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How to use SVMAs to reduce the Carbon Pricing and Climate Finance Gap: numerical illustrations

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The spectrum of options available to handle the gap between the Social Value of Mitigation Activities (SVMA) and implementable carbon prices encompasses devices that give different weights to 'command and control' measures and to economic incentives. This paper analyzes how to send a signal about this the SVMA by ***combining an explicit carbon price*** that rewards mitigation activities every year and ***a notional price*** embedded in devices that reward low carbon investment beforehand through lowering their risk-weighted capital costs.

The latter option offers the advantage of hedging against two uncertainties that adversely affect technologies having high capital costs[1]. The *first* relates to technologies which are at the beginning or mid-way of their experience curve. The second relates to the net signal launched by explicit carbon prices given the presence of noises that swamp it.

We first demonstrate, based on 5 case studies, the equivalence curves between carbon prices and percentages of reduction of capital costs. We argue that a notional price equated to the SVMA can maximize the economic efficiency of financial devices that reduce the capital costs of a low carbon project and we discuss the necessity of a world SVMA and of national SVMAs.

We then introduce uncertainty in the analysis and show that carbon prices needed to overcome the barrier it constitutes can grow exponentially, together with their political unacceptability. We then show that cutting down the risk-weighted capital costs and rewarding upfront low-carbon investments the present value of the SVMA is an efficient way of overcoming this difficulty.

Finally, we show, in the Indian case, how to assess a national SVMA that includes the climate benefits and the development co-benefits of mitigation activities. We then discuss how to articulate a World SVMA, national SVMAs and explicit carbon prices to bridge the funding gap and tackle the *'100G$ and +'* issue and maximize the gains of cooperation around climate policies.

1. Capital costs and switching carbon prices

Hirth and Steckel (2017) establish clearly how lowering the capital costs of low-carbon technologies allows for triggering their adoption with lower switching prices. This can be done through various financial devices (subsidies, public guarantees). One problem is to secure their overall efficiency and hedge against their potential arbitrariness. Let us examine how a notional price based of an SVMA is to overcome it.

For simplicity sake the numerical exercises below will be based on a ***World SVMA*** which, as defined in WP CIRED n° 59, translates the willingness of the international community to pay for a given climate target. We calculate corridors of this world SVMA from the 900 trajectories of the shadow costs of staying below the 2°C target. Retaining the maximum likelihood space of these results gives the following ranges: [35$/t -60$/t] in 2015, [62$/t – 140 $/t] in 2030, [140$/t – 260

[1] La Rovere, E., Hourcade J.C., Priyadarshi S., Espagne E., Perrissin-Fabert B., Social Value of Mitigation Activities and forms of Carbon Pricing, Working Paper CIRED n°2017-60 Paris, March 2017

$/t] in 2050 and [980$/t – 2030 $/t] in 2100. These ranges correspond to optimistic and pessimistic visions of carbon saving technical change.

Let us now assess the present value of these trajectories of SVMA per avoided ton of emission. This is the amount of money that should be given upfront to a project in the absence of explicit carbon prices to trigger the same choice. With $SVAT$ denoting this present value and *r* the discount rate this value is[2]: $SVAT = \left[\sum_{i=0}^{T-1} \frac{SVMA_{t+i}}{(1+r)^i}\right]/T$. Table 1 gives its possible values for four lifetimes of the built equipment. of costs of climate policies and two discount rates, 5% and 2%.

This table confirms that the choice of discount rate is important: the $SVAT$ with a 2% discount rate leads to a 1,60 higher upfront support to 30 years projects, 1,86 for 40 years projects against only 1,18% higher for 10 years projects. Starting from a given carbon value at t_0, the present value of SVMAs increases when the discount rate is lower than the rate of growth of their nominal value, and decreases when it is higher.

The left panel of graphs 3 give, for n pairs of techniques in different contexts, the switching explicit prices in favor of the low-carbon techniques in function of the level of decrease of their capital costs through devices that incorporate the SVATs attached to each project in function of the lifetime of the equipment. This actually correspond to giving upfront a percentage of the present value of Global SVMA to the project: 64$ and 127$ per ton for coal+ccs projects in France, 56$ to 115$ per ton and 36$ to 74$ per ton for Hydro projects and firewood projects respectively in Brazil and from 36$ to 74$ for solar PV in India.

If there is an upper bound to the explicit price that can be implemented, this would be an efficient way of bridging the carbon price gap. In the 'French case' (coal to CCS) a 50$ upper bound would be a high enough explicit price with a 8% to 17% guarantee. If we retain a 20$ upper limit for Brazil a 10% to 20% guarantee would suffice for firewood projects and a 5% to 10% for hydro projects. This guarantee should be between 15% to 30% for the solar PV in India with a 5$ upper limit (note that the marginal value of income is 20 times higher in India than in France).

These graphs show the risks of 'overprotection' since carbon prices are negative beyond a certain share of cut in capital costs. This is a strong argument for public guarantee against other forms of subsidy. The guarantee is indeed exerted only in case of failure, and will entail no cost for public budgets if it concerns all the low-carbon investments.

2. Introducing risks in the analysis

Let us now introduce uncertainty in the analysis, starting with a simple two-period analysis in which an investor considers at the first period the investment costs '*c*' of a project and, at the second period, its commercial benefit '*b'* plus a reward '*p'* for the avoidance of one ton of carbon emission. Let us now consider risks that investment costs will be higher than expected and that ***risk-weighted cost*** becomes *c*+ε, where 'ε' follows a probability law of mean 0 (things can go

[2] Assuming that the avoided emissions are evenly distributed over the lifetime of the project

equally better or worse than expected). In this case, the Net Expected Values (NPV) of the project with and without uncertainty are identical of the decision-maker is risk neutral:

$$\boldsymbol{NPV} = \in \left[-\boldsymbol{c} - \boldsymbol{\varepsilon} + \frac{\boldsymbol{b}+\boldsymbol{p}}{\boldsymbol{1}+\boldsymbol{r}}\right] = -\boldsymbol{c} + \frac{\boldsymbol{b}+\boldsymbol{p}}{\boldsymbol{1}+\boldsymbol{r}}$$

The equivalence between NPVs with and without uncertainty no longer holds, if, when additional expenditures are needed to complete the project, its level of deficit of operating accounts leads close to a "danger line" that the investor does not want to cross. This is due to the asymmetry between a 'bad surprise' on future revenues that only makes investment less profitable, and a 'bad surprise on technical costs'. The latter puts indeed the investor at risk of losing its cash advance and of seeing its assets recuperated by a bank or another investor.
Let us denote '$\hat{c}$' the maximum investment expenditures beyond which the investor loses his cash advance. Conditional upon ε, the NPV of the project becomes:

$$\boldsymbol{NPV}(\boldsymbol{\varepsilon}) = \begin{cases} -c + \varepsilon + \frac{\boldsymbol{b}}{\boldsymbol{1+r}} & when\ \ c + \varepsilon \leq \hat{c} \\ -\hat{\boldsymbol{c}} & when\ c + \varepsilon > \hat{c} \end{cases}$$

Its expected NPV is then

$$ENPV = \mathrm{E}\left[-c - \varepsilon + \frac{b}{1+r} \mid \varepsilon \ < \ \hat{c} - c\right].\mathrm{P}\left[\varepsilon \ < \ \hat{c} - c\right] - \hat{c}.\mathrm{P}[\ \varepsilon \geq \ \hat{c} - c]$$

Let us assume ε uniformly distributed between $-e$ and e for whatever value of c. The decision is simple for low capital cost projects ($c \leq \ \ \hat{c} - \ \varepsilon$) because it is impossible that the costs rise to the limit $\hat{c}$, and for high capital cost projects ($c > \ \ \hat{c} + \ \varepsilon$) because they cannot be below this limit even in case of good surprise. In the intermediary case ($c - e \ \leq c < \hat{c} + \ \varepsilon$) the ENPV writes:

$$ENPV = \left(-c - \frac{\hat{c} - e - c}{2} + \frac{b}{1+r}\right).\ \frac{\hat{c} - e - c}{2e} - \ \hat{c}.\frac{c - \hat{c} + e}{2e}$$

With the simple probability law selected here, the probability of staying below the danger line and of reaping the benefits of the project is $\frac{\hat{c}-e-c}{2e}$ whereas the probability of overshooting it is $\frac{c-\hat{c}+e}{2e}$. The closer to $\hat{c}$ is $c + e$ the lower is the probability of getting a positive revenue and the higher is the probability of losing $\hat{c}$. Higher revenues are then needed to keep a positive ENPV and a higher carbon price. This is pictured in graph 2: the needed carbon price is higher than in the certainty case (blue line in the right panel to be compared with the red line in the left panel). If instead the SVAT is given *ex ante* (this is the value *s*=*p*/(1+*r*)) it is the discounted value of the red trajectory of carbon prices in the right panel which is below the blue one.

Let us now check the orders of magnitude of this very simple mechanisms by introducing uncertainty if the above case studies We did so with a 'weak form' of treatment of uncertainty without an explicit 'danger line' and only with the discount rates commonly used in the three countries (France, Brazil, India) for long-lived projects perceived as technologically more 'risky'.

In the right panels of graph 3 we can first observe that the switching carbon prices increase very much by comparison with the analysis without uncertainty: they move from about 87$ to 150$ for the coal with CCS in France, 121$ to 144$ for firewood in Brazil, 27$ to 85$ for hydro in Brazil and

10$ to 40$ for the best located sites for PV in India. The difference is far higher for the hydro case compared with firewood because it is a more long-lived project. This helps appreciating one major source of the ‘funding gap’.

The benefit of using a SVMA to calibrate public guarantees and cut the risk-weighted capital costs appears immediately: depending whether we assume a high or low SVAT, a 15% to 25% guarantee suffices in France in case of a 50$/t limit on carbon prices, a 10% to 20% guarantee in India in case of a 5$ explicit price. The two Brazilian cases are interesting because, while a 10% to 23% guarantee suffices for the hydro with a 20$ limit on explicit carbon prices, a 40% to 80% guarantee is necessary for firewood which confirms the interest of selecting high SVMA to promote mitigation action.

3. World SVMAs, national SVMAs and explicit carbon prices: reaping the benefits of financial cooperation

The World SVMA used for convenience in the above simulations is climate centric and does not incorporate the development co-benefits of mitigation actions that are country-specific in nature. As developed in the companion WP CIRED No 2017-60 this world SVMA is necessary to create mechanisms apt to deliver tangible ***gains of international financial cooperation around climate policies.*** But this support is necessarily supplemental to each country’s policies and governments should use a ***national SVMA*** to secure the alignment between climate policies and development objectives and support projects with poor access to international fund and to maximize the leverage effect of international transfers.

These national SVMAs encompass the climate and development benefits of mitigation activities for a country and, to make clear the difference between the World SVMA and the national SVMAs, let us use the the results of the Indian case study in the DDPP project. In a first scenario this study considers policies based on a carbon price that starts from 40$ in 2020 to reach 130$ in 2050. In a second scenario, India achieves the same level of emissions reduction by embedding its climate policy in its development policy (reduction of air pollution, energy security, better urban transport). In this scenario, the needed carbon price is 5$ only in 2020 and 105$ in 2050. The difference between the prices in the two scenarios can be interpreted as a measure of the minimum co-benefits of avoiding one ton of emissions in a $/t metric. Indeed the second scenario is judged politically acceptable whereas the first is not. One can then interpret the carbon price trajectory of the first scenario as the SVMAs of India and derive both the SVAT to be used in national financial devices to lower the capital costs of mitigation activities.

Table 2 gives the SVMA for India and the SVATs, the present social value of avoided emissions for 10 and 40 years lifetime projects that could be used as to calibrate for example public guarantees by the Indian government. Interestingly, these SVATs are lower than the World SVATs in table 1 and decrease more sharply with the lifetime of the projects. This reflects the fact that, even with the inclusion of their co-benefits, mitigation actions do not generate co-benefits for a large range of development priorities in India and that a country prioritizing the reduction of poverty necessarily adopts high discount rates. This is why an articulation between the World SVMA and national SVMAs is needed. They can anchor financial devices triggering international financial transfers which cannot be reached by other means and that will exert a leverage effect of countries public policies.

This will help countries to reinforce their NDCs and create the enabling conditions for higher explicit carbon prices. Interestingly, the Indian case shows how between the SVMA and the explicit carbon price will be progressively bridged (from one to seven in 2020 to one to three in 2050 in the Indian case).

Overall Conclusions

Pricing the full Social Value of Mitigation Actions can be made through explicit carbon prices or by notional prices incorporated in devices cutting down the capital costs of low-carbon investments. These notional prices can support strong immediate action even in the presence of low corridors of prices.

Two levels of SVMA are to be considered: country-specific SVMAs which translate the assessment by each country of the development co-benefits of mitigation activities and a world SVMA which translates the willingness of the world community reach the 2°C target. Their articulation is needed to foster financial cooperation and accelerate the adoption of low carbon projects by lowering their risk-weighted capital costs.

Because climate policies evolve through a sequential process, we do not need to adopt corridors of SVMAs and prices up to the end of the century. SVMAs can be updated periodically based on the evidence of the effectiveness of climate policies in accelerating technical progress of low-carbon techniques.

One overarching conclusion is that the switching price of carbon is a necessary but not sufficient condition to set the explicit price of carbon in a country since it can be null with a sufficient level of public guarantee. Actually, explicit carbon pricing is necessary to a) raise revenues to mitigate the adverse impacts of higher energy costs; b) control of the rebound effects of demand after gains in energy efficiency; and c) send an all pervading signal for the myriad of decision-makers which escape rule-based policies and cannot be covered by specific financial devices.

TABLE 1 $\overline{SVAT}$ ($/t) for projects of different duration

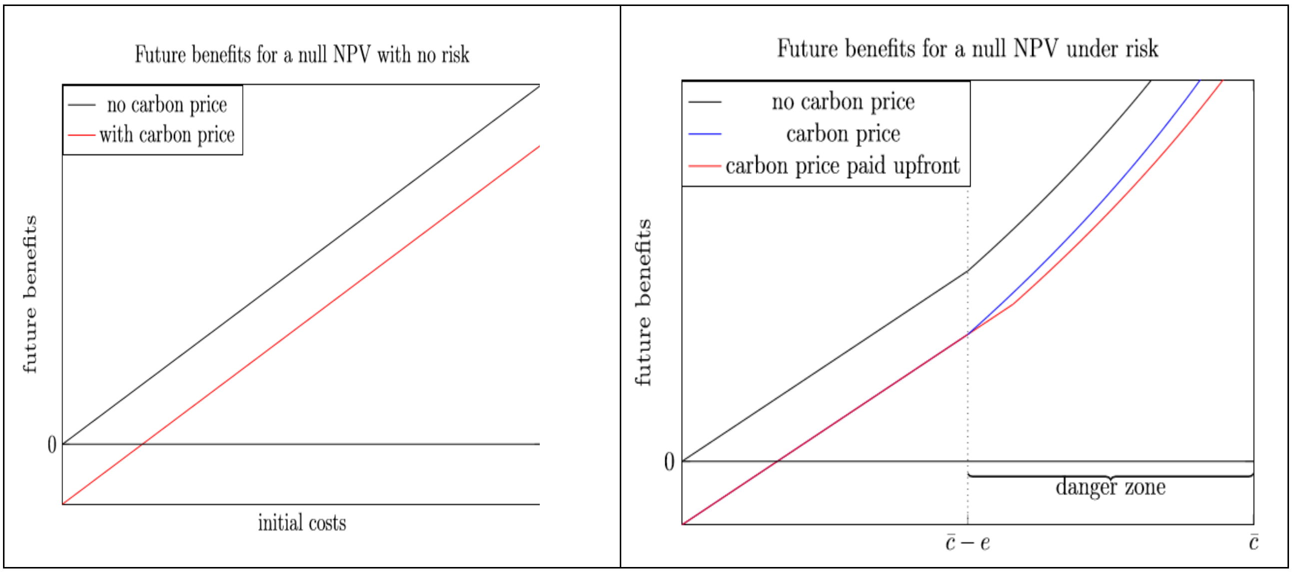
	Technological optimism path		Technological pessimism path	
Discount rate	5%	2%	5%	2%
T=10	73,50	87,25	36,66	43,24
T=20	75,76	104,71	36,54	50,20
T=30	72,26	115,34	35,56	56,96
T=40	68,82	127,50	34,34	64,22

TABLE 2: notional SVATs ($/t at 2% discount rate), their present value and carbon prices in India

	2020	2030	2040	2050
Indian SVMA	20	50	70	105
Explicit carbon prices	3	10	18	30
$\widehat{SVAT}_{10}$	25,51	*46,76*	*67,98*	*81,08*
$\widehat{SVAT}_{40}$	19,96	*29,76*	*37,08*	*40,35*

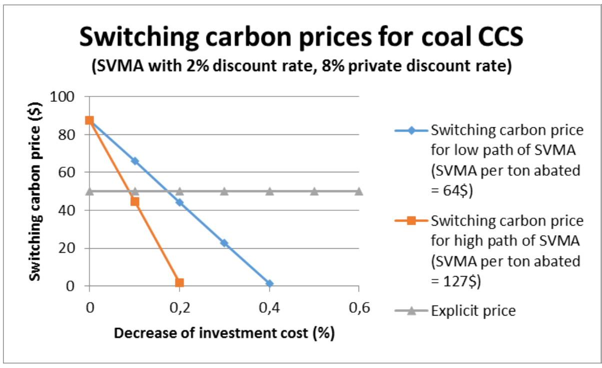
Note: figures in italics show how the present value of SVMA evolves for projects starting at various points in time (only for informative purposes)

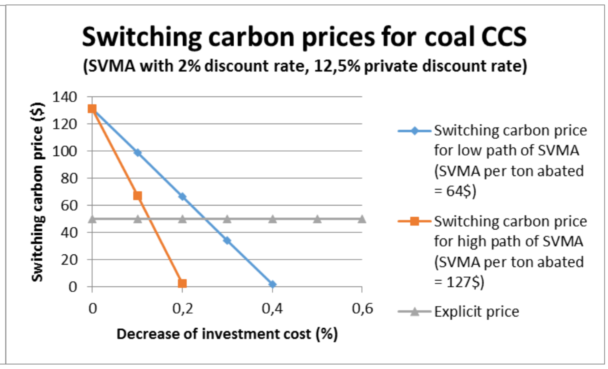
GRAPHE 2 Carbon price paid upfront vs along the project life time



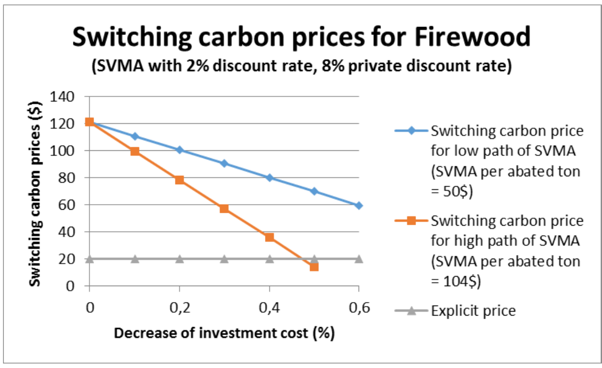
GRAPHE 3 Switching carbon prices and lowering capital costs using a SVMA

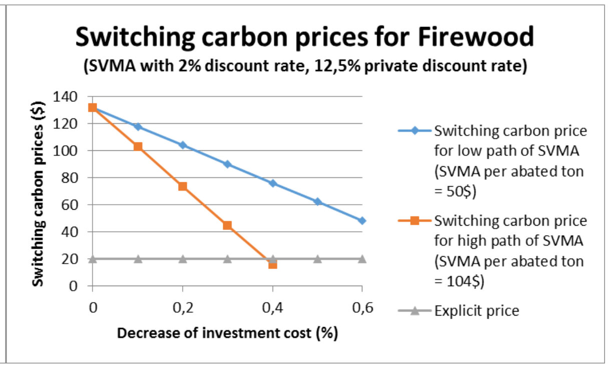
Coal – CCS (France)



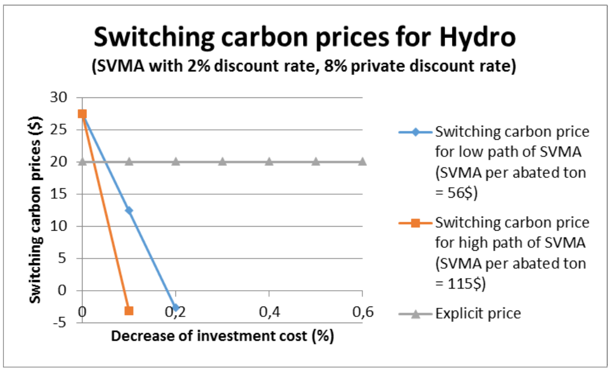


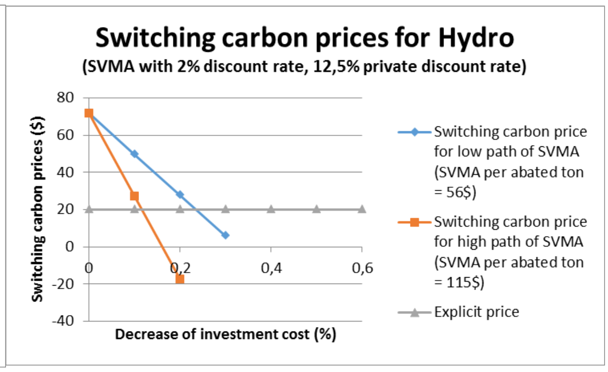
Firewood (Brazil)



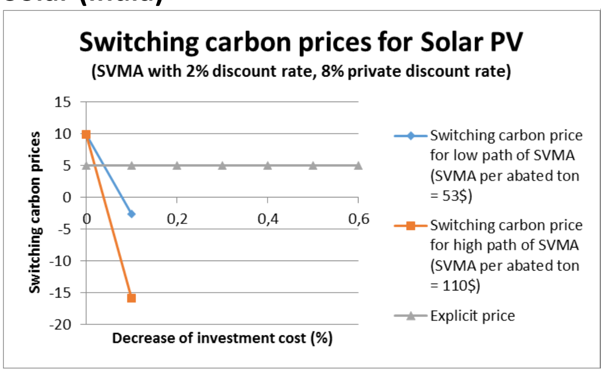


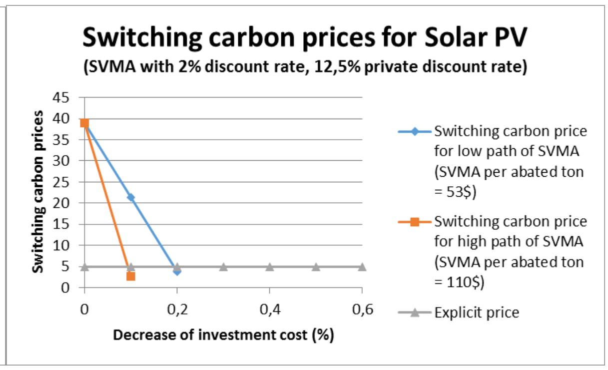
Hydro (Brazil)





Solar (India)





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