Pitfalls of Insuring Production Risk

A Case Study on some Wind Power Auctions in France

Lamy Laurent, Leblanc Clément

Feed-in-Tariffs and Auctions for Renewables

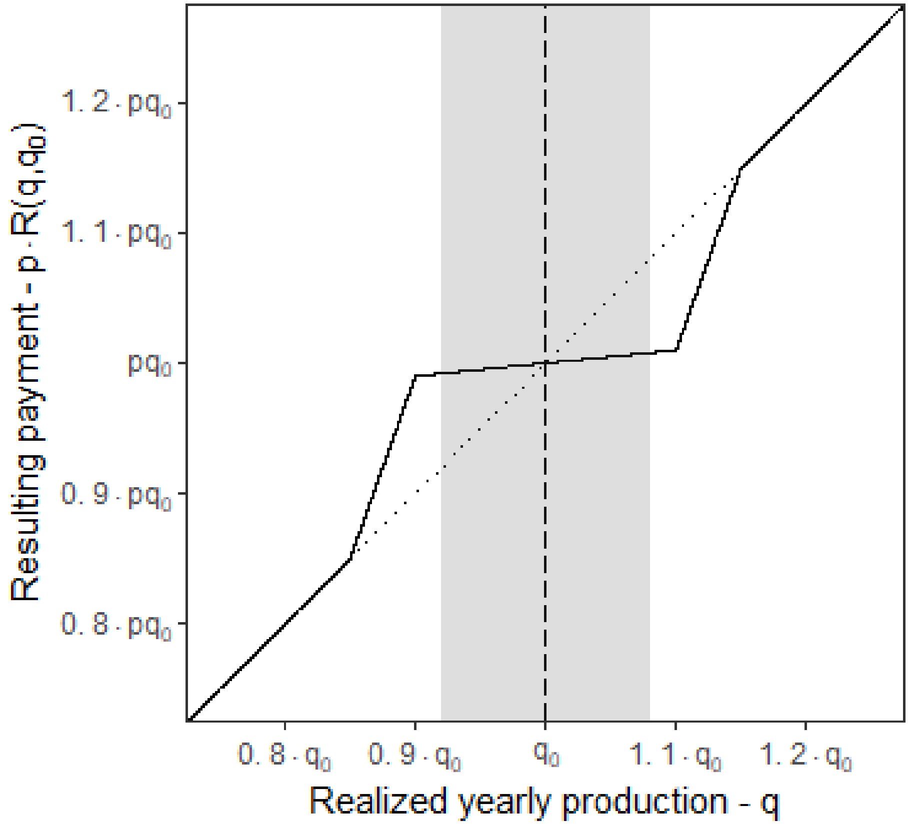
Widespread mechanism to support renewable electricity development

- *Feed-in-Tariffs:* Fixed price paid to eligible renewable producers
- *Awarded through Auctions:* Eligible producers/power plant projects asking for the lowest price are selected by the auctioneer

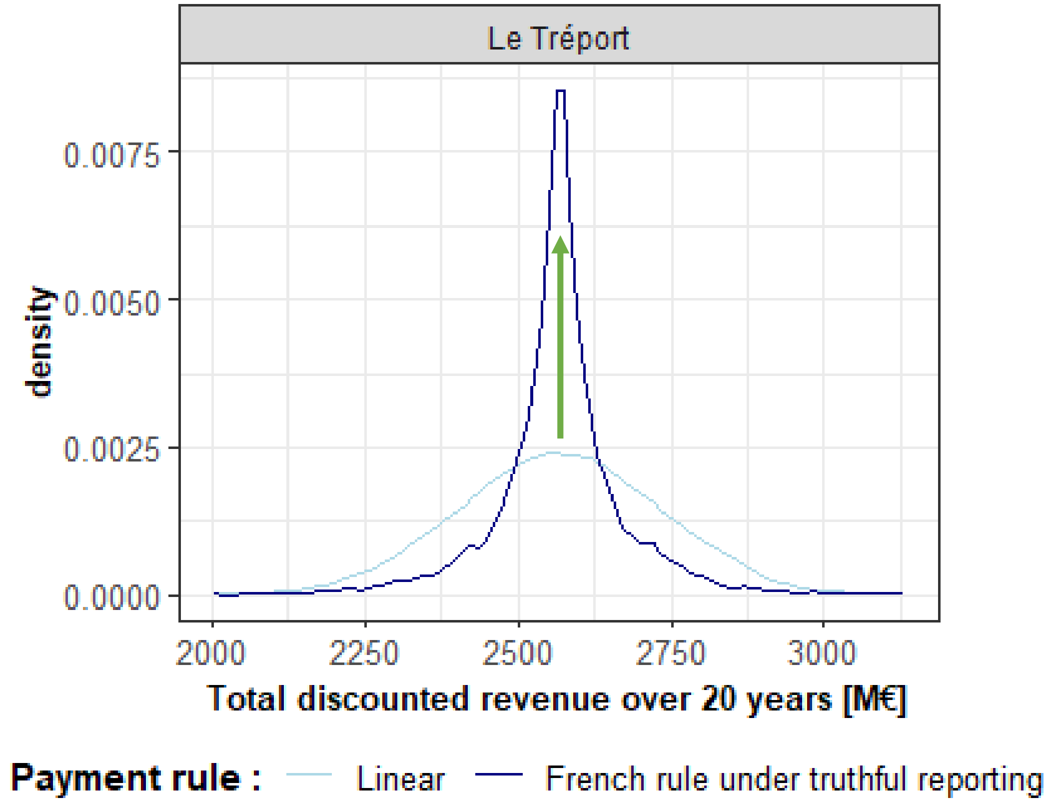
Innovative contract design motivating our study

- In 2011 and 2013, France auctioned away 6 offshore wind sites
- Insurance against production risk was provided through a modified “payment rule” lowering payment variability around a reference production:
  - *Bidders were asked to self-report their expected yearly production (or equivalently their average capacity factor)*
  - *Yearly payments vary very little as long as actual yearly production falls within +/- 10% of the stated expected production*

French Payment Rule with truthful bidders

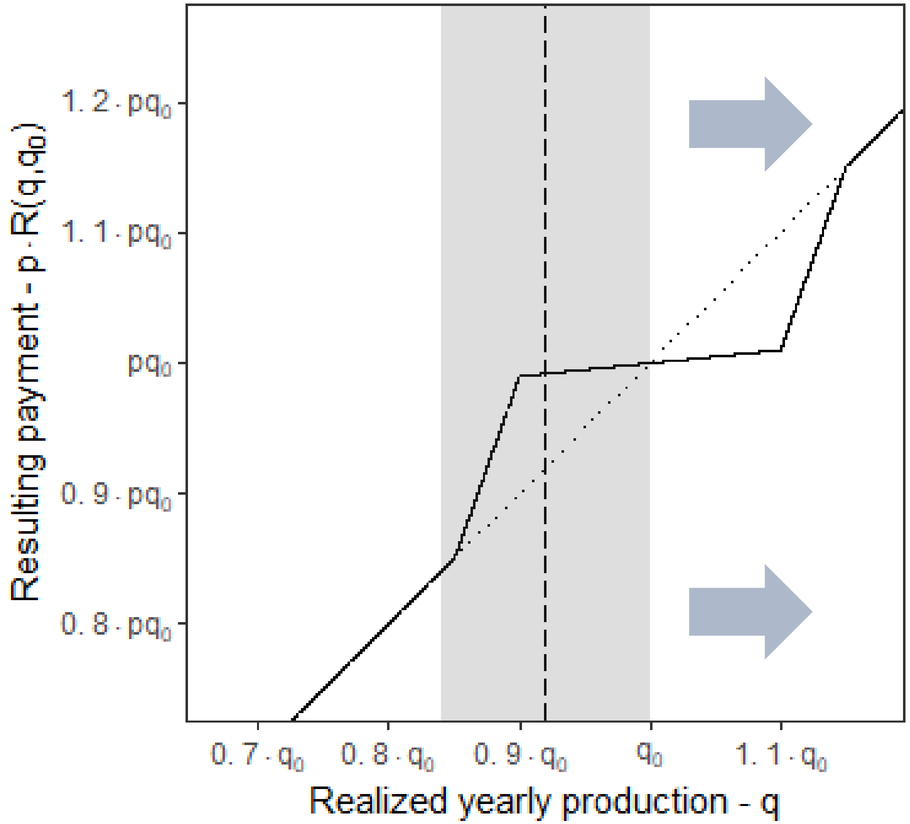


Payment Rule used for French Offshore Wind Power Auctions in 2011 and 2013



Firm's Revenue distribution with a standard contract and with the French payment rule

French Payment Rule with strategic bidders



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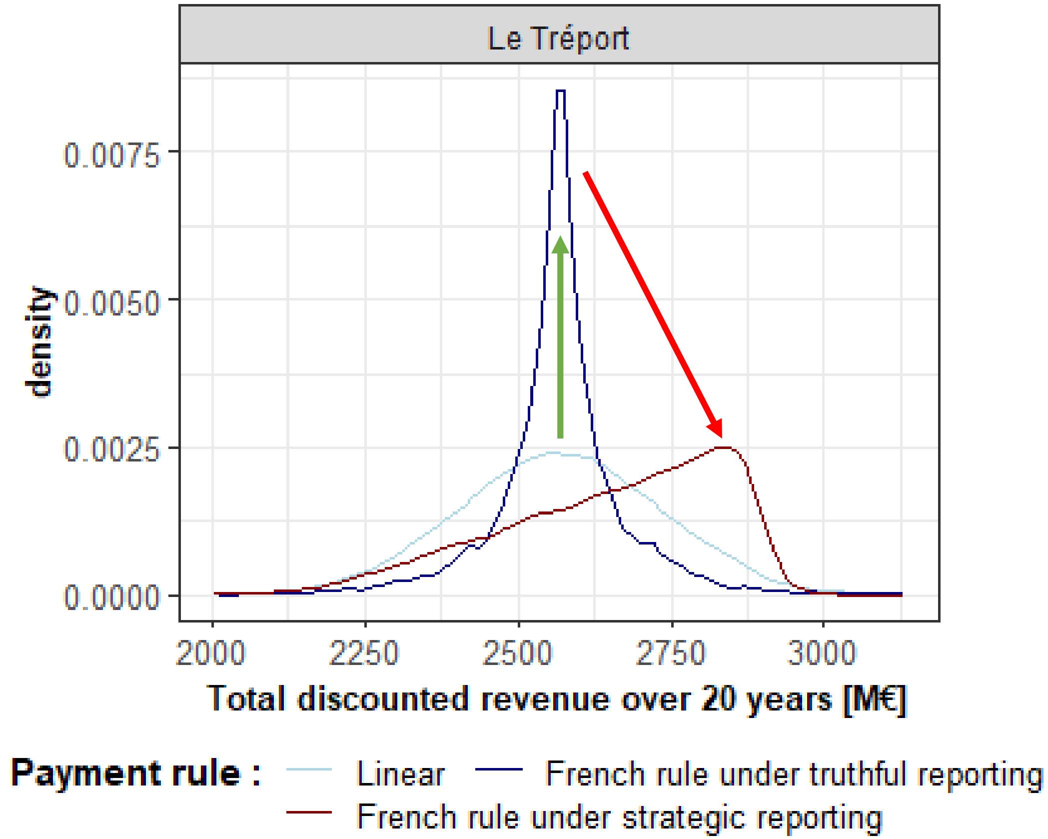


Firm’s Revenue distribution with a standard contract and with the French payment rule

Overview

1. Introduction: Why insure renewables against production risk?
2. **A Model of Production Insuring Payment Rules**
3. Consequences for the French Offshore Wind Auctions
4. Can we improve Production Insuring Payment Rules ?
5. Conclusion

The Baseline Model

A buyer organizes an auction settling a procurement contract with the winning firm before knowing the quantity of good produced (which is subject to an ex post risk)

Firms

- Firms' **production**: $q \sim f(.)$ with $E[q] = \bar{q}$
- Firms' **payoff function**: $U(.)$
- Firms' **initial investment cost**: C

The Auction

- Bids are composed of **a price** p and **a reference production** q_0
- The lowest price bid is selected

The Contract

- The contract is characterized by a **payment rule** $R(q, q_0)$
- The firm is paid (ex-post): $p * R(q, q_0)$

We say a firm is either…

- **Truthful** if $q_0 = \bar{q}$
- **Strategic** if $q_0 = \underset{q_0}{Argmax}\, E\left[U\left(p * R(q, q_0)\right)\right]$

Production Insuring Payment Rules – A Definition

Definition

A Payment Rule $R(.,.)$ is production-insuring if

$\forall f$ symmetric
$\forall p > 0$
$\forall U(.)$ concave

- If $U(.)$ is linear : $E[U(p * R(q, \bar{q}))] = E[U(p * q)]$
- If $U(.)$ is strictly concave : $E[U(p * R(q, \bar{q}))] > E[U(p * q)]$

- *Production insuring payment rules do indeed lower the risk premium when firms are truthfully report their expected production as* q_0
- *In particular, it can be checked that the French payment rule is production insuring according to this definition*

Main Research Question

"Do production insuring payment rules lower the buyer's cost compared to the linear contract?"

(i.e. the contract where $R(q, q_0) = q$)

- Yes if all firms truthfully report their expected production as q_0, but **what happens in presence of strategic bidders ?**
- Why do we take the linear contract as a benchmark:
  - From a **positive perspective**: commonly used (beyond the RES-E application)
  - From a **normative perspective**: the optimal contract is linear in the quantity produced if the principal values the output linearly and bidders are risk neutral

Incentives to strategically report q_0

General Result

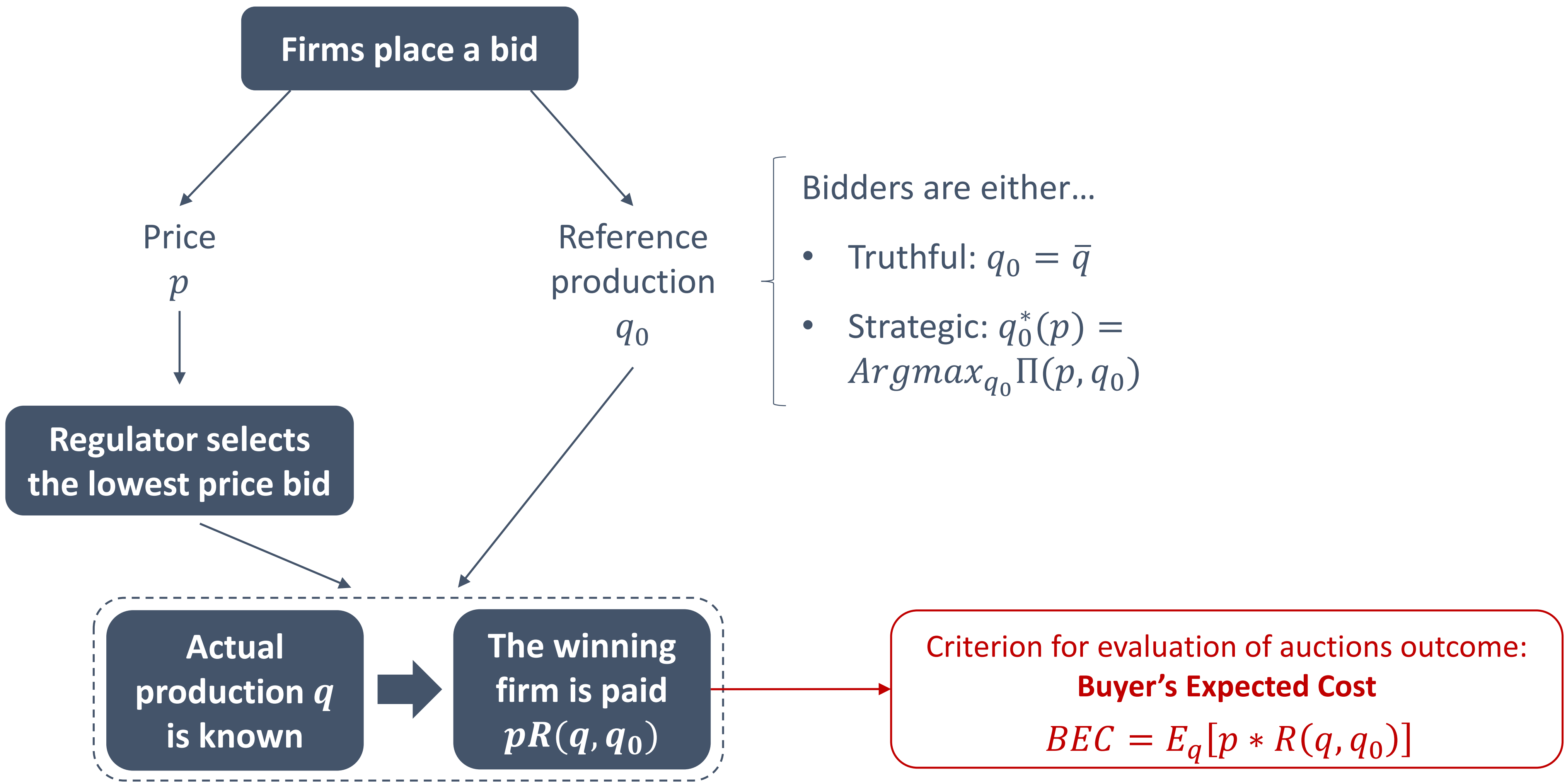
For **any payment rule that is production-insuring** and **any price p** if

- f **symmetric & single-peaked**
- **the firm is risk-neutral**

⇒ The firm increases its expected payoff by **overstating its expected production**

- In general, overstating q_0^* implies $E[R(q, q_0)] > E[q]$ *(even with risk-averse bidders)*
- Deception effect: if the firm overstates its expected production, the expected payment per unit made by the buyer is higher than p

The Auction Game



Consequences of a Production-Insuring Payment Rule

Homogeneous reporting of q_0

Equilibrium price bids are determined by **zero-profit conditions**

$\Delta BEC = \Delta RiskPremium$

All firms truthfully report $\bar{q}$

Risk Premium ↘

All firms strategically report the q_0 that maximizes their payoff

Risk Premium ?

Heterogeneous reporting of q_0
(e.g. if only one firm is strategic)

Heterogeneity allows for **non-competitive rents**

$\Delta BEC = \Delta RiskPremiums + Rents$

Rents > 0

Empirical Question: $-\Delta RiskPremium \lesseqgtr Rents$?

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Calibration on the French Offshore Wind Auctions

Objective – Estimate the French regulator's potential loss due to the production-insuring payment rule it employed

Method:

Production risk distribution: built for each location accounting for

- Historic production variability based on weather data
- Typical resource estimation mistake (at that time)

Other Hypothesis:

- CRRA utility function with parameter γ
- Interest rate = 5.7 % (contract dur. = 20 years)
- Firms' cost based on state aid examination documents disclosed by the EC

↓

Estimation of the optimal reporting q_0^* of a strategic firm through utility maximization

↓

For **each payment rule,** computation of :

Equilibrium price p

&

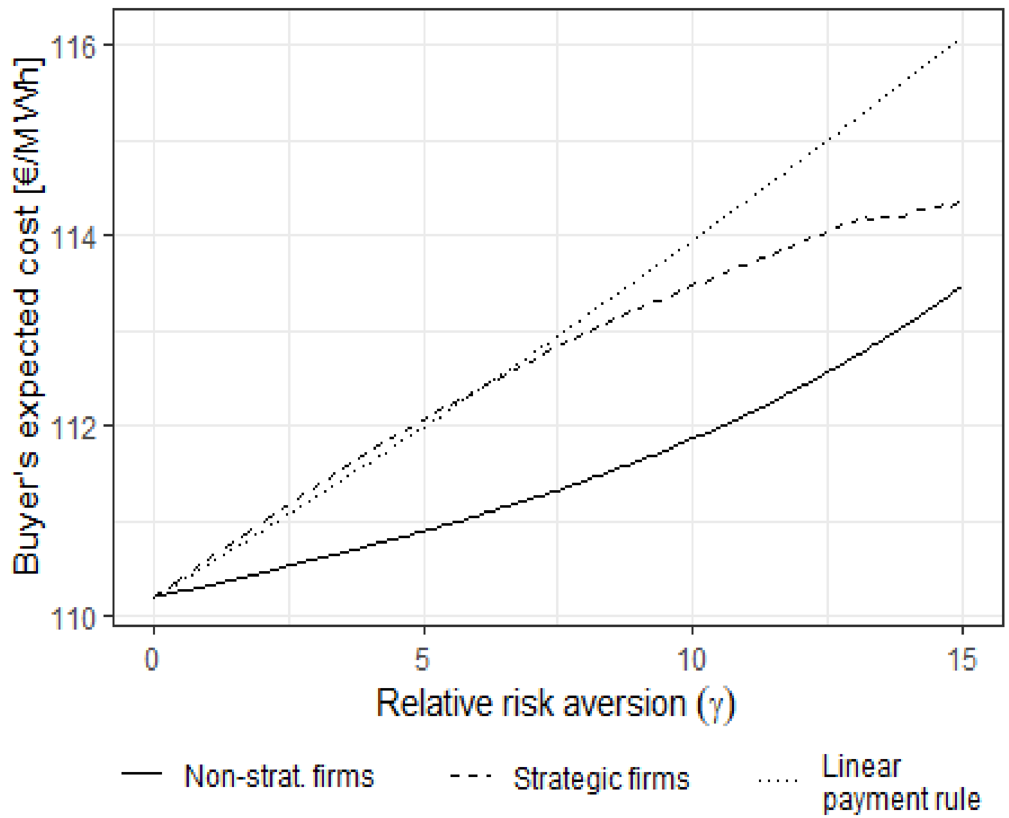
Expected cost in subsidies $p * E[R(q, q_0)]$

Impact on the Buyer's Expected Cost

Considering a standard risk aversion ($\gamma = 1$),
Simulation for 5 offshore wind sites

Linear Contract	Risk premium vary between 0.29 - 0.36 %
*French Rule with **truthful bidders***	The risk premium is **divided by 2**
*French Rule with **strategic bidders***	These **gains are lost**
*French Rule with only **one strategic bidder** (worst scenario)*	The strategic bidder captures a **rent 15 times larger** than the potential gain if all firms were truthful

Simulation for Courseulles Site (Normandy)



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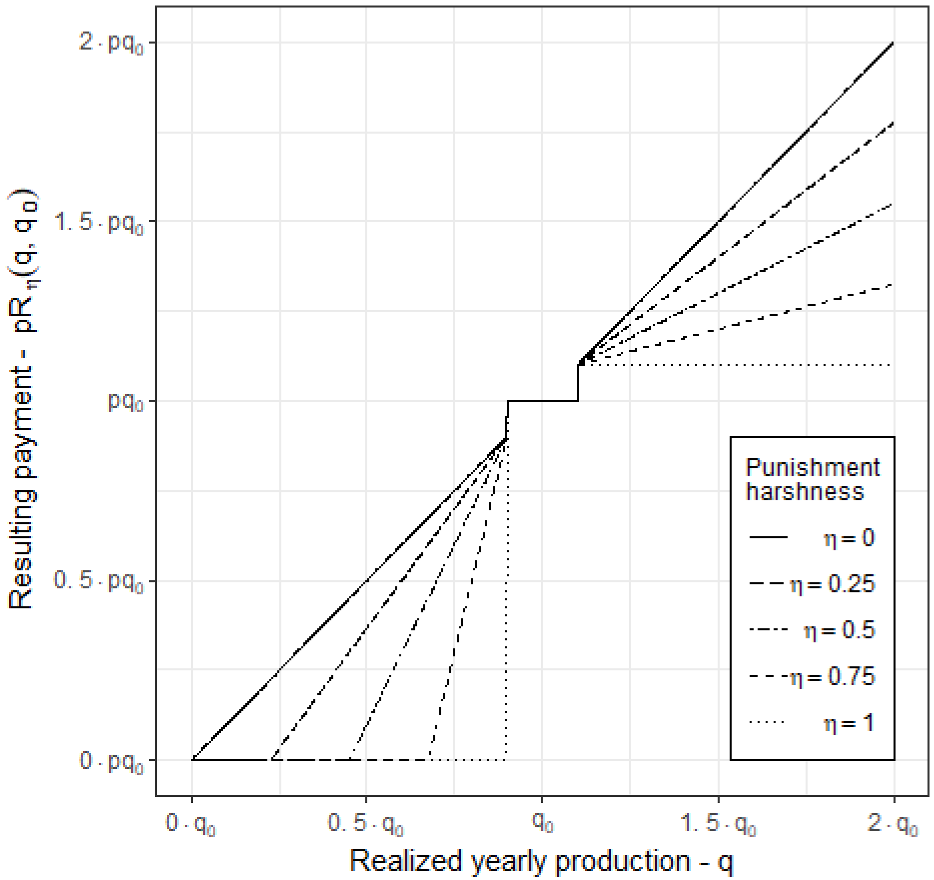
Limiting Strategic Behavior with "Punishments"

New class of payment rules parameterized by (w, η), with payment depending on production being…



- **Flat within $\boldsymbol{w}$** % around reported expected production q_0
- **Punished with intensity $\boldsymbol{\eta}$** out of this interval

  payment increase (resp. decrease) all the more slowly (resp. rapidly) that η is high when above (resp. below) the flat part

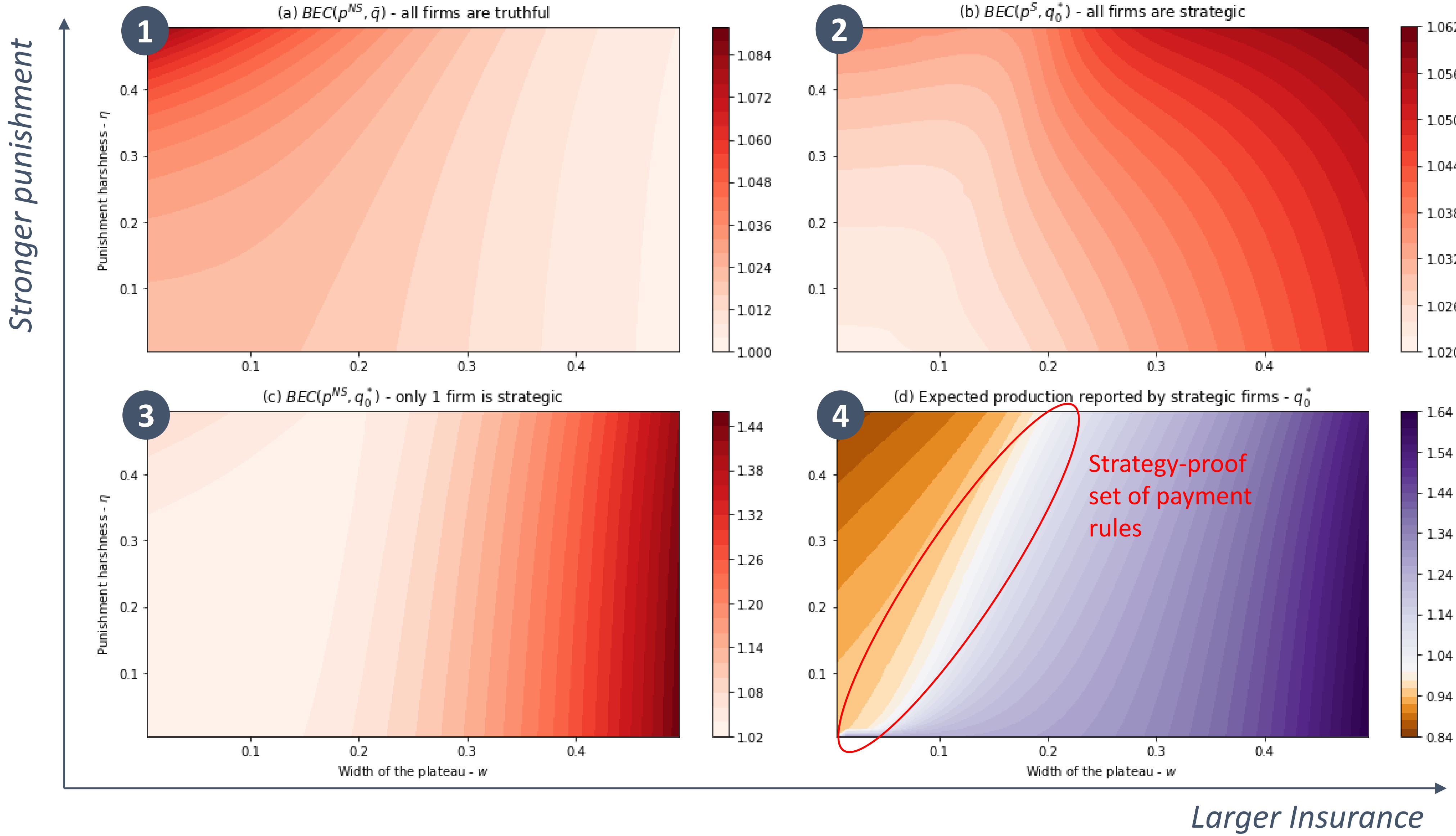
Simulation of firms' best response for

- Risk-averse firms with **CRRA ($\boldsymbol{\gamma = 1}$)**
- Production q :
  - **normally distributed** with standard deviation equal to 20% of the mean
  - **uniformly distributed** on $[0.5\,\bar{q}, 1.5\,\bar{q}]$

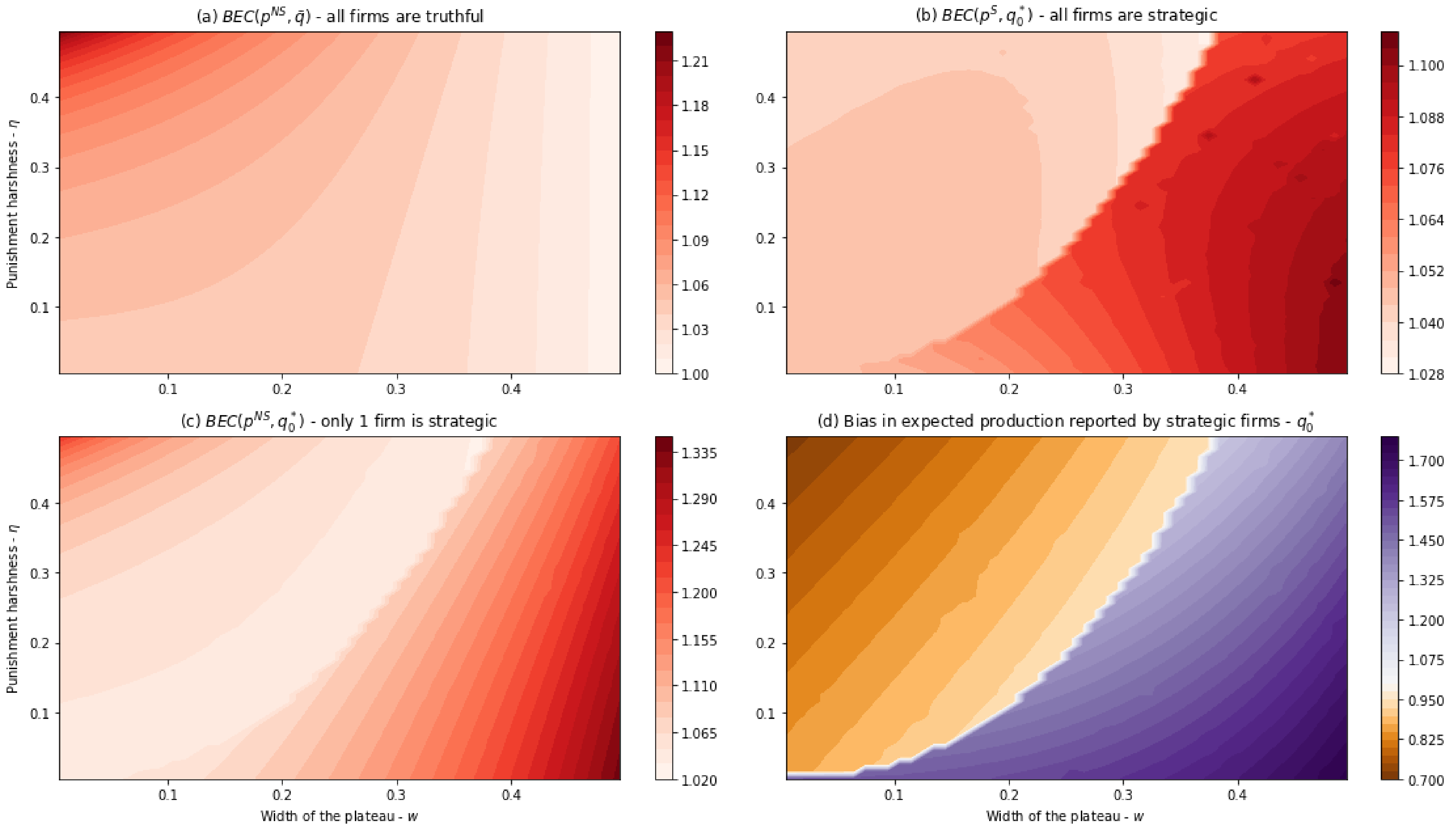
Auction Outcome with Punishments

	Normal Distribution of q	Uniform Distribution of q
All firms are truthful	**Wider insurance (w) and lower punishments (η) brings smaller risk premiums**	
Strategic reporting of expected production	• Existence of a set of strategy-proof payment rules (w, η) performing better than average • Optimal report of expected production is continuous in w and η	• No strategy-proof set (w, η) • Existence of a discontinuity regarding optimal report of expected production w.r.t. w and η
All firms are strategic **Only one firm is strategic**	No payment rule bring a better outcome than a linear contract	Slightly smaller insurance/harsher punishments compared to the discontinuity result in **smaller buyer's expected cost than the linear contract**

Auction's outcomes



Auction's outcomes with Uniformly Distributed Production



Overview

Extensions

Beyond the specific framework of our model, our conclusions can be extended in the following directions:

- A **mixed strategy equilibrium** is derived when firms being strategic or truthful is subject to a given probability α
- Similar conclusions can be reached with
  - **Additive payment rules** (in the form $A(p) * R(q, q_0) + b(p)$) instead of multiplicative
  - **Non-zero variable costs** when they are observable
- An equivalent phenomenon can be derived in a **moral hazard** model where firms lower the quality of their project in reaction to the insurance provided by the buyer
- **Asymmetry between firms** imply different conclusions depending on whether the dominant firm and competing firm are truthful or strategic
- **Costly manipulation** would mitigate over-reporting but would incur wasteful spending devoted to falsification of q_0

Conclusion

For the design of subsidies in RES-E auctions

VS
- Low risk premiums, then low benefits from risk premium reduction
- Firms could largely benefit from manipulation, while inflating public cost

- *Alternative designs:* multi-year contracts in Brazil adjust when the observed average production consistently depart from q_0

Relevance for contingent auction beyond RES-E

- Insurance against other resource availability risk, e.g. for oil, minerals or timber auctions
- Insurance against demand uncertainty, e.g. for transportation infrastructure or public transportation (see Engel, Fischer & Galetovic, 2001)
- Insurance against cost overruns, e.g. for construction procurements

Thank you for your attention

Contact: cl.clement.leblanc@gmail.com ; laurent.lamy78@gmail.com

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Related Literature

Auctions & procurements with ex post risks

- Risk premiums
  - Engel, Fischer, Galetovic (2001)
  - Eso White (2004)
- Informational rents in contingent auctions
  - Hansen (1985)
  - DeMarzo, Kremer, Skrzypacz (2005)
  - Skrzypacz (2013) - *Survey*

Manipulations in auctions

- Skewed bidding in scaling auctions and procurements
  - Athey, Levin (2001)
  - Agarwal, Athey, Yang (2009)
  - Luo, Takahashi (2019)
- Phantom/Shill/Cover bidding
  - Yokoo, Sakurai, Matsubara (2004)
  - Lamy (2013)
- Heterogeneous renegotiation abilities
  - Ryan (2020)

Overestimation under additional assumptions

Adding more structure, including assumptions that:

- *The payment is constant within a range around q_0 and proportional to quantity outside this range*
- *The firm has a constant relative risk aversion (CRRA = γ)*

We can derive that:

1. Firms with higher risk aversion report a higher q_0^*
2. Firms report a higher q_0^* when facing a less risky production distribution
3. A wider range of insurance pushes firms to report a higher q_0^* (under the additional hypothesis that $\gamma \geq 1$)

Auction's equilibrium

Under Homogeneous Reporting

	Equilibrium Price	*Buyer's Expected Cost (per unit)*
Linear Contract	p^{LC}	p^{LC}
	$\vee$	$\vee$
Production Insuring – Truthful Reporting	p^{T}	p^{T}
	$\vee$	?
Production Insuring – Strategic Reporting	p^{S}	$p^{S} * \frac{E_f[R(q, q_0^*(p^S))]}{\bar{q}}$

Under Heterogeneous Reporting

Worst Case Scenario

- *One firm strategically report* q_0
- *And knows all other firms report their true expected production* $\bar{q}$

→ **The Strategic Firm gets a positive payoff:**

Eq. Price	*BEC*
p^{T}	$p^{T} * \frac{E_f[R(q, q_0^*(p^T))]}{\bar{q}}$

A Proxy of the Risk faced by Offshore Wind Bidders

- **Raw Data:** Electricity generation simulated for each of the 6 offshore wind projects, based on historic weather data from 2000 to 2018 (from https://www.renewables.ninja/) → 18 one-year long observations
- **Recombinations at the quarter level:** Random draws of one of each quarter to obtain a larger sample of one-year long observations → About 100 000 different one-year long observations
- **Drawing of full life-time observation:** Random draws of 20 years-long series from the previous sample → We choose to draw 5 000 life-time long observations
- **Misestimation risk:** A time-persistent normal noise is added, whose spread accounts for a 5% mean absolute error in line with common estimation mistakes made until recently in the industry

↓

5 000 observations sample of the distribution of the lifetime production of the power plant →

Payoff of the firm

$$E\left[U\left(\sum_{t=1}^{20}\frac{p * R(q_t, q_0) - OC}{(1+r)^t}\right)\right] - U(IC)$$