Shadow banking and consistency of a carbon-intensive Counter-Cyclical Capital Buffers regulation

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40th meeting of the European Economic Association, Bordeaux

August 27th, 2025

This work of the Interdisciplinary Thematic Institute MAKErS, as part of the ITI 2021-2028 program of the University of Strasbourg, CNRS and INSERM, was supported by IdEx Unistra (ANK-10-IDEX-0002), and by SFRI-STRAT'US project (ANR-20-SFRI-0012).

Context
and
Paper's motivations

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  ➢ Differentiated treatment of green credit risk in banks' capital requirements → Green Supporting Factor (Dombrovskis, 2017, HLEG, 2018, EBF, 2018), "Brown" Output Floor (Roussel, 2024).

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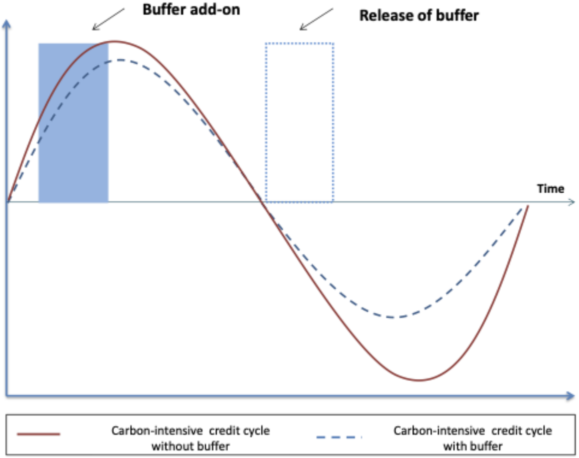
  - ➢ Differentiated treatment of green credit risk in banks' capital requirements → Green Supporting Factor (Dombrovskis, 2017, HLEG, 2018, EBF, 2018), "Brown" Output Floor (Roussel, 2024).
  - ➢ **Design of carbon-intensive Counter-Cyclical Capital Buffers for banks (D'Orazio and Popoyan, 2019).**

Carbon-intensive CCyB mechanism



Source : D'Orazio and Popoyan (2019)

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  - ➢ **It is possible that the carbon-intensive CCyB regulation could favor green excess credits, which fuel the accumulation of systemic risk in the economy.**
  - ➢ **The potential green benefits of the carbon-intensive CCyB regulation could be undermined by the risk of carbon-intensive credit leakages toward unregulated banks (i.e., shadow banks).**

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  ➢ Analyzing the consistency when traditional banks have different levels of involvement in the green credit market.

  ➢ Checking the consistency when polluting firms face an emissions tax on their production (**additional analysis**).

The Model

The model in a nutshell

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Financial
Regulator

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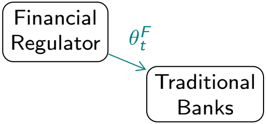

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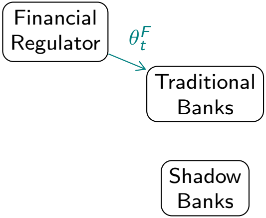

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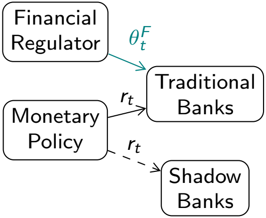

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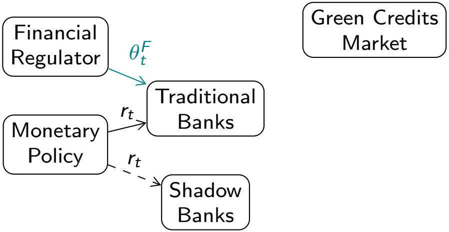

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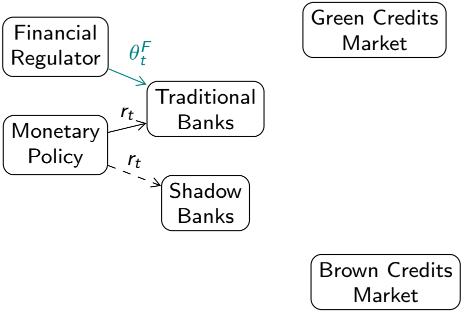

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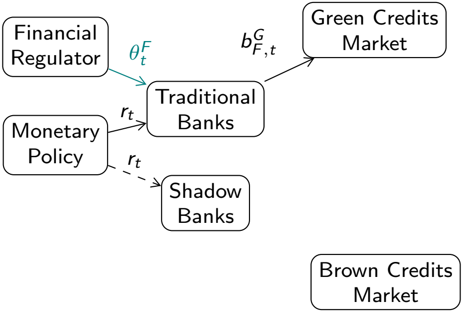

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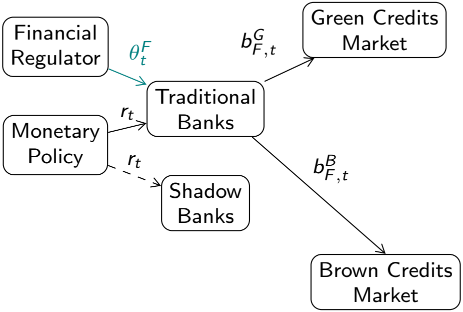

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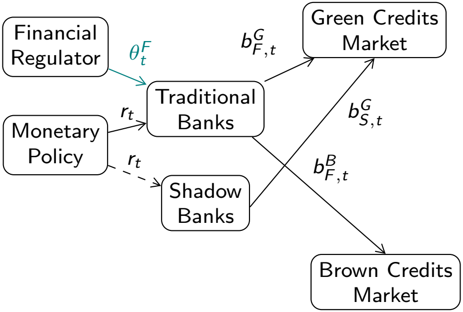

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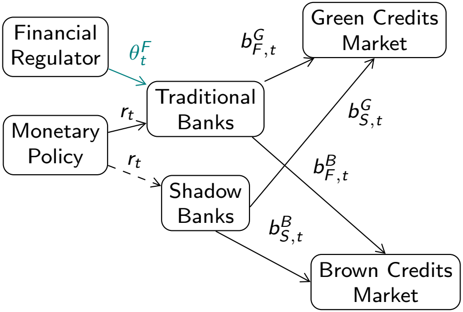

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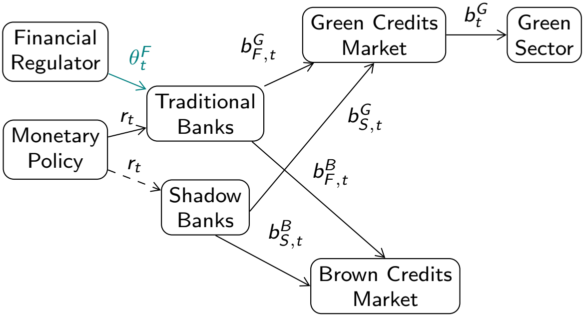

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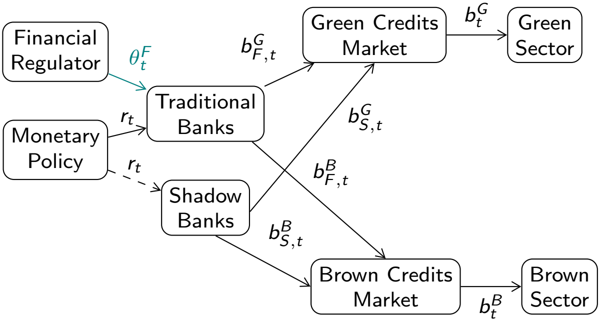

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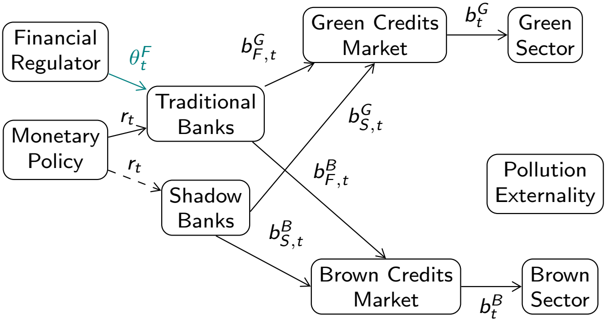

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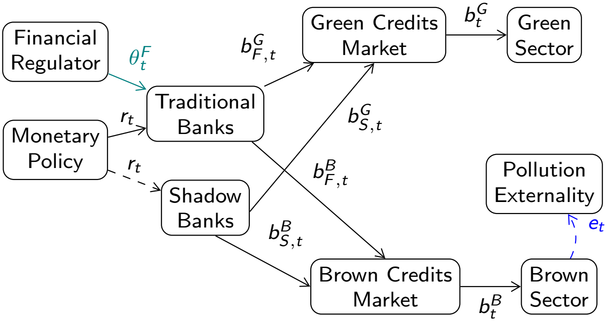

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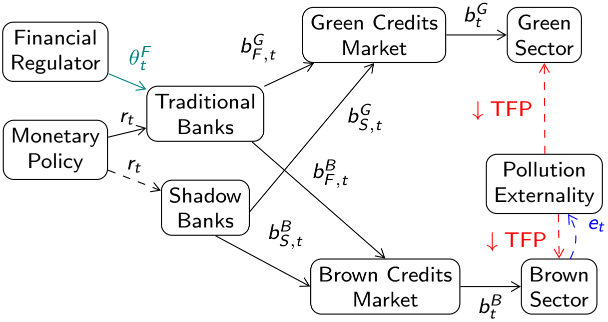

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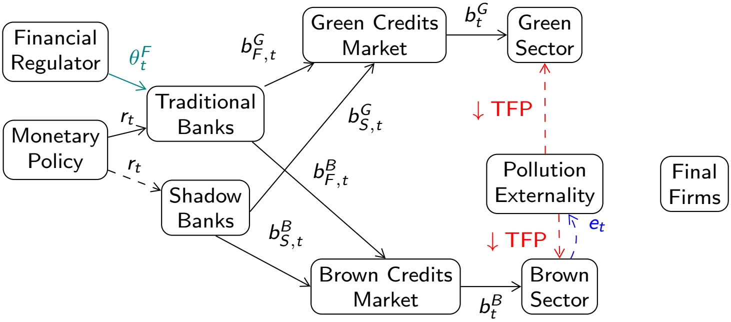

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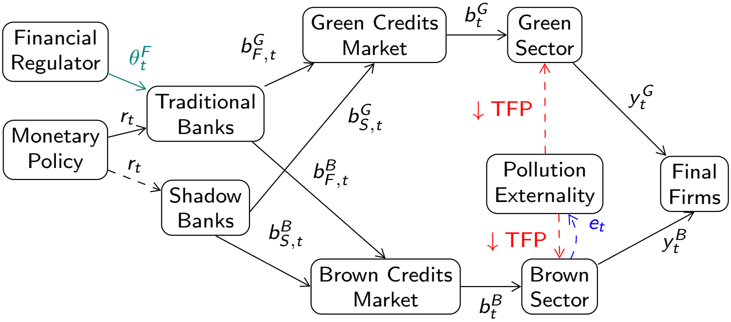

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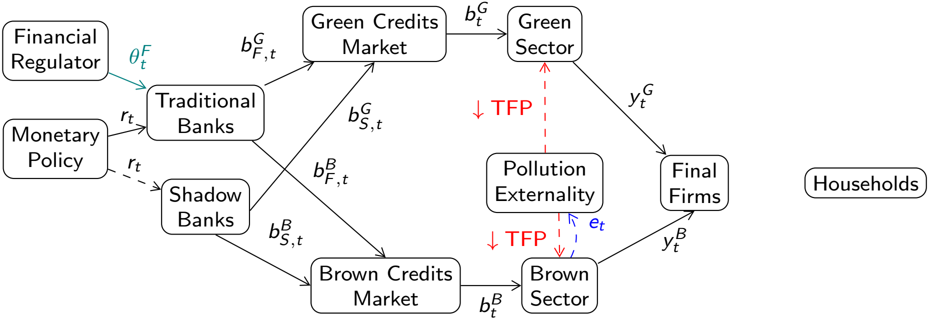

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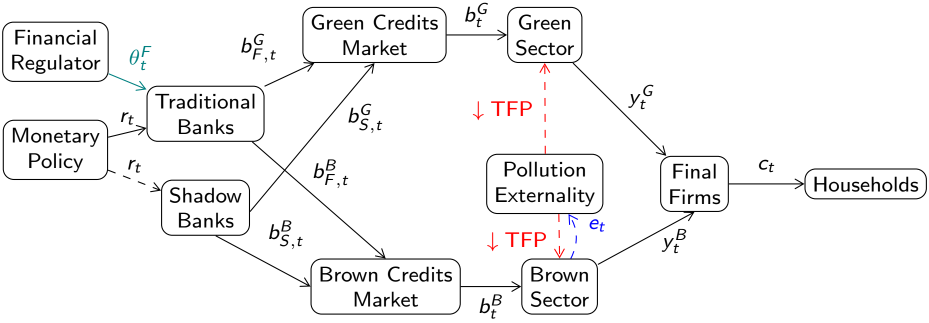

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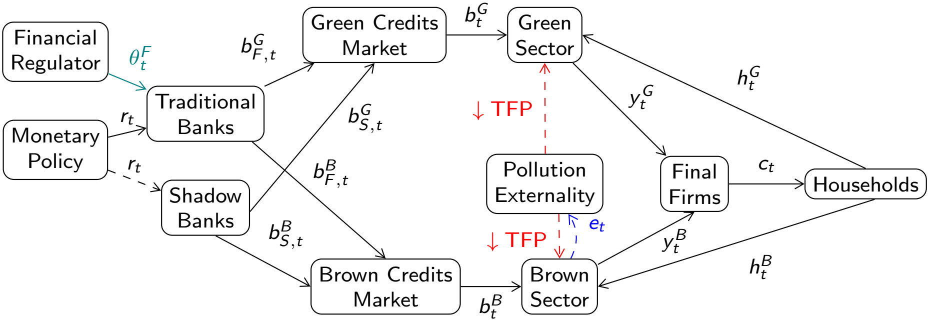

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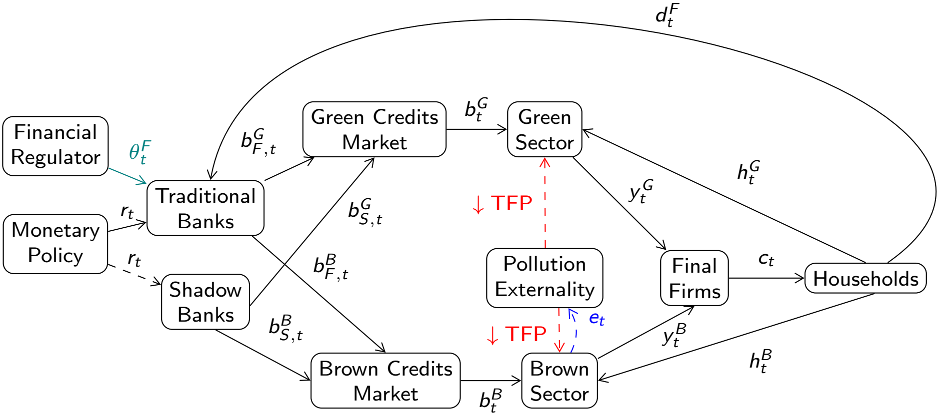

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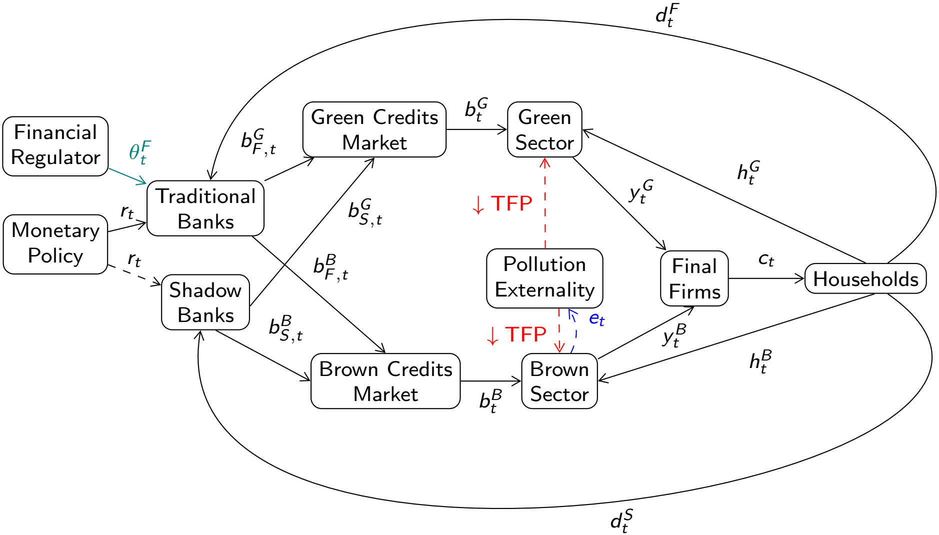

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Where ρ_{θ^F} is the smoothing parameter of the regulation, and $\phi_{\mathcal{T}}$ is the sensitivity of the regulation with respect to the financial systemic risk indicator. The component $\overline{\theta^F}$ denotes the long-term target of the regulation.

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Definition of the CCyB efficiency

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- As underlined by Angelini et al.(2014), Poutineau and Vermandel (2017), and Garcia-Revelo and Levieuge (2022), the minimization of this volatility is a good proxy for the efficiency of the CCyB regulation.

Simulations

Consistency of a carbon-intensive CCyB regulation over business and financial cycle (1)

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  - ➢ A positive productivity shock on firms' production (real shock).
  - ➢ A negative shock on the default probability of banks (financial shock).
- These two shocks allow us to consistently study the efficiency of the CCyB regulation during upturn and downturn periods over the business and financial cycles.

Consistency of a carbon-intensive CCyB regulation over business and financial cycle (2)

	Scenario	Total Credit-to-GDP Volatility	
		TFP shock	Bankruptcy shock
a.	Traditional and shadow banks credits	-26.342	-28.571
b.	Traditional banks credits	-26.065	-27.008
c.	Traditional and shadow banks brown credits	-26.327	-28.505
d.	Traditional banks brown credits	-26.016	-26.731

Note : Values are expressed in percentage changes from values obtained under the baseline scenario (i.e. without CCyB regulation). As a example, the first value of the table reads as following : compared to no CCyB regulation, a CCyB regulation indexed to traditional and shadow bank loans leads to a reduction of -26.342% of the volatility of total credit-to-GDP ratio. Volatilities are obtained with the resolution of the model under a second order approximation. (Additional results : Figure 1 ; Figure 2 ; Table 4)

Traditional banks involvement in green credit market and consistency of carbon-intensive CCyB regulation

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- Our baseline results highlight that a carbon-intensive CCyB regulation is not the most suitable regulation for financial regulators' objectives.
- However, this conclusion holds when there are no asymmetric leakages between green and brown loans for traditional and shadow banks.
- A stronger (weaker) involvement of traditional banks in the green credit market, compared to the brown one, may contribute to these asymmetric leakages, which could lead financial regulators to adopt carbon-intensive CCyB regulations.

Definition of traditional banks involvement in credit market

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- For each $h \in \{G, B\}$ firms, the aggregate loan $b_t^h(e)$ corresponds to a mix of traditional bank loans $b_{h,t}^F(e)$ and shadow bank loans $b_{h,t}^S(e)$, which is expressed via the following CES function :

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Where $\gamma_h^F \in [0, 1]$ denotes the bias for traditional bank loans in financing credits of type h, while $\psi_h^F > 0$ is the elasticity between traditional and shadow bank loans in the credit market of type h.

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- The involvement of traditional banks in the credit market for type h is reflected by the parameter γ_h^F.

Varying level of traditional banks' involvement in the green credit market

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Varying level of traditional banks' involvement in the green credit market

- We examine the consistency of a carbon-intensive CCyB regulation under two scenarios for traditional banks' involvement in the green credit market :
    - Higher involvement in the green credit market than in the brown one $\rightarrow \gamma_G^F > \gamma_B^F$
    - Lower involvement in the green credit market than in the brown one $\rightarrow \gamma_G^F < \gamma_B^F$

Impact of higher traditional banks involvement in green credit market on carbon-intensive CCyB consistency (i.e., $\gamma_G^F > \gamma_B^F$)

	$\gamma_G^F = 0.85$		$\gamma_G^F = 0.9$		$\gamma_G^F = 0.95$	
Scenario	**Total Credit-to-GDP Volatility**		**Total Credit-to-GDP Volatility**		**Total Credit-to-GDP Volatility**	
	TFP shock	**Bankruptcy shock**	**TFP shock**	**Bankruptcy shock**	**TFP shock**	**Bankruptcy shock**
a. Traditional and shadow banks credits	-26.565	-29.24	-26.483	-29.405	-26.393	-29.526
b. Traditional banks credits	-26.202	-27.28	-25.989	-27.097	-25.749	-26.802
c. Traditional and shadow banks brown credits	-26.765	-30.323	-26.937	-31.193	-27.181	-32.151
d. Traditional banks brown credits	-26.456	-28.915	-26.533	-29.844	-26.688	-30.799

Note : Values are expressed in percentage changes from values obtained under the baseline scenario (i.e. without CCyB regulation). Volatilities are obtained with the resolution of the model under a second order approximation.
(Additional results : Table 5 ; Figure 3 ; Figure 4)

Impact of lower traditional banks involvement in green credit market on carbon-intensive CCyB consistency (i.e., $\gamma_G^F < \gamma_B^F$)

	$\gamma_B^F = 0.85$		$\gamma_B^F = 0.9$		$\gamma_B^F = 0.95$	
Scenario	**Total Credit-to-GDP Volatility**		**Total Credit-to-GDP Volatility**		**Total Credit-to-GDP Volatility**	
	TFP shock	**Bankruptcy shock**	**TFP shock**	**Bankruptcy shock**	**TFP shock**	**Bankruptcy shock**
a. Traditional and shadow banks credits	-28.375	-31.719	-29.116	-32.912	-29.885	-34.042
b. Traditional banks credits	-28.309	-29.787	-29.041	-30.833	-29.773	-31.847
c. Traditional and shadow banks brown credits	-28.326	-29.32	-28.991	-28.716	-29.587	-27.574
d. Traditional banks brown credits	-28.217	-27.354	-28.904	-27.119	-29.529	-26.642

Note : Values are expressed in percentage changes from values obtained under the baseline scenario (i.e. without CCyB regulation). Volatilities are obtained with the resolution of the model under a second order approximation.
(Additional results : Table 6 ; Figure 5 ; Figure 6)

Conclusion

- The aim of the paper was to examine whether a carbon-intensive CCyB regulation is consistent with financial regulators' objectives when shadow banks operate in the credit market.

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  ➢ **Additional results** : A strict emissions tax applied to production of brown firms could favor the adoption of a carbon-intensive CCyB regulation.

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  - ➢ Studying the coordination of carbon-intensive CCyB regulation across different countries.
  - ➢ Incorporating green microprudential proposals, such as the green supporting or brown penalizing factor, to assess the interaction between green micro and macroprudential policies.

Shadow banking and consistency of a carbon-intensive Counter-Cyclical Capital Buffers regulation

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BETA (Strasbourg University)

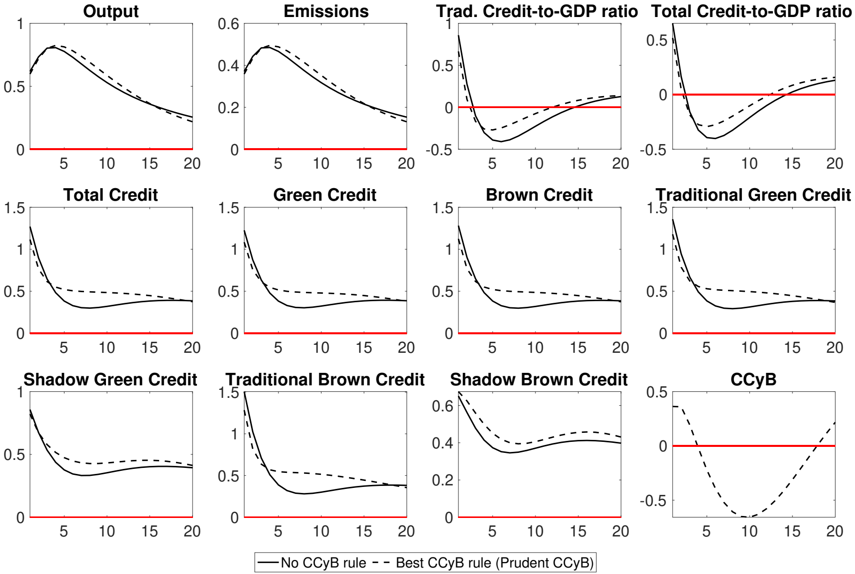
40th meeting of the European Economic Association, Bordeaux

August 27th, 2025

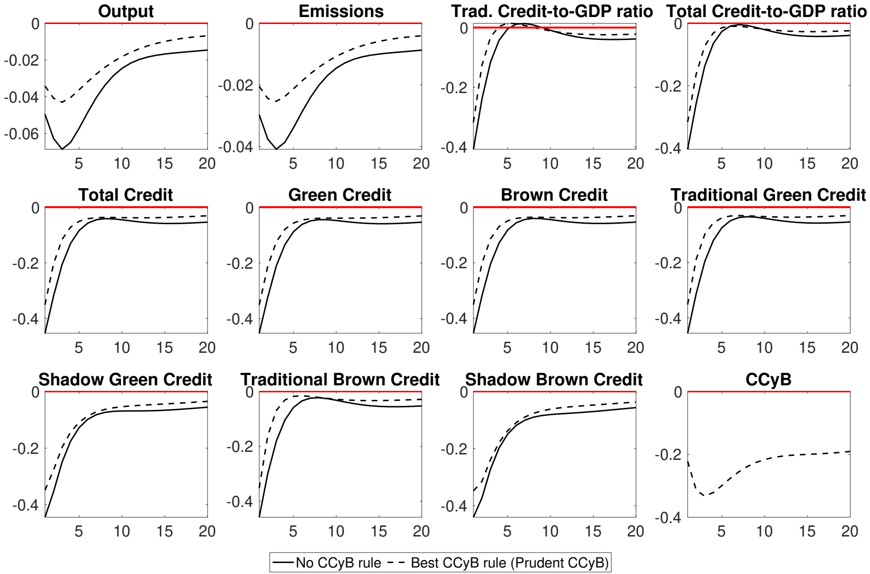
This work of the Interdisciplinary Thematic Institute MAKErS, as part of the ITI 2021-2028 program of the University of Strasbourg, CNRS and INSERM, was supported by IdEx Unistra (ANK-10-IDEX-0002), and by SFRI-STRAT'US project (ANR-20-SFRI-0012).

Appendix

IRFs under a positive TFP shock - (R : Table 1)



IRFs under a negative bankruptcy shock - (R : Table 1)



Decomposition of volatility changes with respect to loan and lender types (baseline scenario)

	Scenario	Green Credit-to-GDP Volatility	Brown Credit-to-GDP Volatility	Traditional Credit-to-GDP Volatility	Shadow Credit-to-GDP Volatility
	TFP shock				
a.	Traditional and shadow banks credits	**-25.006**	**-26.668**	-31.521	**-7.804**
b.	Traditional banks credits	-24.667	-26.408	-31.686	-7.457
c.	Traditional and shadow banks brown credits	-24.987	-26.654	-31.532	-7.785
d.	Traditional banks brown credits	-24.608	-26.361	**-31.693**	-7.403
	Bankruptcy shock				
a.	Traditional and shadow banks credits	**-27.796**	**-28.752**	-31.006	**-15.403**
b.	Traditional banks credits	-25.972	-27.26	**-31.114**	-12.552
c.	Traditional and shadow banks brown credits	-27.714	-28.692	-31.047	-15.245
d.	Traditional banks brown credits	-25.667	-26.991	-31.029	-12.157

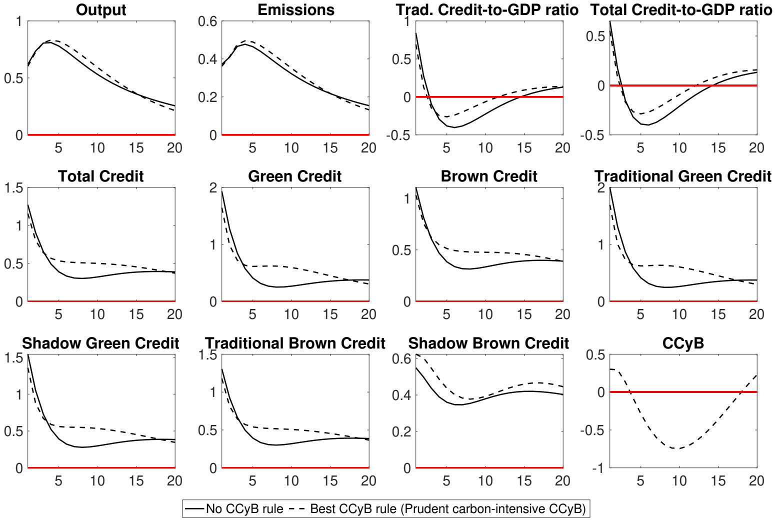
(R : Table 1)

Decomposition of volatility changes with respect to loan and lender types (with HGCI : $\gamma_G^F = 0.85$ and $\gamma_B^F = 0.735$)

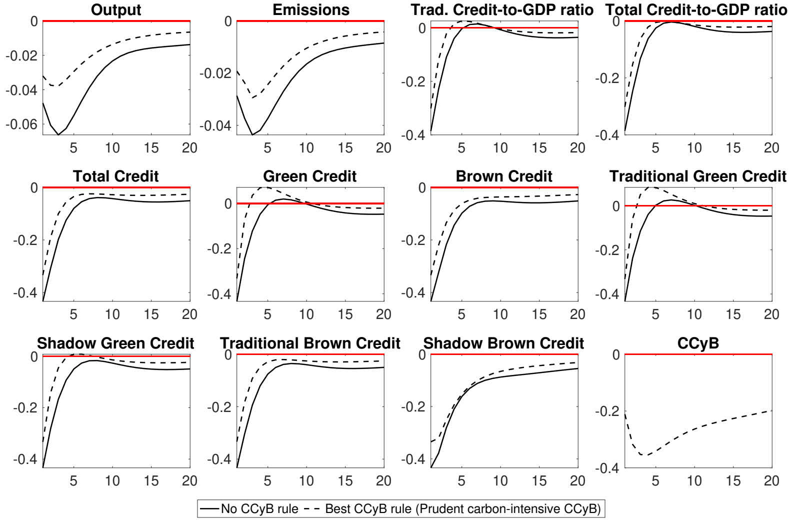
	Scenario	Green Credit-to-GDP Volatility	Brown Credit-to-GDP Volatility	Traditional Credit-to-GDP Volatility	Shadow Credit-to-GDP Volatility
	TFP shock				
a.	Traditional and shadow banks credits	-37.928	-21.406	**-31.531**	-6.873
b.	Traditional banks credits	**-39.012**	-20.922	-31.519	-6.716
c.	Traditional and shadow banks brown credits	-36.471	**-21.797**	-31.354	**-6.98**
d.	Traditional banks brown credits	-37.855	-21.337	-31.473	-6.883
	Bankruptcy shock				
a.	Traditional and shadow banks credits	-28.02	-25.528	-32.096	-13.907
b.	Traditional banks credits	**-33.691**	-22.891	-31.623	-11.145
c.	Traditional and shadow banks brown credits	-21.314	**-27.516**	-31.417	**-16.385**
d.	Traditional banks brown credits	-29.269	-25.044	**-32.102**	-13.362

(R : Table 2)

IRFs under a positive TFP shock (with HGCI : $\gamma_G^F = 0.85$ and $\gamma_B^F = 0.735$) - (R : Table 2)



IRFs under a negative bankruptcy shock (with HGCI : $\gamma_G^F = 0.85$ and $\gamma_B^F = 0.735$) - (R : Table 2)

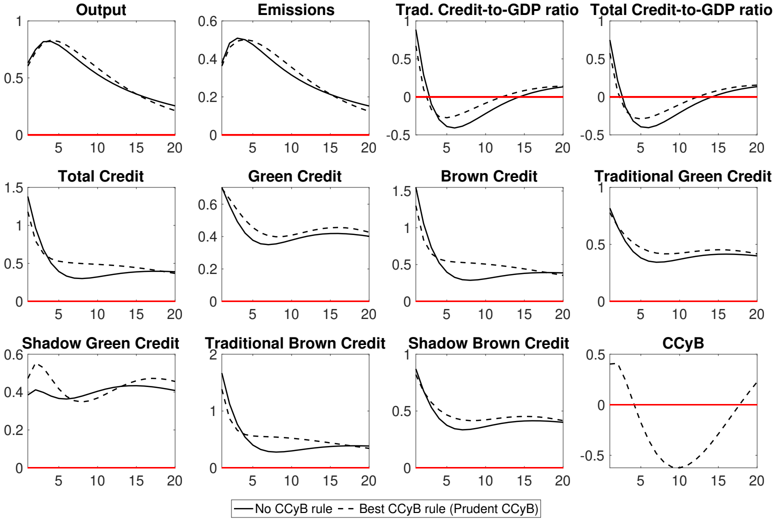


Decomposition of volatility changes with respect to loan and lender types (with LGCI : $\gamma_G^F = 0.735$ and $\gamma_B^F = 0.85$)

	Scenario	Green Credit-to-GDP Volatility	Brown Credit-to-GDP Volatility	Traditional Credit-to-GDP Volatility	Shadow Credit-to-GDP Volatility
	TFP shock				
a.	Traditional and shadow banks credits	**-8.573**	-32.348	-31.717	**-7.637**
b.	Traditional banks credits	-8.558	-32.506	-31.84	-7.525
c.	Traditional and shadow banks brown credits	-8.492	-32.606	-31.906	-7.474
d.	Traditional banks brown credits	-8.445	**-32.666**	**-31.941**	-7.349
	Bankruptcy shock				
a.	Traditional and shadow banks credits	**-13.16**	**-34.842**	**-34.418**	**-13.35**
b.	Traditional banks credits	-10.995	-33.955	-33.299	-11.167
c.	Traditional and shadow banks brown credits	-10.528	-33.68	-32.979	-10.697
d.	Traditional banks brown credits	-8.736	-32.328	-31.484	-8.89

(R : Table 3)

IRFs under a positive TFP shock (with LGCI : $\gamma_G^F = 0.735$ and $\gamma_B^F = 0.85$) - (R : Table 3)



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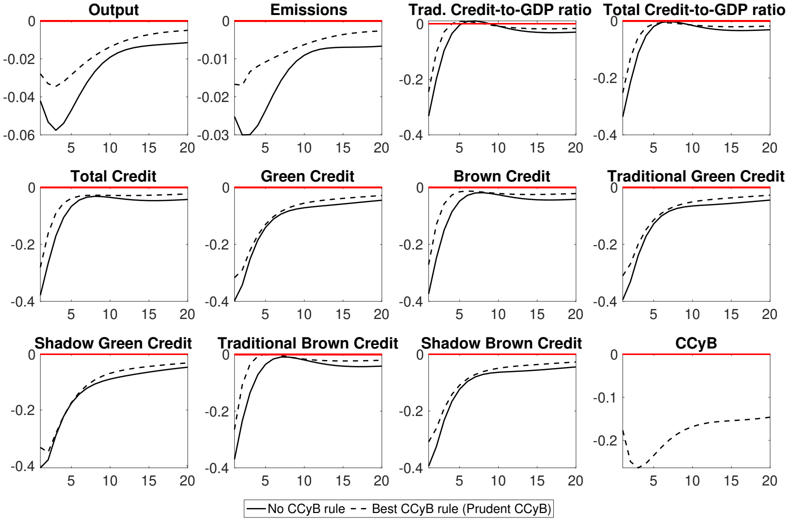


Emissions tax and consistency of carbon-intensive CCyB regulation

- Our baseline results highlight that a carbon-intensive CCyB regulation is not the most suitable regulation for financial regulators' objectives.
- However, the asymmetric leakages between green and brown loans for traditional banks and shadow banks could be fueled by another factor, such as the introduction of an emissions tax on production of brown firms.
- The introduction of an emissions tax on the production of brown firms may generate these asymmetric leakages and, thus, lead a carbon-intensive CCyB setting to be a potentially consistent regulation with financial regulators' objectives.

Emissions tax setting

- The government introduces an emissions tax τ^B that is proportional to the volume of emissions e_t produced by brown firms, as in Minesso & Pagliari (2023).
- Furthermore, brown firms are able to abate an endogenous fraction $\Upsilon \in [0,1]$ of their emissions. The abatement technology allows brown firms to reduce their emissions at a cost given by $\theta_1 \mu^{\theta_2} y_t^B$.
- The introduction of the emissions tax and the abatement technology cost implies a new profit function $\Pi_t^{B\prime}$ for brown firms :

$$\Pi_t^{B}\prime = \Pi_t^B - \tau^B e_t - \theta_1 \Upsilon_t^{\theta_2} y_t^B$$

Where Π_t^B is the baseline profit function of brown firms, and :

$$\Upsilon_t = \left(\frac{\tau^B \left(y_t^B\right)^{-\psi}}{\theta_1 \theta_2} \right)^{\frac{1}{\theta_2 - 1}} \quad \text{and} \quad e_t = (1 - \Upsilon_t) \left(y_t^B\right)^{1-\psi}$$

Where ψ reflects the sensitivity of emissions to brown firms' production.

Impact of emissions tax on carbon-intensive CCyB consistency

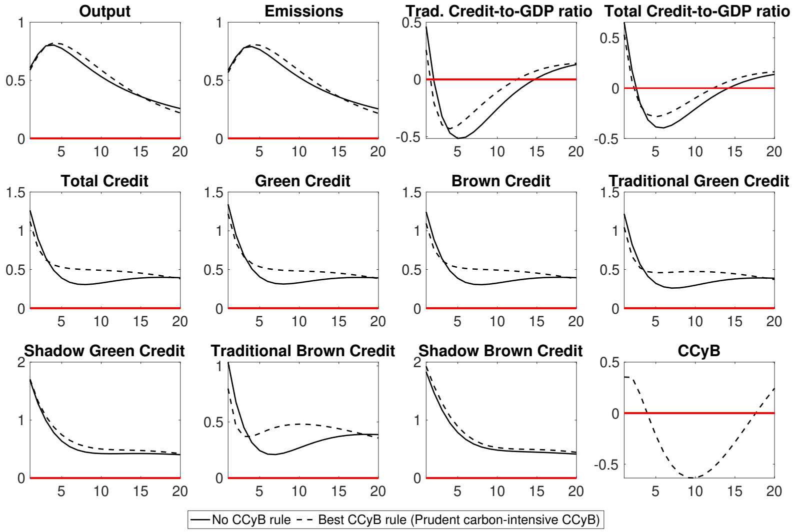
Scenario	TAX=1% Total Credit-to-GDP Volatility TFP shock	TAX=1% Total Credit-to-GDP Volatility Bankruptcy shock	TAX=10% Total Credit-to-GDP Volatility TFP shock	TAX=10% Total Credit-to-GDP Volatility Bankruptcy shock	TAX=15% Total Credit-to-GDP Volatility TFP shock	TAX=15% Total Credit-to-GDP Volatility Bankruptcy shock
a. Traditional and shadow banks credits	-26.359	-28.606	-26.288	-28.852	-25.92	-28.953
b. Traditional banks credits	-26.061	-27.294	-15.584	-29.273	3.135	-30.086
c. Traditional and shadow banks brown credits	-26.332	-28.568	-26.31	-29.005	-26.27	-29.187
d. Traditional banks brown credits	-25.995	-27.069	-12.631	-29.394	9.966	-30.339

Note : Values are expressed in percentage changes from values obtained under the baseline scenario (i.e. without CCyB regulation). Volatilities are obtained with the resolution of the model under a second order approximation.

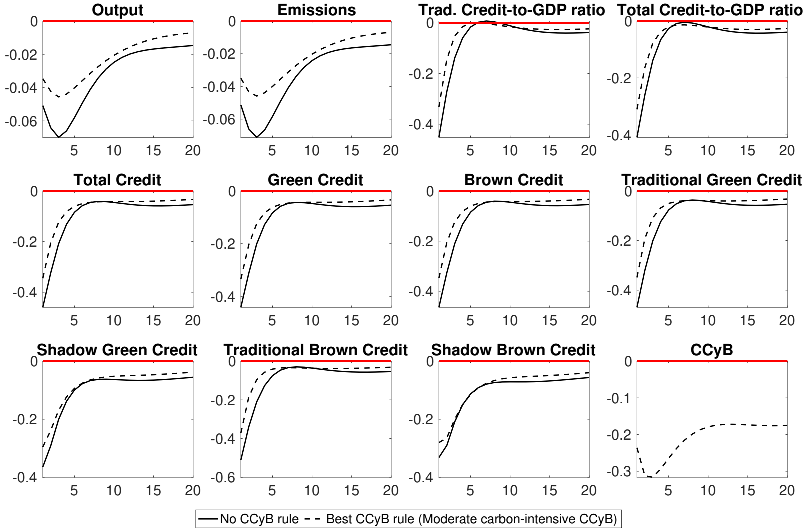
Decomposition of volatility changes with respect to loan and lender types (with an emissions tax of 10%)

Scenario	Green Credit-to-GDP Volatility	Brown Credit-to-GDP Volatility	Traditional Credit-to-GDP Volatility	Shadow Credit-to-GDP Volatility
TFP shock				
a. Traditional and shadow banks credits	**-20.648**	-26.398	-1.896	13.069
b. Traditional banks credits	0.159	-19.784	-30.168	12.272
c. Traditional and shadow banks brown credits	-19.758	**-26.73**	-3.8	12.801
d. Traditional banks brown credits	3.458	-17.097	**-33.322**	**11.905**
Bankruptcy shock				
a. Traditional and shadow banks credits	-27.72	-29.12	-31.764	**-11.969**
b. Traditional banks credits	-27.924	-29.594	-33.45	-9.596
c. Traditional and shadow banks brown credits	-27.857	-29.276	-31.979	-11.911
d. Traditional banks brown credits	**-28.018**	**-29.722**	**-33.717**	-9.357

IRFs under a positive TFP shock (with an emissions tax of 10%)



IRFs under a negative bankruptcy shock (with an emissions tax of 10%)



Combined effect of emissions tax and traditional banks involvement in green credit market

- The previous tables indicate that a higher involvement of traditional banks in the green credit market leads financial regulators to adopt a prudent carbon-intensive CCyB regulation.
- This result highlights the usefulness of using a carbon-intensive CCyB regulation alongside other financial policies that encourage traditional banks to increase their participation in the green credit market.
- Our last analysis consists of checking whether this conclusion holds when brown firms are subjected to an emissions tax.

Emissions tax and higher traditional banks involvement in green credit market (i.e., $\gamma_G^F = 0.85$ and $\gamma_B^F = 0.735$)

	TAX=1%		TAX=10%		TAX=15%	
Scenario	**Total Credit-to-GDP Volatility**		**Total Credit-to-GDP Volatility**		**Total Credit-to-GDP Volatility**	
	TFP shock	**Bankruptcy shock**	**TFP shock**	**Bankruptcy shock**	**TFP shock**	**Bankruptcy shock**
a. Traditional and shadow banks credits	-26.585	-29.272	-26.711	-29.486	-26.753	-29.571
b. Traditional banks credits	-26.234	-27.305	-26.439	-27.474	-26.512	-27.54
c. Traditional and shadow banks brown credits	-26.76	-30.373	-26.701	-30.719	-26.663	-30.858
d. Traditional banks brown credits	-26.464	-28.961	-26.502	-29.279	-26.502	-29.407

Note : Values are expressed in percentage changes from values obtained under the baseline scenario (i.e. without CCyB regulation). Volatilities are obtained with the resolution of the model under a second order approximation.

Emissions tax and lower traditional banks involvement in green credit market (i.e., $\gamma_G^F = 0.735$ and $\gamma_B^F = 0.85$)

	TAX=1%		TAX=10%		TAX=15%	
Scenario	**Total Credit-to-GDP Volatility**		**Total Credit-to-GDP Volatility**		**Total Credit-to-GDP Volatility**	
	TFP shock	**Bankruptcy shock**	**TFP shock**	**Bankruptcy shock**	**TFP shock**	**Bankruptcy shock**
a. Traditional and shadow banks credits	-28.389	-31.746	-28.465	-31.92	-28.484	-31.987
b. Traditional banks credits	-28.334	-29.813	-28.475	-29.986	-28.516	-30.052
c. Traditional and shadow banks brown credits	-28.341	-29.36	-28.415	-29.63	-28.423	-29.738
d. Traditional banks brown credits	-28.243	-27.395	-28.383	-27.67	-28.415	-27.779

Note : Values are expressed in percentage changes from values obtained under the baseline scenario (i.e. without CCyB regulation). Volatilities are obtained with the resolution of the model under a second order approximation.

Decomposition of volatility changes with respect to loan and lender types (with HGCI : $\gamma_G^F = 0.85$ and $\gamma_B^F = 0.735$ and an emissions tax of 10%)

	Scenario	Green Credit-to-GDP Volatility	Brown Credit-to-GDP Volatility	Traditional Credit-to-GDP Volatility	Shadow Credit-to-GDP Volatility
	TFP shock				
a.	Traditional and shadow banks credits	-36.039	-22.041	-31.417	-7.474
b.	Traditional banks credits	**-37.241**	-21.575	**-31.544**	-7.293
c.	Traditional and shadow banks brown credits	-34.155	**-22.374**	-30.906	-7.725
d.	Traditional banks brown credits	-35.593	-21.952	-31.175	**-7.62**
	Bankruptcy shock				
a.	Traditional and shadow banks credits	-27.202	-25.866	-32.327	-14.239
b.	Traditional banks credits	**-33.01**	-23.165	-31.798	-11.432
c.	Traditional and shadow banks brown credits	-20.354	**-28.019**	-31.777	**-16.826**
d.	Traditional banks brown credits	-28.392	-25.503	**-32.424**	-13.778

Decomposition of volatility changes with respect to loan and lender types (with LGCI : $\gamma_G^F = 0.735$ and $\gamma_B^F = 0.85$ and an emissions tax of 10%)

Scenario		Green Credit-to-GDP Volatility	Brown Credit-to-GDP Volatility	Traditional Credit-to-GDP Volatility	Shadow Credit-to-GDP Volatility
TFP shock					
a.	Traditional and shadow banks credits	-7.889	-32.581	-31.677	**-8.052**
b.	Traditional banks credits	-7.985	-32.806	-31.874	-7.964
c.	Traditional and shadow banks brown credits	-8.047	-32.774	-31.82	-8.029
d.	Traditional banks brown credits	**-8.077**	**-32.909**	**-31.937**	-7.91
Bankruptcy shock					
a.	Traditional and shadow banks credits	**-12.821**	**-35.134**	**-34.633**	**-13.447**
b.	Traditional banks credits	-10.728	-34.195	-33.492	-11.274
c.	Traditional and shadow banks brown credits	-10.344	-34.007	-33.269	-10.877
d.	Traditional banks brown credits	-8.608	-32.628	-31.77	-9.077

Traditional banks activity (1)

- Each traditional bank j provides an amount of loans $b^F_{B,t}(j)$ to brown entrepreneurs and $b^F_{G,t}(j)$ to green ones. The traditional bank finances these loans with household deposits $d^F_t(j)$ and its own capital (or bank net worth) $n^F_t(j)$, such that the traditional bank's balance sheet is written as :

$$b^F_{B,t}(j) + b^F_{G,t}(j) = d^F_t(j) + n^F_t(j)$$

- Furthermore, a traditional bank j can exit the market with a probability of $(1 - \chi^F_{t+1})$ and collect funds $n^F_{t+1}(j)$ at the beginning of period $t + 1$. These funds are transferred to households, as they are the bank's stockholders.

Traditional banks activity (2)

- Hence, with a probability χ_t^F, traditional bank j continues its activity, and the value of this bank (written recursively) is given by :

$$V_{j,t}^F\left(n_t^F(j)\right) = \max \mathbb{E}_t\left[(1-\chi_{t+1}^F)\beta\frac{\lambda_{t+1}}{\lambda_t}n_{t+1}^F(j) + \chi_{t+1}^F\beta\frac{\lambda_{t+1}}{\lambda_t}n_{t+1}^F(j)V_{j,t+1}^F\left(n_{t+1}^F(j)\right)\right]$$

Where $\beta\frac{\lambda_{t+1}}{\lambda_t}$ is the stochastic discount factor of households.

- The bankruptcy shock of traditional banks is captured by the stochastic evolution of the probability of exit of banks :

$$\chi_t^F = \chi^F\varepsilon_t^\chi$$

Where χ^F is the long-run value of the probability and ε_t^χ is an exogenous auto-regressive process.

Traditional banks activity (3)

- After collecting deposits and providing loans in period t, traditional bank j is able to divert a fraction θ_t^F of available funds for personal use.
- To prevent traditional banks from "running away", depositors will lend to a traditional bank if the value of the latter is higher than a fraction θ_t^F of RWA :

$$V_{j,t}^F\left(n_t^F(j)\right) \geq \theta_t^F \mathrm{RWA}_t(j)$$

With :

$$\mathrm{RWA}_t(j) = \phi_t^B(j) b_{B,t}^F(j) + \phi_t^G(j) b_{G,t}^F(j)$$

Where ϕ_t^G and ϕ_t^B stand for the risk-weight of green and brown loans, respectively.

Traditional banks activity (4)

- The evolution of θ_t^F is closely linked to the evolution of the CCyB regulation set by the financial regulator.
- Indeed, depositors are aware that an increase in the CCyB (i.e., a tighter macroprudential regulation) implies an economy more exposed to financial systemic risk.
- This additional risk increases the bank's insolvency risk, and depositors require banks to raise their value to cover this risk, which implies an increase in θ_t^F at equilibrium.

- The maximization of the value of traditional banks gives the optimal spread rate between green and brown loans :

$$\mathbb{E}_t \left\{ r^G_{F,t+1} - r^B_{F,t+1} \right\} = \mathbb{E}_t \left\{ \left[\frac{\kappa^{FG}}{l^F_t} \left(\frac{l^F_{G,t}(j)}{l^F_t(j)} - b^*_F \right) + \frac{\theta^F_t}{\beta} \frac{\lambda_t}{\lambda_{t+1}} \frac{\lambda^F_t}{1+\lambda^F_t} \left(\phi^G_t - \phi^B_t \right) \right] \right.$$
$$\left. * \left[\frac{1}{\left[1 - \Phi \left(1 - \eta^{F,E}_{G,t+1} \right) \right]} \right] + r^B_{F,t+1} \left(\frac{\left[1 - \Phi \left(1 - \eta^{F,E}_{B,t+1} \right) \right]}{\left[1 - \Phi \left(1 - \eta^{F,E}_{G,t+1} \right) \right]} - 1 \right) \right\}$$

Shadow banks activity

- Shadow banks exhibit the same behavior as traditional banks, except that they are not subject to capital requirements constraints and, thus, the CCyB regulation.
- Therefore, shadow banks maximize their value function subject to the following financial constraint :

$$V_{j,t}^{S}\left(n_t^S(j)\right) \geq \theta^S b_t^S(j)$$

- First order conditions of this maximization provide the optimal spread rate between green and brown loans for shadow banks :

$$\mathbb{E}_t\left\{r_{S,t+1}^{G} - r_{S,t+1}^{B}\right\} = \mathbb{E}_t\left\{\left[\frac{\kappa^{FG}}{l_t^S}\left(\frac{l_{G,t}^S(j)}{l_t^S(j)} - b_S^*\right)\right]\frac{1}{\left[1-\Phi\left(1-\eta_{G,t+1}^{S,E}\right)\right]} + r_{S,t+1}^{B}\left(\frac{\left[1-\Phi\left(1-\eta_{B,t+1}^{S,E}\right)\right]}{\left[1-\Phi\left(1-\eta_{G,t+1}^{S,E}\right)\right]} - 1\right)\right\}$$

Design of the standard and carbon-intensive CCyB (1)

- It is assumed that the CCyB regulation θ_t^F has a negative relationship with the spread between the level of the financial systemic risk indicator $\mathcal{T}$ and its steady-state value $\overline{\mathcal{T}}$, such that :

$$\frac{\theta_t^F}{\overline{\theta^F}} = \left(\frac{\theta_{t-1}^F}{\overline{\theta^F}}\right)^{\rho_{\theta^F}} \left[\left(\frac{\mathcal{T}_t}{\overline{\mathcal{T}}}\right)^{\phi_{\mathcal{T}}}\right]^{1-\rho_{\theta^F}}$$

Where ρ_{θ^F} is the smoothing parameter of the regulation, and $\phi_{\mathcal{T}}$ is the sensitivity of the regulation with respect to the financial systemic risk indicator. The component $\overline{\theta^F}$ denotes the long-term target of the regulation.

Design of the standard and carbon-intensive CCyB (2)

- Since our model incorporates traditional and shadow bank loans, the design of the standard and carbon-intensive CCyB regulation leads to four possible CCyB settings :
  - ➢ A "prudent" CCyB regulation that considers the total traditional ($b_{F,t}$) and shadow ($b_{S,t}$) bank credit $\rightarrow \mathcal{T}_t = \frac{b_{F,t}+b_{S,t}}{y_t}$
  - ➢ A "moderate" CCyB regulation that considers total traditional bank credit only $\rightarrow \mathcal{T}_t = \frac{b_{F,t}}{y_t}$
  - ➢ A "prudent carbon-intensive" CCyB regulation that considers brown credit of traditional ($b^B_{F,t}$) and shadow ($b^B_{S,t}$) banks $\rightarrow \mathcal{T}_t = \frac{b^B_{F,t}+b^B_{S,t}}{y_t}$
  - ➢ A "moderate carbon-intensive" CCyB regulation that considers brown credits of traditional banks only $\rightarrow \mathcal{T}_t = \frac{b^B_{F,t}}{y_t}$