Monnaie carbone et finance pour le climat

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Context

- Article 2 of the Paris Agreement puts to the forefront the necessary alignment of financial flows with the mitigation and adaptation objectives of the UNFCCC.
- Climate change engages the financial sector through several channels (Carney, 2015) :
  - Risks linked to the repercussions of the physical impact of climate change (*Physical risk*)
    - sur la valorisation des actifs
    - via les assurances
  - Risks linked to societal reaction
    - liability suits (*Legal risk*)
    - transition risk (*Policy risk*)
- A need for integrated climate-economy-financial economy models

Research questions

The questions we seek an answer to are :

1. What are the minimal changes needed to add a representation of the financial sector to an economy-climate model ?
2. Through what channels do the financial sector and the climate-economy part of the model interact ?

We address these questions starting from the most well known economy-climate Integrated Assessment Model (IAM) DICE (Nordhaus 1993, 2016).

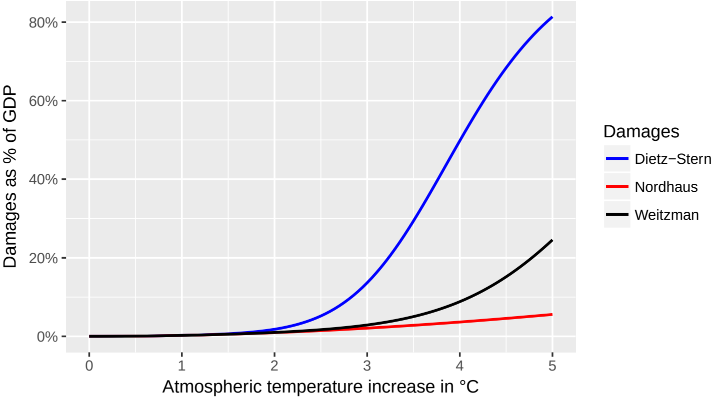
Characteristics of the model (1/2)

The climate-economy integration in the DICE model :

- the economy according to Solow/Ramsey,
- industrial production generates GHG emissions $EMIS_{IN} = \sigma \, \mu \, F(k, LF)$,
- the climate module transforms emissions in an increase of the average global temperature with respect to pre-industrial times T_{AT},
- Climate damages $\Omega(T_{AT})$ increase with this temperature,
- damages are counted as % of GDP,
- abatement efforts reduce emissions by a factor μ, the cost of abatement $\Lambda(\mu)$ is accounted for as lowering value added.

$$c + i = \Omega(T_{AT}) \, \Lambda(\mu) \, F(k, LF)$$

The damage function



Characteristics of the model (2/3)

The economic module of DICE — Solow/Ramsey — is a model of a barter economy.

- The model's agents, firms and households, exchange composite goods and capital and labour services.
  - (Investment is an exchange the firms engages in with itself.)
  - The agents do not exchange forms of payment.
- We build our climate-economy-finance model by representing for each exchange of goods and services the accompanying form of payment.
  - This will necessitate both the introduction of new variables and of a third agent : a bank. The bank writes out loans, receives deposits and sets the interest rate.

Characteristics of the model (3/3)

MDICE is constructed to be an extension of the reference IAM DICE, which is obtained as a limit case.

- DICE's unique firm is disaggregated in a non-financial and a financial corporation. The financial corporation (a bank) :
  - sets the interest rate on loans and deposits,
  - emits credit. There is no credit rationing.
- The non-financial corporation (the firm) finances investment through loans.
- MDICE is demand driven :
  - Fiscal policy can influence short term demand, which in turn influences long term growth through the capital utilization ratio.
- Under limit conditions, it dynamically behaves just like DICE.
- The financial firm does not per se alter the dynamics of the original DICE model.

Introduction of the financial sector (1/3)

Introduction of the form of payment :

- Consumption goods, labour and capital services are paid for in currency : they are immediately useful and deliver value within the accounting period.
- Investment is paid for with a loan : investment delivers value over an extended period. The loan allows for paying as value is delivered over the capital's lifetime.

As result, new variables are created :

- The stock of loans L.
- A non-constant price-level, the price of the composite good p.
  - The firm sets the price of the composite good every period in its decision making on how to pay for its costs. The firm can pay for its costs either by raising its price or by taking out loans.
  - In reaction, wages are renegotiated.
  - The capital stock needs to be re-evaluated : from k to K is a non-trivial process.
- The interest rate on loans int_L and deposits int_D. Let's keep them

Introduction of the financial sector (2/3)

The introduction of new variables creates new dynamics with respect to the original IAM due to the possible difference between the new variables and the sister variables in the "barter"-model :

DICE	MDICE
capital stock k	loans L
marginal productivity of capital mpk	interest rate int

- The leverage ratio $lev = L/K$ measures the difference between the firm's debt, the stock of loans L and the value of its capital stock $K = p\,k$.
- The interest rate int set by the bank is not necessarily the same as the marginal productivity of capital mpk.

Introduction of the financial sector (3/3) — channels

Direct effects of the introduction of the financial sector pass via the investment function. Investment increases with :

- low leverage $lev < 1$
- high productivity of physical capital mpk
- low interest rate int
- the influence of the interest rate on the investment function is designed such that when $mpk = int$, the interest rate has none.

Indirect effects are generated *via* the firm's price-setting :

- When the price-level evolves — for whatever reason —, the re-evaluation of capital at replacement cost $K = p\,k$ will influence the leverage ratio.
- The price level will evolve because of :
  - a carbon tax
  - $int \neq mpk$, the firm will either lower/raise its price or take out loans to cover its costs, which will influence investment.
  - ...

Transaction flow matrix of MDICE

	Households	Firms		Commercial banks		Total
		Current	Capital	Current	Capital	
Consumption	$-C$	$+C$				0
Investment		$+I$	$-I$			0
Replacement capital damages		$+C_{Dam}$	$-C_{Dam}$			0
Wages	$+w\,LF$	$-w\,LF$				0
Interests on deposits	$+int_D\ D(-1)$			$-int_D\ D(-1)$		0
Interests on loans		$-int_L\ L(-1)$		$+int_L\ L(-1)$		0
Repayment of principal		$-rep\,L(-1)$		$+rep\,L(-1)$		0
Repayment of principal				$-rep\,L(-1)$	$+rep\,L(-1)$	0
Firms' profits	$+0$	-0	$+0$			0
Bank's profits	$+0$			-0		0
Bank profit transfer						0
Change in deposits	$-\Delta D$				$+\Delta D$	0
Change in loans			$+\Delta L$		$-\Delta L$	0
Repaid loans			$+rep\,L(-1)$		$-rep\,L(-1)$	0
Write down of loans			$+L^{NP}(-1)$		$-L^{NP}(-1)$	0
Total	0	0		0	0	0

Conditions to find DICE as a limit-case:
$w = \partial_{LF} F$
$int_D = int_L = \Omega_T(T_{AT})\partial_k F - \delta$
$rep = \delta$
With these prices : $K = L = D$

Applications

We briefly discuss two applications :

1. The effect of the financial sector changes with the nature of climate damages (keeping the total cost of damages as a % of output is independent of the nature of damages).
    - Climate damages can take on different natures. We consider output reducing damages and direct damages on capital, caused by extreme weather events attributed to climate change.
        - Opportunity cost : reduced productivity of capital and labour.
        - Replacement cost : we suppose that damaged capital is replaced in the same period.
2. Evaluation of non-conventional climate policies that target the financial sector.
    - lowered interest rate for green investment

Application 1 : Behaviour of the bank

Climate change causes lowered productivity of the factors, and capital damages. The bank can adopt two attitudes in the face of these costs of climate change.

- The bank adapts to climate change :
  - it lowers the interest rate on loans and deposits, following decreased productivity,
  - it writes down non-performing loans.
- The bank does not adapt to climate change :
  - it does not lower the interest rate,
  - it does not write down non-performing loans.

Application 1 : Scenarios

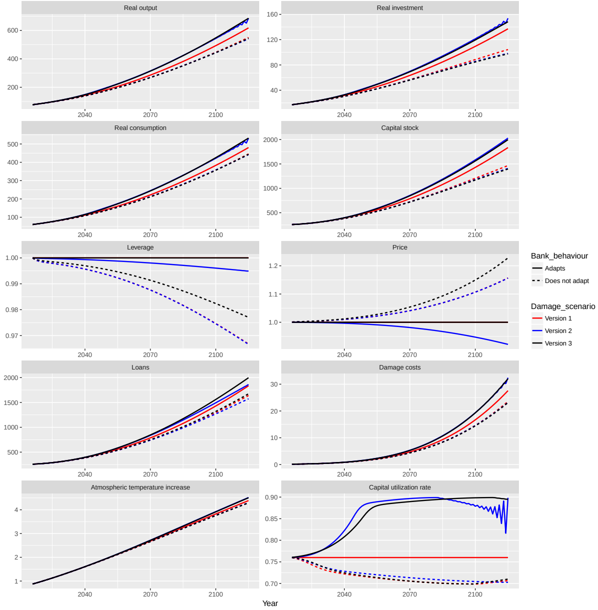
6 scenarios are simulated, made up of :

- three versions of damage specifications,
- 2 versions of bank behaviour.

Nature of damages	Productivity	Productivity & Capital	
Financing of capital replacement		price	credit
Version of damage specification	v1	v2	v3
Bank adapts to climate change	Scenario 1	Scenario 2	Scenario 3
Bank does not adapt to climate change	Scenario 4	Scenario 5	Scenario 6

In all three damage specifications, damages reduce productivity. In v2 and v3, there are also direct capital damages.

Application 1 : Simulation



Application 1 : Results

When the bank does not adapt :

- Positive effect on growth from inflation, via decreasing leverage, from high interest rate and replacement cost of capital (through loans or by direct price increase) ; increases investment.
- Direct negative effect on growth from the ratio marginal productivity / interest rate which dampens investment.

When the bank does adapt :

- The replacement cost of capital damages is largely neutralized by the writing-down of non-performing loans and the economy behaves as a more productive economy.
- v3 : total neutrality of the financial sector because replacement cost financed through loans, lev = 1, p = 1.
- v2 : no exact balancing of replacement cost and written-off loans. Slight deflation. Leverage decreases.

Application 2 : non-conventional climate policies

The presence of the financial sector in MDICE allows for the representation and assessment of non-conventional climate policies that use financial tools.

- Two firms are introduced,
  - a conventional firm that emits GHG during production,
  - a green firm that does not emit GHG,
- to track and evaluate :
  - policies' differential effect on the profitability of the two firms.
  - Incentive power of policies.

Simulations with exogenous demand trajectories

As an intermediary step, the 2-firm model is used with exogenous demand trajectories :

- Output from a 1-firm transition scenario is used as input to the 2-firm model.
  - Linear carbon tax trajectory $p^*_{CO_2}$, starting at $70\$$ in 2015 and increasing yearly with $2\$$ (inspired by the Stern-Stiglitz report).

- Capital stock k and abatement μ trajectories are used to construct exogenous investment demand trajectories for the 2-firm model.

$$k^1(t) = \mu(t)\, k(t)$$
$$k^2(t) = (1 - \mu(t))\, k(t)$$

Application 2 : policy scenarios

Three policy scenarios are simulated :

1. Carbon tax

$$p^*_{CO_2}$$

2. Carbon tax + investment subsidy

$$p_{CO_2} = \frac{3}{4} p^*_{CO_2}$$
$$sub_{CO_2} = p^*_{CO_2} - p_{CO_2}$$

3. Carbon tax + green interest rate

$$int_{L2} = 90\% \, (mpk - \delta)$$

The interest rate for the non-emitting firm is 10% lower than what would be set by marginal product of capital.

The level of the green rate is chosen such that the cost of the green firm is lowered to a similar extent as by policy scenario 2 tax + subsidy.

Application 2 : behavioural scenarios

Each of the three policy scenarios are simulated for two behavioural assumptions on the price set by each of the firms, and the resulting market price :

- the green firm reacts to lowered costs, subsidies and the green interest rate.

Application 2 : Policy-mix comparison, behavioral scenario 1

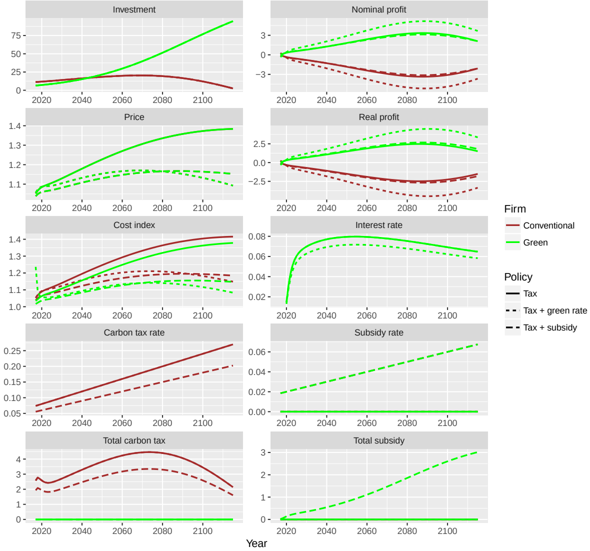


Figure: Profits and deficits are passed on to households. Market price reacts fully to costs.

Application 2 : behavioural scenario 1

As can be seen from the profit trajectories, the green firm makes a differential rent : it's profits are positive and the conventional firm functions at a deficit.

- (The sum of their profits $= 0$ because the market price is by hypothesis equal to the average of the prices set by the two firms, weighted by their market share.)
- The conventional firm raises its price to finance the carbon tax. This raises the market price.
- The households demand increasing wages to retain their purchasing power which also increases the costs for the green firm.
- The conventional firm's costs remain higher because of the tax.

The negative profit can be interpreted as the transition risk. Policy mix 3 increases profit for the green firm with respect to policy mix 2.

Application 2 : Policy-mix comparison, behavioral scenario 2

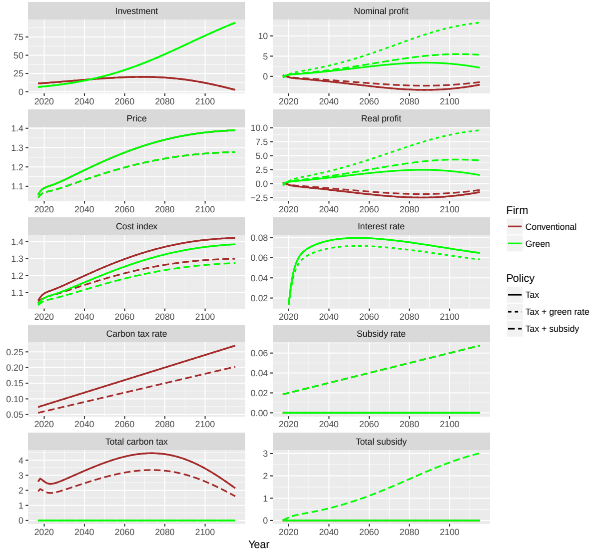


Figure: Profits and deficits are passed on to households. The green firm does not reduce its price in reaction to lowered costs, subsidy and green interest rate.

Application 2 : behavioural scenario 2

In this scenario, the overall profitability of industry is higher : the green firm does not exert pressure onto the brown firm by keeping its price low.

- (The sum of their profits $= 0$ because the market price is by hypothesis equal to the average of the prices set by the two firms, weighted by their market share.)
- The conventional firm raises its price to finance the carbon tax. This raises the market price.
- The households demand increasing wages to retain their purchasing power which also increases the costs for the green firm.
- The conventional firm's costs remain higher because of the tax.

The negative profit can be interpreted as the transition risk. Policy mix 3 increases profit for the green firm with respect to policy mix 2.

Thank you for your attention !