Energy Performance Certificates and Investments in Building Energy Efficiency: A Theoretical Analyis

Pierre Fleckinger, Matthieu Glachant, Paul-H. T. Kamga

MINES ParisTech, PSL University

June 26-29, WCERE 2018

What is an Energy Performance Certificate?

- Established under the 2002 Energy Performance of Buildings Directive
- A certificate gives information on
  - a property's typical energy use and energy cost
  - an energy efficiency rating from A (most efficient) to G (least efficient)
  - practical advice on improving such performance
- Compulsory in all advertisements for the sale or rental of buildings since 2007
  - In other countries, energy labels are usually voluntary (e.g. Energy Star, LEED)

An example

Energy Performance Certificate

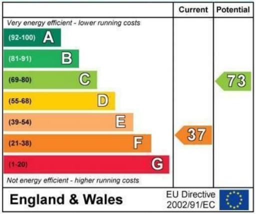
SAP

17 Any Street,
Any Town,
County,
YY3 5XX

Dwelling type:	Detached house
Date of assessment:	02 February 2007
Date of certificate:	[dd mmmm yyyy]
Reference number:	0000-0000-0000-0000-0000
Total floor area:	166 m²

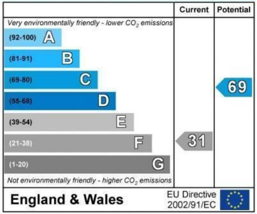
This home's performance is rated in terms of the energy use per square metre of floor area, energy efficiency based on fuel costs and environmental impact based on carbon dioxide (CO_2) emissions.

Energy Efficiency Rating



The energy efficiency rating is a measure of the overall efficiency of a home. The higher the rating the more energy efficient the home is and the lower the fuel bills will be.

Environmental Impact (CO_2) Rating



The environmental impact rating is a measure of a home's impact on the environment in terms of carbon dioxide (CO_2) emissions. The higher the rating the less impact it has on the environment.

Estimated energy use, carbon dioxide (CO_2) emissions and fuel costs of this home

	Current	Potential
Energy Use	453 kWh/m² per year	178 kWh/m² per year
Carbon dioxide emissions	13 tonnes per year	4.9 tonnes per year
Lighting	£81 per year	£65 per year
Heating	£1173 per year	£457 per year
Hot water	£219 per year	£104 per year

The Economic Rationale for EPCs

- In the absence of an EPC, buyers/tenants do not observe a dwelling's energy performance **before moving in**
  - An experience good
- EPCs are expected to improve the **matching** between dwellings and households on the housing market
  - Households with high (low) energy needs can choose energy efficient (less efficient) dwellings reciprocally
- They are expected to increase **energy efficiency investments.**
  - The price energy-efficient dwellings becomes higher than that of energy-inefficient dwellings
- Both mechanisms are expected to reduce energy use, to increase investments, and to improve social welfare

Our Paper

A dynamic model which examines the impact of EPCs on energy use, investments, and social welfare + (preliminary) simulations with French data

Main findings:

Our Paper

A dynamic model which examines the impact of EPCs on energy use, investments, and social welfare + (preliminary) simulations with French data

Main findings:

1. In the absence of other market imperfections, the EPC implements the first best social optimum (not surprising)

Our Paper

A dynamic model which examines the impact of EPCs on energy use, investments, and social welfare + (preliminary) simulations with French data

Main findings:

1. In the absence of other market imperfections, the EPC implements the first best social optimum (not surprising)
2. However, the impact on the level of energy use and on the volume of energy efficiency investments is ambiguous

Our Paper

A dynamic model which examines the impact of EPCs on energy use, investments, and social welfare + (preliminary) simulations with French data

Main findings:

1. In the absence of other market imperfections, the EPC implements the first best social optimum (not surprising)
2. However, the impact on the level of energy use and on the volume of energy efficiency investments is ambiguous
3. As a result, in a second-best world where energy externalities are under-priced and/or where consumers have behavioral biases that hinder investments (myopia), EPCs can damage social welfare

Our Paper

A dynamic model which examines the impact of EPCs on energy use, investments, and social welfare + (preliminary) simulations with French data

Main findings:

1. In the absence of other market imperfections, the EPC implements the first best social optimum (not surprising)
2. However, the impact on the level of energy use and on the volume of energy efficiency investments is ambiguous
3. As a result, in a second-best world where energy externalities are under-priced and/or where consumers have behavioral biases that hinder investments (myopia), EPCs can damage social welfare
4. Preliminary simulations suggest this is unlikely to be the case in France

Literature

- To the best of our knowledge, nothing on the impacts of mandatory building energy certification on energy use, investments, social welfare
- Almost all contributions are empirical studies of the impact on housing prices or rents
  - Fregonara et al. 2014; Fuerst et al. 2015; Fuerst and McAllister 2011; Hoegberg 2013; Jensen et al. 2016; Kholodilin and Michelsen 2014; Kok and Jennen 2012; Olaussen et al. 2015; Ramos et al. 2015; Wahlstroem 2016
  - Similar studies on voluntary labels (e.g., Energy Star, LEED)
- A well-established literature in industrial organization on the labeling/certification of experience goods (see Dranove and Jin 2010 for a survey)
  - In comparison with a standard buyer-seller model, quality is endogenous and sellers (i.e. homeowners) use the good before selling it on the real estate market

The Model

- A dynamic game in discrete time
- A city with dwellings of endogenous energy performance θ
  - $\theta = 1$ if the dwelling is energy-efficient
  - $\theta = 0$ if it is energy-inefficient
- q_t is the (endogenous) share of efficient dwellings in period t. At $t = 0$, we assume $q_t = 0$.
- A continuum of households (owner-occupiers) with heterogeneous energy needs
  - When living in an inefficient dwelling ($\theta = 0$), a household's per-period energy expenditure is e, with $e \in [0, +\infty)$ and cumulative distribution function F
  - Energy consumption is zero if $\theta = 1$
- Households can invest I in any period to upgrade their inefficient dwelling.

Timing within Period t

1. m households exogenously move out and m households living outside the city move in
   - Incoming and outgoing households are drawn from the same distribution.
2. Outgoing households sell their dwellings to incoming households in a competitive housing market
   - In the absence of certification, newcomers only observe energy performance after the purchase.
3. Each household living in an inefficient dwelling ($\theta = 0$) decides whether to invest I to increase energy performance ($\theta = 1$) or not.
4. Payoffs are realized

First Best Investment Path

Proposition 1

In the first best optimum, all investments are made at $t = 0$ and the (constant) share of efficient dwellings is $q_t^* = 1 - F(e^*)$ with $e^*/(1-\delta) = I$ for any $t > 0$. [δ is the discount factor]

Intuition

- The distribution of e is constant over time; hence, any investment should be made at $t = 0$
- A household of type e should invest in energy efficiency iff the investment cost is less than the net present value of the cumulative energy cost:

$$I \leq \sum_{k=0}^{\infty} \delta^k e = \frac{e}{1-\delta}$$

- Hence optimal investment and perfect matching (efficient dwellings are occupied by the highest types)

Decentralized Equilibrium with Energy Certification

- At $t = 0$, all households live in inefficient homes
- Households with the highest types anticipate that other highest types would purchase in the next periods if they invest and move out
- As the housing market is competitive, the price captures the full investment benefit
- Hence they invest as if they were going to stay forever in the dwelling, trading off the investment cost and the total discounted energy cost $e/(1-\delta)$.

Proposition 2

Perfect certification implements the first best optimum.

No Certification: $p_t^0 = p_t^1$

- They do not fully internalize the investment benefit because it has no market value
- Households invest iff

$$I \leq \frac{e}{1 - \delta(1 - m)}$$

- That is, the discount factor is $\delta(1 - m)$ as they may move out with per-period probability m after investment.
- However, **investments never stop** because incoming high types inevitably move in inefficient dwellings in each period and cannot but invest to consume less energy
- Mismatching on the housing market sustains investments in the long run

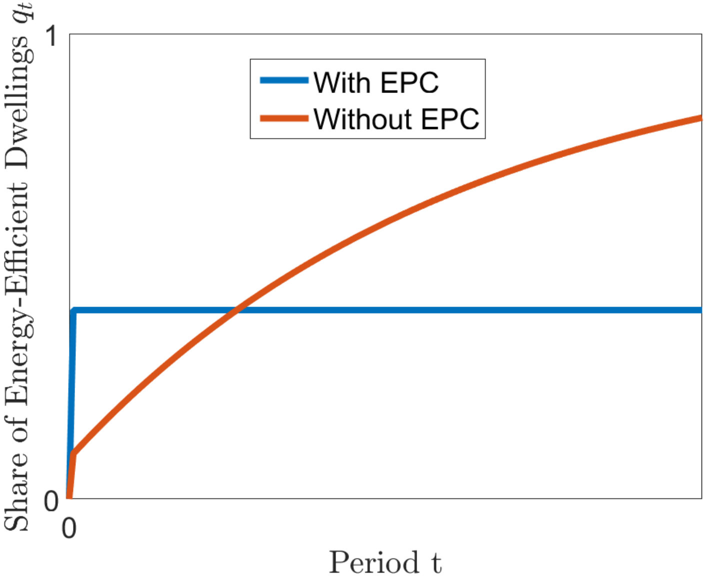
Proposition 3

Without certification:

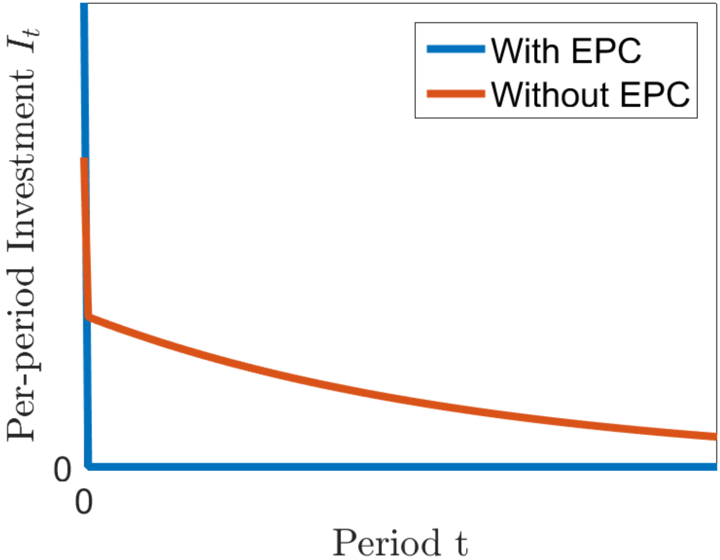
- Households never stop investing and $q_t \to 1$ in the long run
- The levels of per-period investments and energy use converge to zero in the long run: $E_t \to 0$ and $I_t \to 0$

- A too high energy performance and a too low energy consumption in the long run.

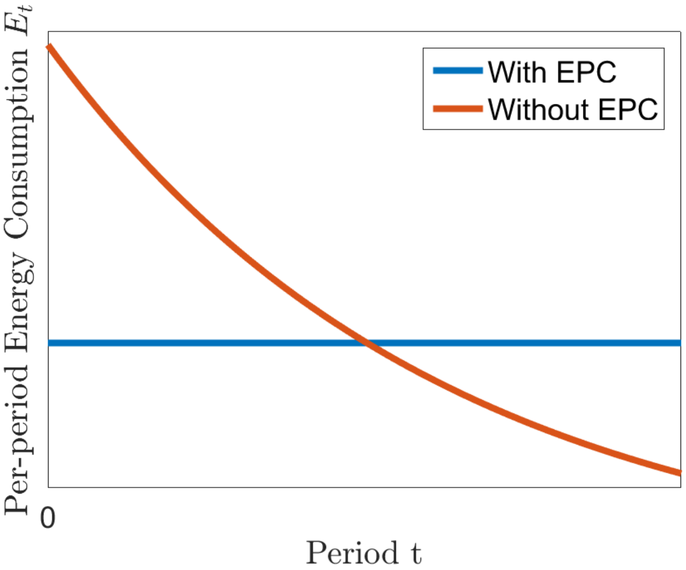
Building Stock



Investment Flow



Energy Consumption



Cumulative energy use

- Reminder: $e^* < \hat{e}$
- With EPC:

$$\frac{1}{1-\delta}\int_0^{e^*} e\,\mathrm{d}F(e)$$

- Without EPC:

$$\frac{1}{1-\delta(1-m(1-F(\hat{e}))}\int_0^{\hat{e}} e\,\mathrm{d}F(e)$$

- **We can have a higher consumption without EPC**, for example, if F combines
  - A mass of households above $\hat{e}$, who invest with or without certification (limiting under-investment witout EPC)
  - A mass of households below e^*, so that many consumers that live in inefficient dwellings does not use much energy (less concerns with imperfect matching)

- **New assumption:** Energy expenditure e generates an externality αe
- Hence too much energy consumption with EPCs
- Social cost function is

$$C = \sum_{t=0}^{\infty} \delta^t \left(\int_0^{+\infty} \mathbb{P}_t(\theta = 0|e)(1+\alpha)e \, \mathrm{d}F(e) + (q_{t+1} - q_t)I \right)$$

- **Question:** Do EPCs improve social welfare?
- **Answer:** Not always, because EPCs may increase energy consumption

Welfare comparison

EPCs improve welfare iff:

$$(1+\alpha)\left(\frac{\int_{e^*}^{\hat{e}} e\,\mathrm{d}F(e)}{1-\delta(1-m(1-F(\hat{e})))} - \frac{\delta m(1-F(\hat{e}))\int_0^{e^*} e\,\mathrm{d}F(e)}{(1-\delta)(1-\delta(1-m(1-F(\hat{e}))))}\right)$$

$$+I\left[\frac{1-\delta(1-m)}{1-\delta(1-m(1-F(\hat{e})))}(1-F(\hat{e}))-(1-F(e^*))\right]>0$$

with: $e^* = I(1-\delta)$ and $\hat{e} = I(1-\delta(1-m))$

- The sign of this (cumbersome) welfare difference is ambiguous
  - If α is very small, the EPC scenario converges to the first best
  - If α is large, EPCs may damage welfare if quick convergence of q_t towards 1, which depends on the distribution F (among other factors)

2. "Myopic" owners

- **New assumption:** Owners discount too much.
- Hence underinvestment with EPCs
- The welfare difference is:

$$\left(\frac{\int_{e^*}^{\hat{e}} e \, \mathrm{d}F(e)}{1-\delta(1-m(1-F(\hat{e})))} - \frac{\delta m(1-F(\hat{e}))\int_0^{e^*} e \, \mathrm{d}F(e)}{(1-\delta)(1-\delta(1-m(1-F(\hat{e}))))}\right)$$
$$+ I\left[\frac{1-\delta(1-m)}{1-\delta(1-m(1-F(\hat{e})))}(1-F(\hat{e}))-(1-F(e^*))\right] > 0$$

with $e^* = I(1-\mu)$ and $\hat{e} = I(1-\mu(1-m))$ and μ the owner's discount factor ($\mu < \delta$)

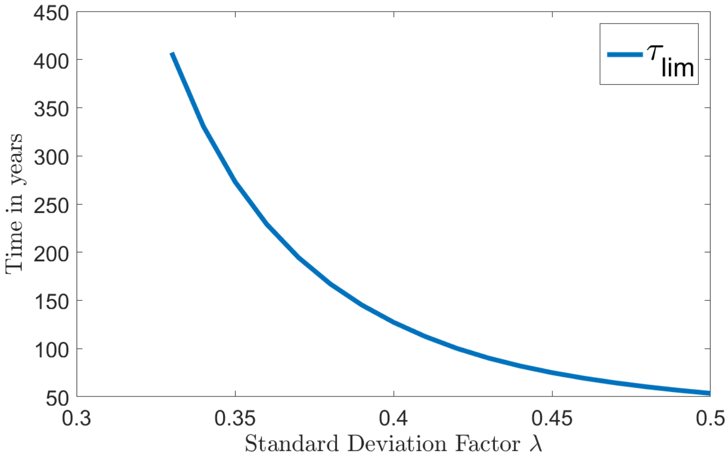
- Which is again ambiguous

Simulations
1. Calibration

- Moving probability $m = 3\%$ (INSEE 2013)
- Discount Rate = 10%
    - Results are robust to discount rate choice
- e is normally distributed: $F(e) \sim \mathcal{N}(\mu, \sigma^2)$ (survey "10,000 ménages")
- μ = conventional consumption per m^2 $\times$ average surface $\times$ energy price
    - Conventional consumption per m^2 = 232 kWh/m^2. Source: Giraudet et al. 2018
    - Average surface = 91 m^2 (INSEE 2013)
    - Energy price = 0.05 euros/kWh
- $\lambda = \sigma/\mu$ in [1%; 50%]
- $q_0 = 14.3\%$ (PHEBUS 2013)
- I = Insulation cost per m^2 $\times$ average surface $\times$ (1 - subsidy rate)
    - Insulation cost per m^2 = 263.75 euros/m^2 (Giraudet et al. 2018)

Simulations
2. results

Time beyond which cumulative energy savings without EPC exceeds savings with EPC as a function of σ/μ. In our data, $\sigma/\mu = 8\%$.



Takeaways

- In the absence of other market failures, EPCs implement the first best social optimum
- The impact of EPCs on the volume of investments and on the level of energy use is ambiguous
- As a result, in a second-best world where energy externalities are under-priced and/or where consumers show behavioral biases that hinder investments (myopia), EPCs could damage social welfare
- Preliminary simulation results suggest that it is unlikely to be the case in France.