used to reduce the systemic risk in the financial sector. Particularly, an ecological shock can affect and increase the systemic risk in the financial sector. Hence, the green capital regulation can be used to dampen the negative impacts of the ecological shock on the financial sector by raising the minimum requirement for brown loans. As a result, an increase in the capital requirement for brown loans will reduce the systemic risk as well as the climate risk. Therefore, the green capital regulation enhances both financial and ecological sustainability.

Indicator for systemic risk: green *K*-Index

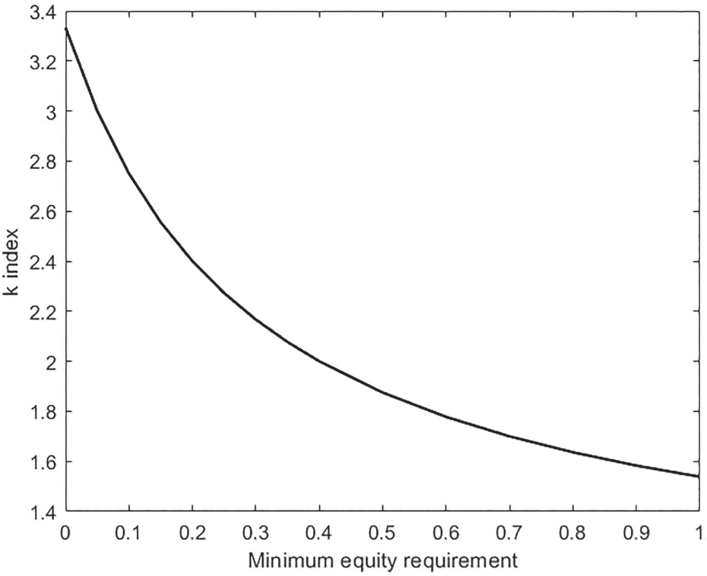
The K-index determines the risky level at the portfolio of commercial banks, which captures the systemic risk in our paper. We define the equity capital ratio with respect to total liabilities, equity capital such that $\frac{\text{Green Equity Capital}}{D^h + B^{fr} - L^{fr}}$, $K \in (0, 1)$ and the borrowing (from the central bank) ratio such that $\frac{B^{fr} - L^{fr}}{D^h + B^{fr} - L^{fr}}$. Suppose the demand for funds is unlimited, by summing up two quantities, the theoretical equity capital multiplier is defined as:

$$k = \frac{\text{Deposits} + \text{Optimized Green Equity Capital}}{\text{Borrowings} + \text{Optimized Green Equity Capital}} = \frac{1 + K_{\text{green}}}{K_{\text{green}} + \beta}$$

where the equity capital ratio with respect to total liabilities and equity capital $\frac{\text{Green Equity Capital}}{D^h + B^{fr} + L^{fr}}$.

Since the deposit is fixed at total 1, borrowings have the constraint that cannot be negatively valued beyond the minimum borrowings. We set the initial deposits level to 1 and initial borrowings level to 0.3. In the following Figure 3, we calculate the series of K-index by varying the minimum equity requirement between 0 and 1.

A decrease in the Green K-index means a decrease of the systemic risk in a financial system. Figure 3 indicates that as the minimum equity requirement for brown loans rises, the systemic risk decreases. The reason is a rise in ecological risks increases OBS risks, which in turn increases the systemic risk in the financial sector. As the minimum equity requirement for brown loans increases, the cost of borrowing for "brown" activities rises. As a result, this will move economic/financial activities away from the brown sector to the green sector, thus



Source(s): Calculated by the author

Figure 3.
Green K-index

this action mitigates ecological risks, which in turn reduce the systemic risk of the financial system.

Conclusion

Social risks and returns related to ESG investment opportunities are gaining visibility among scholars even from more traditional fields such as finance, accounting or economics. What is more, most recent economics' research has been challenged to overcome the traditional macro and meso (institutional) foci, resulting in a new emphasis on the functioning of managerial incentives in research. Indeed, and also from a practical perspective, introducing the concept of sustainability into traditional models is of high significance when it comes to stimulate green innovations by firms. The initiation of such thinking, for example through the French and European legislation on "New Economic Regulations" brought with a global agreement to request (for now) publicy listed companies to mandatorily publish social and environmental (non-financial) information. Based on this reasoning, our paper proposes a number of clear theoretical advancements at the economic level, each for impact-first investment as CSR and thematic impact investment as SRI.

First, we incorporate ecological and systemic risks into a GE model within the financial sector. Our main focus in this was on carbon emissions, allowing us to distinguish between loans for "green" or "brown" firms. Adapting the minimum equity requirement for brown loans succinctly expressed a green capital regulation in order to enhance financial and ecological sustainability. By a GE approach, such ecological risks affect OBS risks and hence the systemic risk of the financial system. What is more, the introduction of the Green K-index uncovers the shut-down risk level of the entire economy according to a brown firms' economic behaviour. Series of equity capital have been numerated from initial deposits to borrowings at the economic level in our model, but some limitations have to be noted. First, the model is limited on periodic short evaluation for accountability and governance with major four economic factors: firms, households, banks and central banks. Over the long run, it would be prudent to include the irrationality of investors or measuring the present value of future sustainability profits more realistically.

Second, we show that an increase in the minimum equity requirement for brown loans reduces the level of carbon emissions as well as the systemic risk measured by the Green K-index as indicator. Hence, our green capital regulation has implications related to both ecological and systemic risks.

The practical implication remains as a question: Is it promising to combine financial stability and ecological sustainability? Basel 3 already introduced a minimum leverage ratio. The leverage ratio was calculated by dividing Tier1 capital by the bank's average total consolidated assets. Within resilient liabilities, three major bank structures, as seen in this article–deposits, borrowings and optimised green capital regulations–are considered as the complementary of minimum capital requirements. Numerous studies show the asset value of commercial banks mainly consists of loans and securities. However, the market's imperfect information arises when OEC grows and deposits are restricted by change. To clarify the measure, thematic impact investing suggests the concept of enhanced borrowings where it should be checked whether borrowings cover the optimised equity by the Green K-index or not. Thus, an overarching design with ecological sustainability is needed that can be combined with financial stability.

Summing up, to explain the potential shutdown of the entire leveraged economic system, we clearly see the ecological sustainability as a major factor of systemic risk. In our paper thus the Green K-index is suggested as the indicator of risk-taking which fulfils the gap between ecological sustainability and financial stability. Its widespread application would certainly boost corporate ethical behaviours and enrich the in-depth discussion of social and environmental risks and returns in the fields of accounting, finance and economics.

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Corresponding author
Othmar M. Lehner can be contacted at: othmar.lehner@hanken.fi