Economising on seasonal storage...
to ensure security of supply
A model on precautionary gas reserve

A. Cretì
Université Paris Ouest la Défense and Ecole Polytechnique

Outline

- Brief literature review
- A model of strategic storage (Chaton-Creti-Villeneuve, REE, 2009)
- Rules to manage gas crisis and antispeculative policy (Creti-Villeneuve, Chapter 5 in «The Economics of natural Gas Storage » 2009)
- The UK case: the « crisis » in 2005-2006

Literature

- Theory of production with storage

Newbery and Stiglitz (1981,1982); Williams and Wright (1991);Sheinkman and Schechtman (1983), Deaton and Laroque (1992,1996);Routledge, Seppi and Spatt (2000)

dynamic programming models: harvests are i.i.d; arbitrage equations; existence of a stationary rational expectation equilibrium

- Natural resources theory: strategic fuel reserve

Teisberg, 1981, Hillman and Van Long, 1983, Lindsey, 1989; Nichols and Zeckhauser, 1977; Devarajan and Weiner, 1987

Trade-off between current and future security of supply; extraction rates

- Price stabilization and buffer stocks

Waugh (1944), Oi (1961) and Massel (1969)

static models; stochastic shifts in linear demand and supply; no private storage

The medium-short term dimension

- So far, the economic literature has not addressed the medium – term security of supply problems

- Either the existing models ignore the existence of long term contracts, therefore focusing on extraction rate of producer countries when there is a trade-off between present and future security, or they look at cartelized supply, or they consider public storage.

- Those are not the primary issues in managing secure gas services to Europe.

- Our model fills this gap by explicitly addressing the incentive to store by a private sector which considers the probability of a supply disruption.
- Private stockholding decisions balance the valorization of gas in the event of a crisis with its carrying costs (capital immobilization and technical costs).
- Our key ingredient is that price trajectories, accumulation and drainage behavior are interdependent in equilibrium.
  - This differentiates the approach from inventory management models in which prices are given,or precautionary reserve studies in which the welfare costs of building the stocks are ignored.

Our approach

- Dynamic model under perfect competition
  - Stock: state variable
  - Probability of supply disruption: Bernoulli law
  - Equilibrium = Optimum
  - Notion of target stock
  - Optimal stockpiling and drainage rules
  - Long-run distributions
  - Evaluation of “simple” suboptimal policies

Model

- Continuous time

- Exogenous random discrete state variable
  - From Abundance A
  - …to Crisis C

The probability that the economy switches from A to C in a time interval dt is λdt, where λ is the publicly known parameter of this survival process.

- Endogenous continuous state variable

S = Stocks

which depends on behaviours and history

Short term Supply = Demand
meaning

Demand =

Final consumption + Commodities put in stock

Supply =

Production + Released commodities

Can be summarized with excess supply functions

- $\Delta_C[p]$ **= Stock variation if C and price *p***
- $\Delta_A[p]$ **= Stock variation if A and price *p***

- Excess supply function Δ_σ is increasing and has a unique finite positive zero in R+ denoted by p_σ^*

- If we denote the total inventories in the economy by $S \geq 0$, conservation of matter imposes

$$\begin{cases} \frac{dS}{dt} = \Delta_\sigma[p] & \text{if } S > 0 \text{ or } \Delta_\sigma[p] > 0, \\ \frac{dS}{dt} = 0 & \text{if } S = 0 \text{ and } \Delta_\sigma[p] \leq 0. \end{cases}$$

Equilibrium

Definition 1. A competitive equilibrium starts at date 0, in state A, with some initial stocks S_0; it consists of contingent prices and stocks trajectories

$$\{p_A[t], p_C[t,\tau]\}_{t\geq 0, \tau\geq 0} \text{ and } \{S_A[t], S_C[t,\tau]\}_{t\geq 0, \tau\geq 0}$$

where t is the current date and τ the (random) date at which the crisis breaks out.

Three conditions must hold: (1) price-taking behavior by all agents (consumers, producers, storers); (2) rational expectations; (3) conservation of matter.

- Storers keep a stock of gas if expected price gains balance storage and interest cost. Whenever storages are non-empty, for a time increment dt, the no-arbitrage equations read

$$p_C[t,\tau] + cdt = (1-rdt)p_C[t+dt,\tau], \qquad t \geq \tau,$$
$$p_A[t] + cdt = (1-rdt)((1-\lambda dt)p_A[t+dt] + (\lambda dt)p_C[t+dt,t]).$$

  - the LHS is the unit price plus stockholding cost in states of crisis C and abundance A respectively. The RHS is the expected present unit value of the stocks after dt has elapsed

We solve the model backwards. Once the crisis has broken out, the economy follows the Hotelling (competitive) dynamics; the gas price increases and the stocks shrink.

Proposition 6. *The equilibrium prices are only functions of current stocks. Functions $p_A[S]$ and $p_C[S]$ are continuous and decreasing for all $S \geq 0$; $p_C[S]$ has a simple implicit expression*

$$S = -\int_{p_C[S]}^{p_C^*} \frac{\Delta_C[p]}{rp+c} dp$$

The economy drains the stocks that were in place at date τ

Drainage time can be explicitly calculated

■ Main results

1. *The maximum inventories during abundance S^* is*

$$S^* = -\int_{\overline{p}_C}^{p_C^*} \frac{\Delta_C[p]}{rp+c}\,dp,$$

where

$$\overline{p}_C \equiv \left(\frac{r+\lambda}{\lambda}\right) p_A^* + \frac{c}{\lambda}.$$

2. *The protection offered to the economy by the stocks has a maximum duration*

$$D^* = D[S^*] = \frac{1}{r}\ln\left[\frac{\lambda}{r+\lambda}\frac{rp_C^*+c}{rp_A^*+c}\right].$$

3. *When $S^* > 0$, the economy approaches S^* without reaching it.*

- Simple rule of thumb to have the interest of building strategic storage (taking c negligible with respect to the opportunity cost of the stock)

$$\frac{p_C^*}{p_A^*} > \frac{r+\lambda}{\lambda}.$$

For instance, with an interest rate of 5% and a “one-in-twenty-years” crisis (λ = 5% approximately), this condition implies that some precautionary storage takes place if the

ratio of prices is larger than 2.

Policy

- Expropriation risk may discourage speculative storage
  - Subsidizing precautionary gas storage may help
    - cost recovery *and* risk exposure compensation
    - target stock *and* the optimal stockpiling and depletion time computation
  - Price stabilization
  - Stock management
    - Constrained rules

- The policy consists of an "antispeculative" gas reserve price $\mathbf{p_c^R}$ which is independent of S for clarity.
  - It is the price at which gas is sold and purchased as long as there are stocks to be drained.

- Since storing during crisis yields negative returns (the price cap prevents capital gains), storers sell all they have as soon as the crisis starts.

- To accommodate this, the Government can establish a public stabilization fund or remunerate owners of storage facilities for their services, or pay stockholders their opportunity cost.

- To evaluate the antispeculative policy, we calculate the expected present surplus based on generated price and stocks trajectories.

  - This yields a function of S, the stocks at the date the value is computed.
  - We normalize our comparisons by setting at zero the value of the counterfactual no-storage policy (as if storage were impossible or too costly).

- The value of the optimal policy with respect to the antispeculative policy is measured by the following indicator:

$$\nu = \frac{V_A^R[S]}{V_A^*[S]}.$$

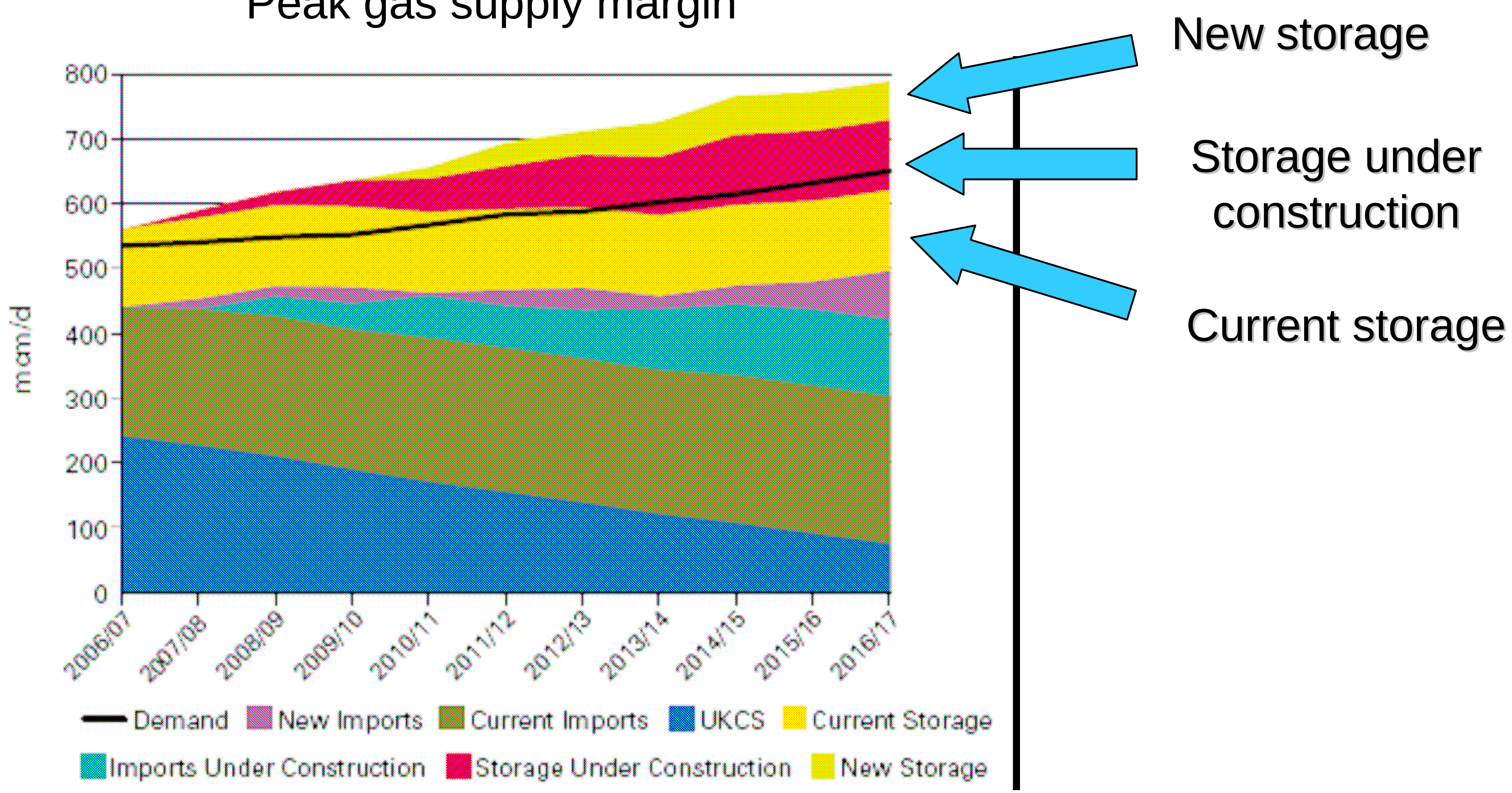
- The maximum possible index is 1.
  - A negative ν would indicate a clear failure as the evaluated policy would do worse that no storage at all: the policy spoils resources by, e.g., building exaggerated stocks too fast and by using them too timidly.

UK: country overview

- With declining North Sea gas production, the UK is now becoming a net importer of gas (winter).
- It receives supplies from an increasingly diverse set of countries.
- 80% of the gas consumed in the UK will be imported by 2016.
- Balance has been traditionally achieved thanks to flexible offshore supplies and gas storage (i.e. peak shaving LNG terminals and/or salt cavity storage).
- Demand for flexibility has had a major role in balancing the Gas Market in winter 2006/2005. The supply-side of the market has poorly reacted

- Activity in the gas storage industry has increased in the past few years as security of supply issues have been emphasized.

Peak gas supply margin



Source: National Grid

To build or not to build strategic stocks in the UK?

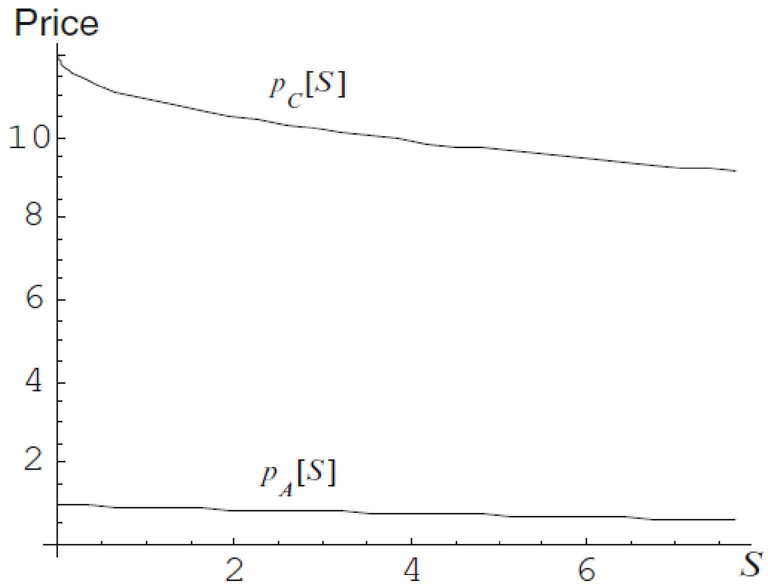
$$\Delta_C[p_C] = bp_C - a; \quad \Delta_A[p_A] = \beta p_A - \alpha.$$

Parameters

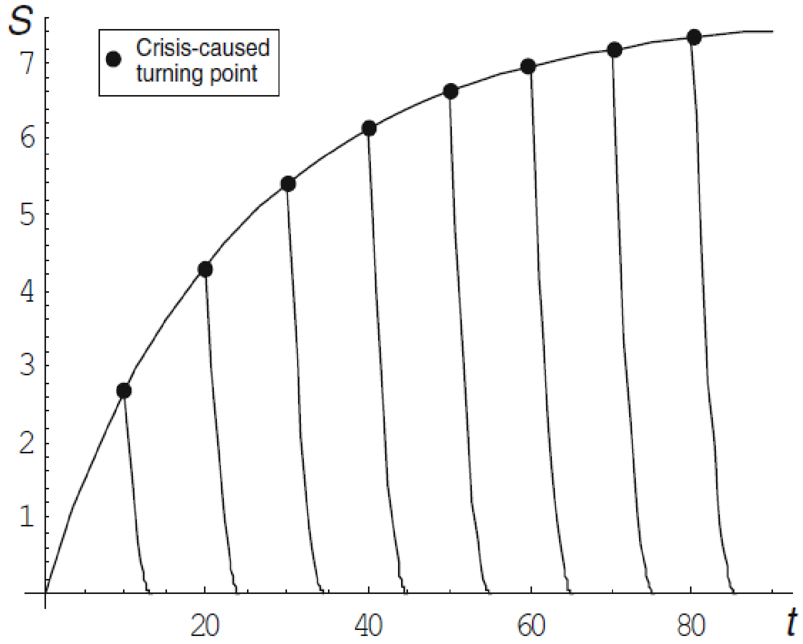
Excess supply in C	$b = 0.95$	$a = 11.48$	$p_C^* = 12$
Excess supply in A	$\beta = 0.95$	$\alpha = 0.57$	$p_A^* = 0.6$
Costs	$r = 0.035$	$c = 0.15$	
Crisis arrival	$\lambda = 0.02$		

Scenario 1:

Competitive model

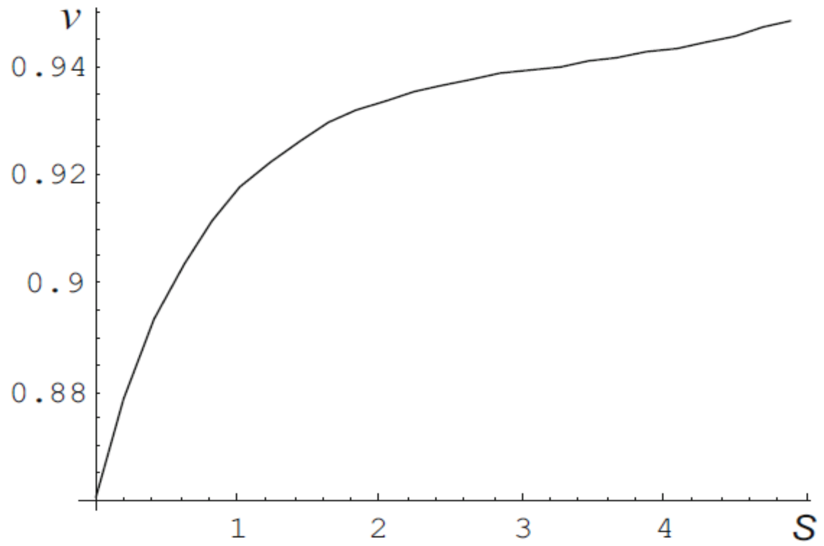


Prices, stocks and drainage time



- Accumulation starts at date $t=0$ with $S=0$ and the shock occurs at dates $t=10,20,\cdots,80$.
- During the abundance phase, stocks are gradually piled up to approach $\mathbf{S^*=7.7}$ and the price decreases toward $\mathbf{p_A^*=0.6}$.
- When the crisis hits the economy, the price jumps to $\mathbf{p_C[S]}$ and increases toward $\mathbf{p_C^*=12}$.
- Though it can take as long as $\mathbf{D^*=5.4}$ years, drainage appears to be much faster than accumulation.

Scenario 2: Optimal antispeculative policy



Relative value of the policy (rule 2)

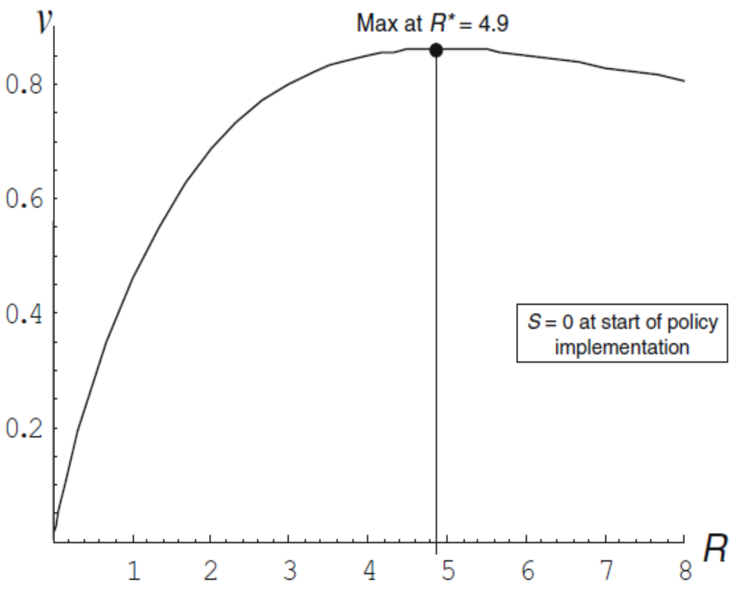
- **R*=4.9**, $\mathbf{p_A}^R$=0.84 and $\mathbf{p_C}^R$=10.5.
- Accumulation takes 21.4 years, if no crisis breaks out before; drainage itself takes a maximum of 3.4 years.

•At S = 0, the suboptimal policy achieves 86% of the potential surplus;

• Gains increase very fast at the beginning of accumulation: at S = 1 (almost 20% of R*), 64% of the initial efficiency loss are recouped;

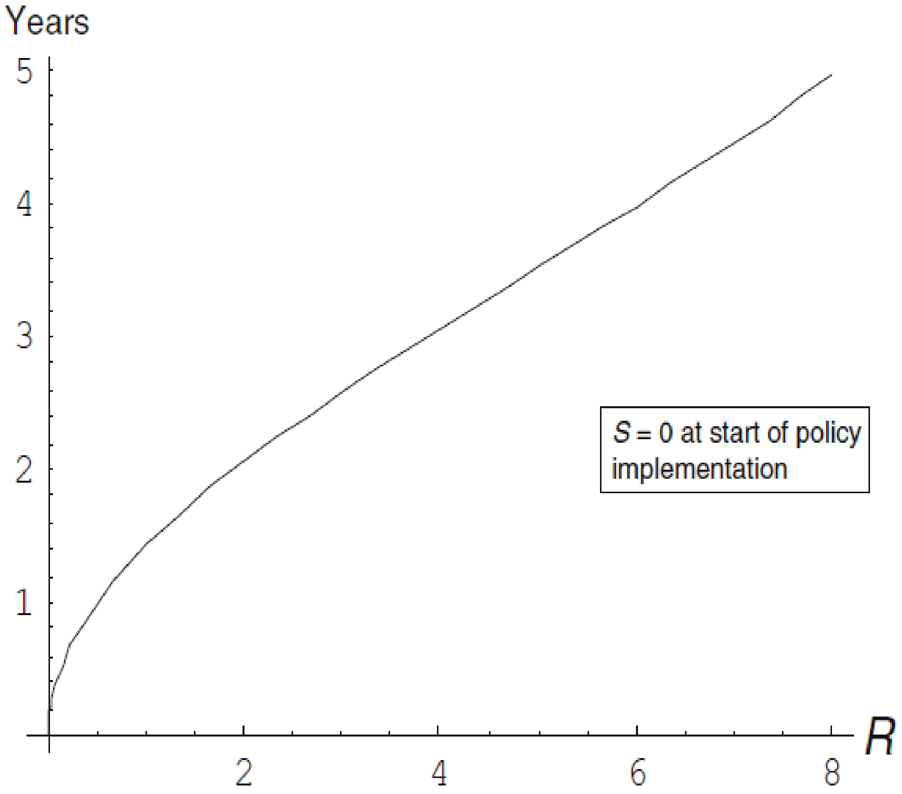
• At R*, 95%of the maximum surplus are captured by the suboptimal policy.

Scenario 3: Exogenous values of R



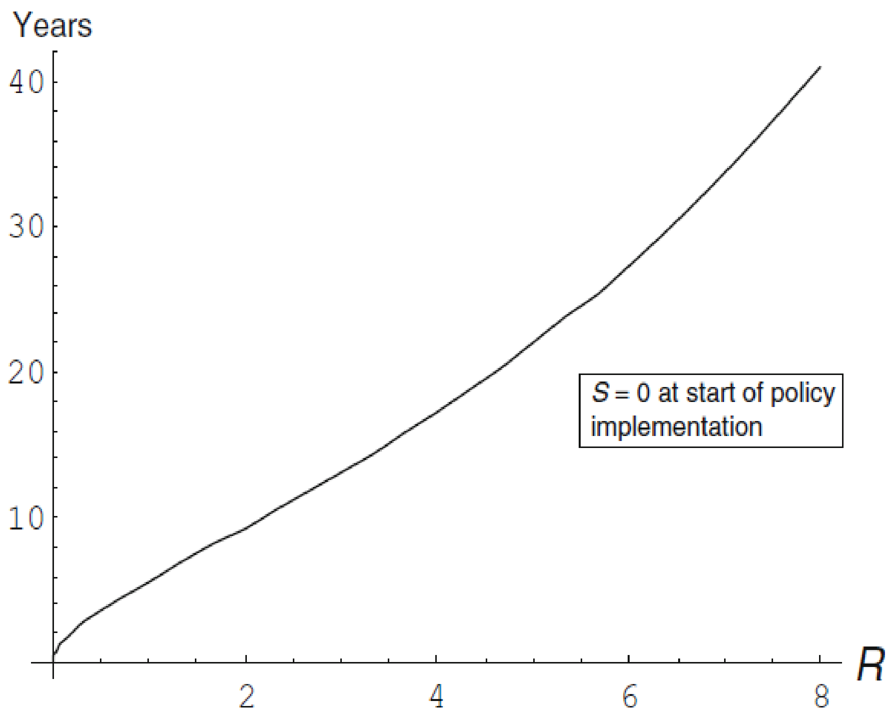
Efficiency of second best policies

- R being only a target, values are given at S=0, namely, when the reserves program is initiated starting from scratch.
- We retrieve maximum efficiency attainable through such second-best policies for R*=4.9
- Small deviations from this optimum have of course second-order effects on efficiency. Dedicated reserves of the order of 2 Bscm would provide substantial benefits.



Maximum duration of protection

- The maximum duration of the protection is calculated by dividing R by the optimal (constant) withdrawal rate.
- Protection of the order of 9 months--1 year does not seem out of reach, as it suffices to set R at only 0.5 Bscm.
- The price smoothing effect would be moderate however, calling for more comfortable buffer stocks.

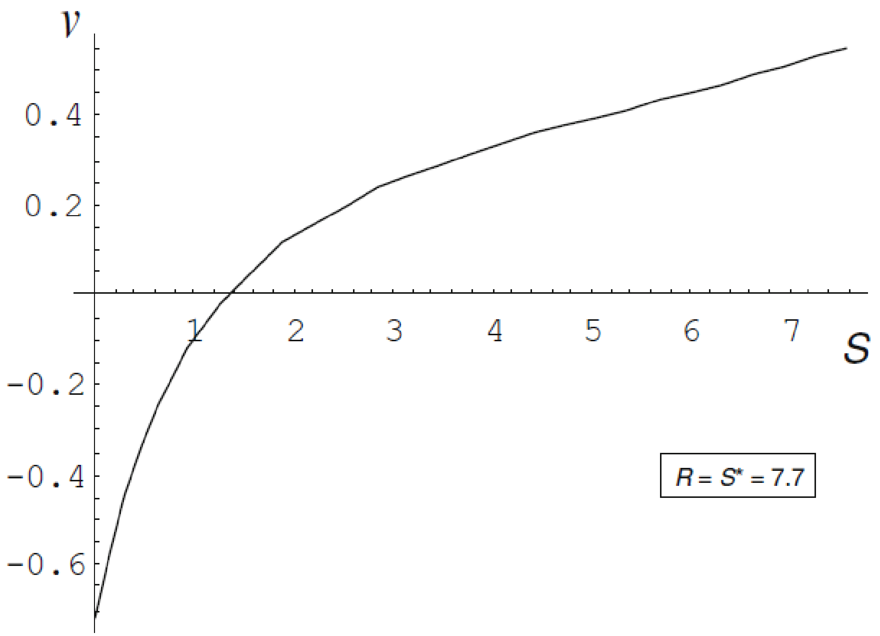


Optimized time to build protection

- The duration is given as a function of the target R.
- This illustrates that increasing R over 10--15 years to reach 2--3 Bscm seems to be an economically sensible policy.

Scenario 4: rules on accumulation and drainage

Government keeps R=S* as a target but imposes a twice larger accumulation rate and a twice slower drainage rate than those obtained under scenario 2.



Relative value of the policy (rule 4)

- At zero stocks and up to S=1.4 approximately, the policy imposes huge welfare costs (the index starts at -0.72). The economy would be better off if storage were impossible (or R=0).
- Due to fast accumulation, the price is very high during the accumulation phase
  - The economy sustains the cost of excessive reserves.
- This effect becomes attenuated as storage expenditures get sunk, but to a much lesser extent than with the constrained optimum.

Which rule work best?

- Our results suggest that the UK decision of not stockpiling precautionary gas stocks could be inefficient.
- In the second best scenario, the ranking is

(1)Optimal antispeculative policy

(2)Exogenous values of R

(3)Administrative rules on accumulation and drainage