Transition to electric mobility

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Introduction: some data

Transition dynamics

Optimal subsidy rule

Introduction

- Electric vehicles (EV) **v.s.** Fossile-fuel Vehicle (FV)
- Renewed interest in electric mobility:
  - peak-oil,
  - decarbonization ambitions,
  - new socio-technical developments, ...

Ambitions	Facts
IEA's goal: 5.9 millions EV/year by 2020	last year: 113000
target: 75% by 2050	currently 0,02%

- barriers to electric mobility?
  [battery costs, other battery concerns, infrastructure, ..]

EV cost of owning

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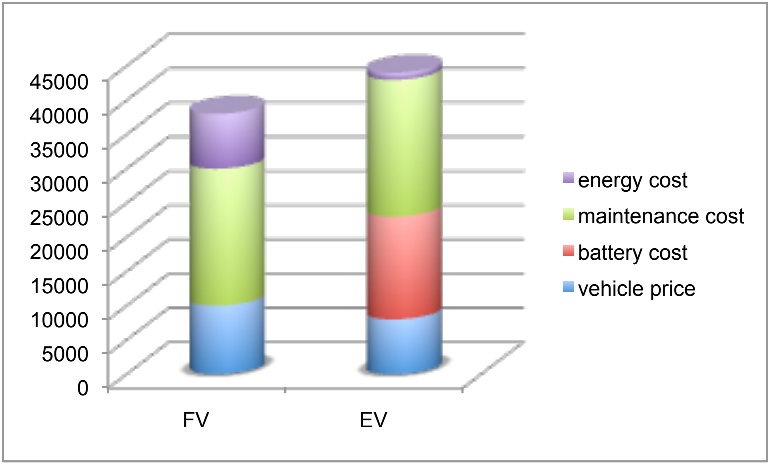


Time Horizon: 15 years, kilometers/year = 13000

Study and documents, n°41, May 2011, General Commissioner for Sustainable Growth

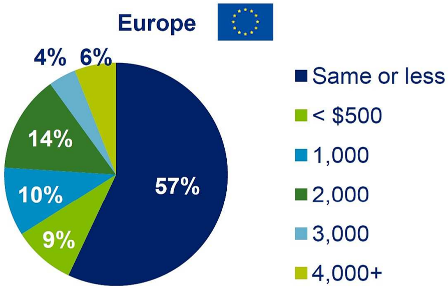


Figure: premium consumers are willing to pay for EV, Europe – (Deloitte)

Cost vs. Social Benefit

- Vehicle Cost-of-owning

$$C_t \quad = \quad P_t + \frac{\text{energy cost}}{\text{discount rate}}$$

- distinction between: short-term private discounting
  & longer time-horizon social discounting

	FV	EV	
vehicle price	15000	30000	
energy cost/year	1125	270	
private disc. rate	16%	16%	
private cost of owning	22000	31700	$FV < EV$
social disc. rate	4%	4%	
social cost of owning	43125	36750	FV >EV

- Social benefit per EV:

$$C_t^{FV} - C_t^{EV} \quad = \quad \Delta \text{ purchase price} + \frac{\Delta \text{ energy cost}}{\text{social discount rate}}$$

A Basic Model

Notations and Hypothesis:

- the EV purchase price, P_t^e
- the FV purchase price, P, constant over time
- the price-spread $x_t = P_t^e - P_t$: explained by the cost of the battery

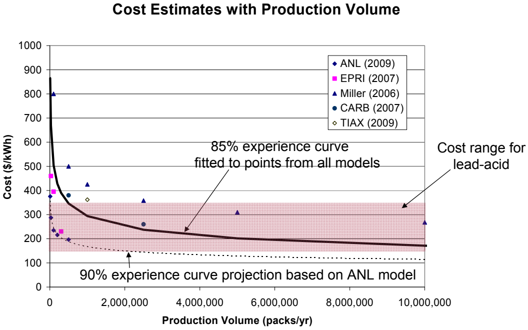


Figure: battery experience curve

A Basic Model

- standard exponential learning dynamics for the Battery cost

$$B_{t+\delta t} \quad = \quad B_t - \alpha(t)\,(B_t - B_\infty)$$

  Then

$$x_{t+\delta t} \quad = \quad x_t - \alpha(t)\,(x_t - \beta)$$

- the speed of learning: $\alpha(t) \sim$ new EV adopters

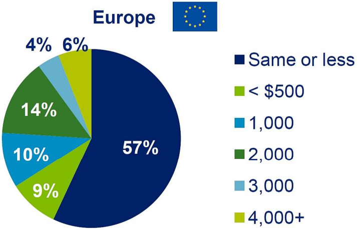
A Basic Model

- W.B. Arthur (1989) ' style model
- annual rate of new EV purchases μ
- Sequentially arriving car buyers at times $\{t_i\}_i$:

$$\text{at time } t_i \text{ agent } i \text{ adopts EV} \quad \text{iff} \quad \mathbf{x_{t_i}} \leq \mathbf{w.t.p(i)}$$

- Number of new EV adopters in $[t_k, t_k + \delta t]$

$$\begin{aligned} n_{t_k}^{EV} &= \sum_{j=1}^{[|\mu\delta t|]} \mathbf{1}_{\{w.t.p(j) \geq \mathbf{x_{t_k}}\}} \\ &= \mu\delta t \left(\mathbb{P}(w.t.p(k) \geq \mathbf{x}_{t_k}) + M_{t_{k+1}}\right) \\ &= \mu\delta t \left(\Phi(\mathbf{x_{t_k}}) + M_{t_k}\right) \end{aligned}$$



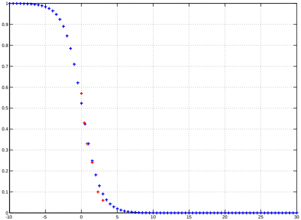


Figure: Willingness to pay statistics – function Φ

The limiting o.d.e.

- Dynamics of the cost-spread $\mathbf{x}$

$$\begin{aligned} x_{t+\delta t} &= x_t - \alpha(t)\,(x_t - \beta) \quad \text{with} \quad \alpha(t) = \alpha n_t^{EV} \\ x_{t+\delta t} &= x_t - \alpha\mu\delta t\,\left(\Phi(x_t)\,(x_t - \beta) + \tilde{M}_{t_k}\right) \end{aligned}$$

- Limit o.d.e

$$\dot{x}(t) = -\alpha\mu\Phi(x(t))\,(x(t) - \beta)$$

Reference: V. S. Borkar (2008).

Optimization Problem

- Objective: maximize the social benefit
- Control: subsidy process $\{s_t\}$
- $\Rightarrow$ Cost spread dynamics

$$\dot{x}^s(t) = -\alpha\mu\Phi(x^s(t) - s_t)\,(x^s(t) - \beta)$$

- Social Benefit: $\left(C_t^{FV} - C_t^{EV}\right) n_t^{EV}$
- Optimization problem

$$\max_{\{s\}} \int_0^T e^{-\rho t}\,\{b - x_t^s - s_t)\,\mu\Phi(x_t^s - s_t)dt\ .$$

where $b := \dfrac{\Delta \text{ energy cost}}{\text{social discount rate}}$ is the fuel economy

Optimal subsidy rule

- optimal $\{s^\star\}$ is such that: $e^{-\rho t}(x_t^\star - s_t^\star)$ constant (Kalish and Lilien (1983))

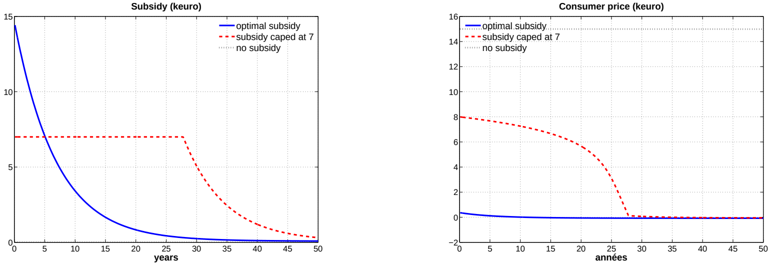


Figure: optimal subsidy rule – Subsidised purchase price of EV

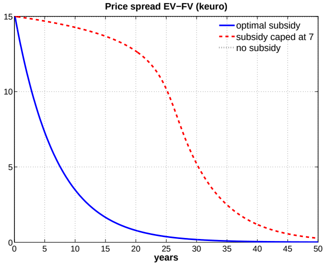


Figure: price-spread evolution – EV purchases evolution

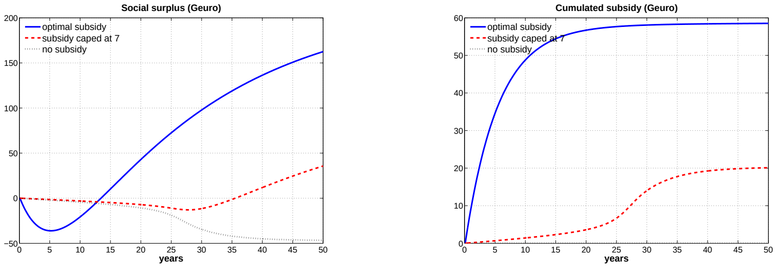


Figure: Social Benefit – cumulated subsidy value

Conclusions and Perspectives

- Without subsidy $\Rightarrow$ no take-off
- Below threshold subsidy $\Rightarrow$ no take-off
- With optimal subsidy rule $\Rightarrow$ take-off

- interacting strategic firms
- R& D investment