MERGING TWO APPROACHES: DIFFUSION OF TECHNOLOGIES AND OPTIMIZATION OF ABATEMENT TECHNOLOGY CHOICES IN THE AUTOMOTIVE SECTOR

Chaire Modélisation prospective
au service du développement durable

Juan VERA and Céline GUIVARCH

CIRED - International Research Center on Environment and Development, Paris - France

Motivation

Technology transitions occur when an ecnomy sector undergoes significant structural changes. Products, producers, suppliers, consumers and regulators evolve in the way that they use to interact with each other within the former ecosystem. Here, we focus on the automotive industry that is going through such a transformation that is questionning how we manufacture, sell and use cars?

Preparing the future technology portfolio that will comply with low emissions, like CAFEx regulations, is a challenging goal that requires adapted solutions like alternative fuel vehicules AFV.

In this research, we present a method to estimate an optimized technology mix that is complying with CO2 regulations and is constrained to past technology diffusion speeds.

Research Questions

- How fast does a technology diffuse?

- How to consider speed of diffusion in a technology mix model?

- What does past diffusion of technologies tell us about the future?

Diffusion of Technologies Framework and Examples

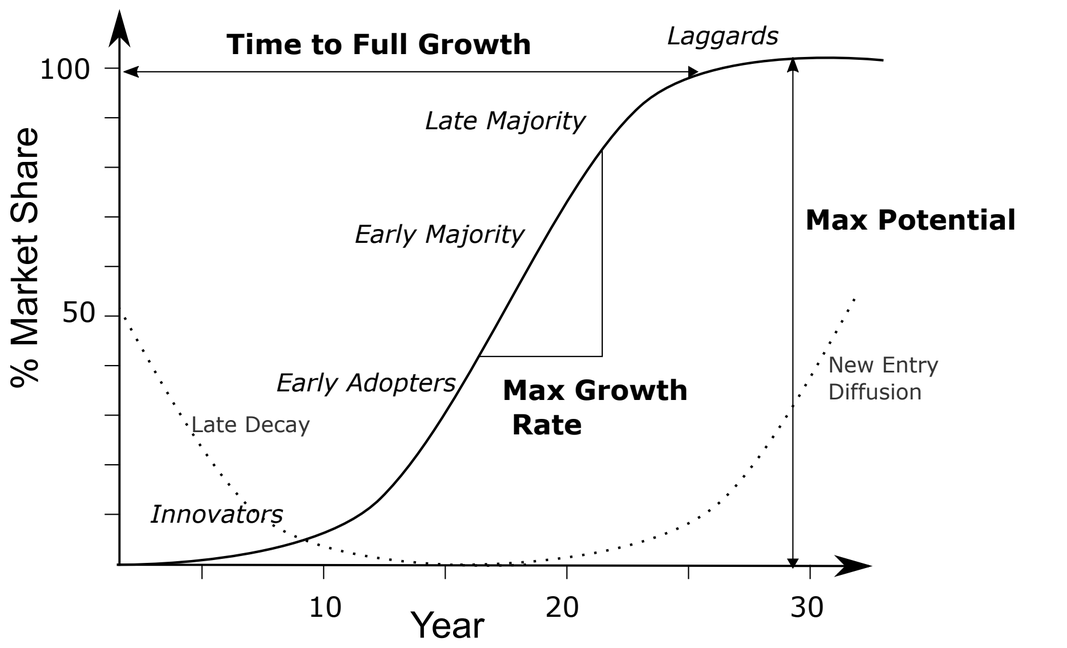

Figure 1. Stages of Product Diffusion and Key Metrics for Measuring Speed

Figure 2. Automobile Technology Deploymet in the USA market: drivetrain, powertrain, fuel injection and transmission technologies. Source: EPA, 2016

Results

Optimization Model: Minimization of total costs to comply with CO2 regulations under diffusion constraints.

Public Policies "Feebates"

- Fees for fossil fuel technologies

- Rebates for low carbon technologies

+

Technology Costs

5 Powertrains: Gasoline, Diesel, HEV, PHEV, EV

+

Abatement Potential

CO2 emission level on NEDC cylce

Optimization Model
Cost Minimization of Investments

Variables:
From year 2014 to 2030
Unit annual sales of all vehicle types
Initial Conditions corresponding to actual mix in 2014

Constraints:
- CAFE targets in 2020, 2025 and 2030
- Annual Volume Sales
- Speed of diffusion treated with 2 logics:
Exogenous: Unconstrained, Constant, Evolving with time and Endogenous

Technology Mix

- Volume Sales
- Total abatement cost
- Total abatement potential

Different approaches to constraints on speed of diffusion:
- Unconstrained
- Constant :
$X(t+1) - X(t) < C$
Constraints are set exogenously and constant for the entire period
- Exogenous:
$X(t+1) - X(t) < F(t)$
Constraints are set exogenously and changes with a sigmoid function of time
- Endogenous:
$X(t+1) - X(t) < F(MS)$
Constraints are endogenous and are a fucntion of the market share, they are obtained with the derivative of the sigmoid function and with a change of variable

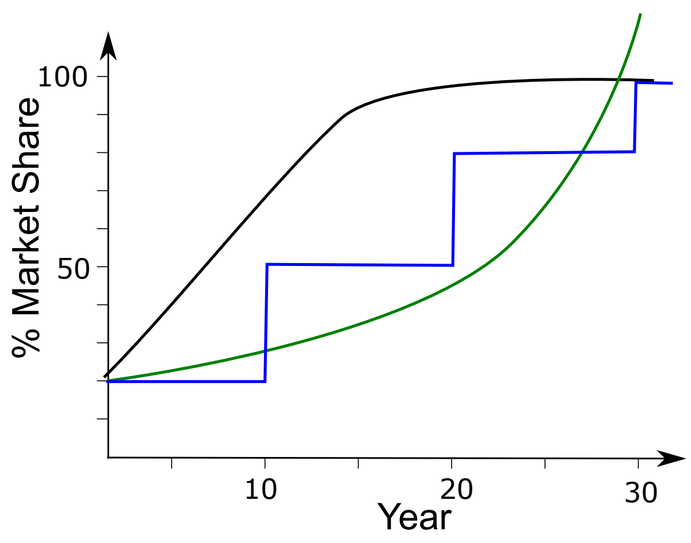

Figure 4. Preview of the output of a technology deployment with different speed constraints: in green, constant, in blue, unconstrained and in black sigmoid constraint.

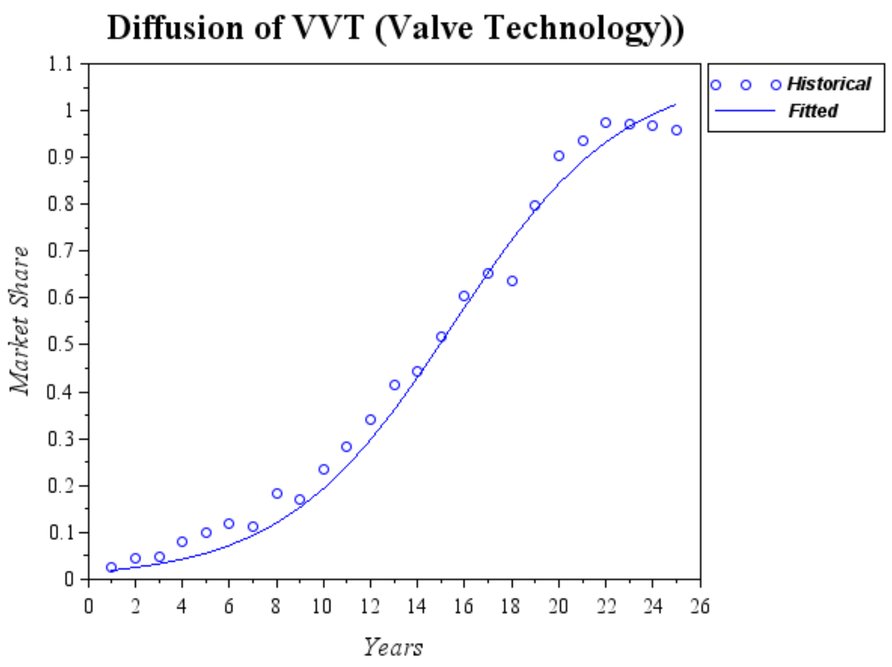

Figure 4. Regression of automobile deployment path with a sigmoid function. Scattered points correspond to historical data and plotted line to the adjusted function. The example is the variable valve timing deployment in USA.

Further Work

- Adapt the speed of diffusion constraint for each product specifications and consumer behaviour.

- Include other type of low emission policies in the model.

- Apply model to obtain optimized vehicle mix for various CAFE targets.

Contact:
Juan Fernando VERA: vera@centre-cired.fr