Identifying Obstacles to Autonomous Energy Efficiency Improvement

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Akira Maeda, University of Tokyo

Makiko Nagaya, Showa Women's University

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Motivations

- Good technologies end up with wide-spread use?
- Standard economic theory:
  - Exogenous technological change / progress / improvement

$$Y = f(K, L) = AK^{\alpha}L^{1-\alpha}$$

In this model, the coefficient "*A*", called Solow residual, simply represents technological change, and is assumed to follow an autonomous increase.

  - Endogenous economic growth

The Solow residual "*A*" is assumed to be a function of capital input "*K*".

(More sophisticated versions assume that it can be a function of human capital as well as other economic factors.)

Initiated by Romer,1986;1990

Leading to Acemoglu's "directed technological change" (RES, 2002)

Motivations, cont'd

- A premise for these theories is that technology improves in either way and that once developed, nothing hinders its deployment.
- Counter examples:
  - Advanced coal combined cycle generation:

    Intensive R&D has been made for many years in Japan, and almost completed. The technology has not been fully deployed and operational even before recent adverse circumstances against coal.
  - PVs:

    PV technology has been constantly progressed, and high efficiency & low cost is attained, but its wide-spread use is not completed even in this affirmative atmosphere across the world.
  - Energy efficiency, in general:

    There are many high-efficiency technology options available, but the market still keeps using old, less-efficient options.

The point of the argument

Technology for efficiency improvement and/or cost reduction might be always welcome, and thus must have been widely used.

The reality is, however, not always the case.

What is the hindering force?

Business strategists may point out a possible gap or leap between stages of R&D and implementation, calling it

“Valley of death” / “Devil river” / “Darwinian sea”.

- These are only describing observations, not giving full explanations of the mechanism.

Economists employ their technical terms such as

“market imperfection” to explain the mechanism.

The point of the argument, cont'd

Adoption of technology for efficiency improvement and/or cost reduction can be hindered by the following factors:

- Microeconomic theory:

  Market imperfection, including

  market entry barrier / transaction cost / information asymmetry / negative externalities

- Investment theory:

  tangible as well as intangible costs, including

  Weighted Average of Cost of Capital (WACC) / risks and uncertainty / payback time / liquidity of asset and capital / opportunity costs

These theories imply that if the market is perfect, and if there is no extra cost needed for deployment after R&D, then nothing can hinder its adoption or wide-spread use.

Aim of the study

Research question:

Even if the market is perfect, and even if there is no extra cost needed for deployment after R&D, is it still possible that adoption of technology for efficiency improvement and/or cost reduction is hindered and face any obstacles?

The purpose of this study is to develop the <u>simplest model</u> for the explanation:

- it excludes any cost and/or market imperfection issue;
- assumptions are minimized;

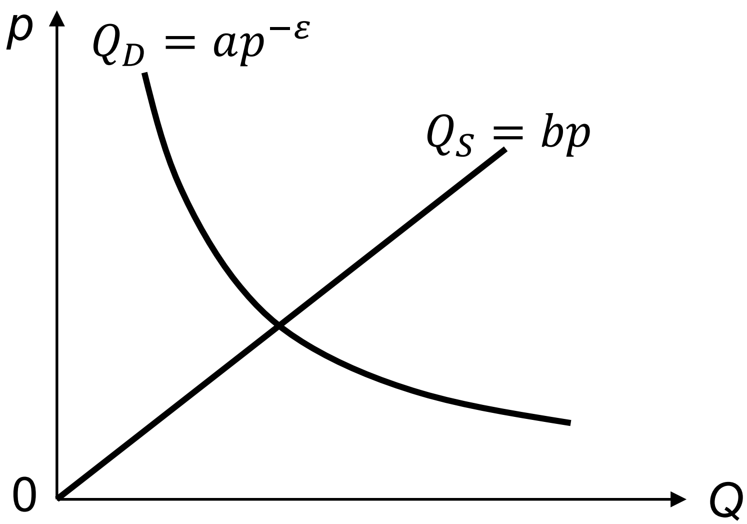
hoping it helps to provide implications for policy formulation

Model

- Consider a single good market partial equilibrium.
  Examples: electricity, gas, heat insulator for building, etc.
- Supply and demand functions are assumed as follows:

$$Q_D = ap^{-\varepsilon}$$
$$Q_S = bp$$

$\varepsilon (> 0)$: price elasticity of demand



Equilibrium:

$$p^* = a^{\frac{1}{1+\varepsilon}} b^{\frac{-1}{1+\varepsilon}}$$
$$Q^* = a^{\frac{1}{1+\varepsilon}} b^{\frac{\varepsilon}{1+\varepsilon}}$$

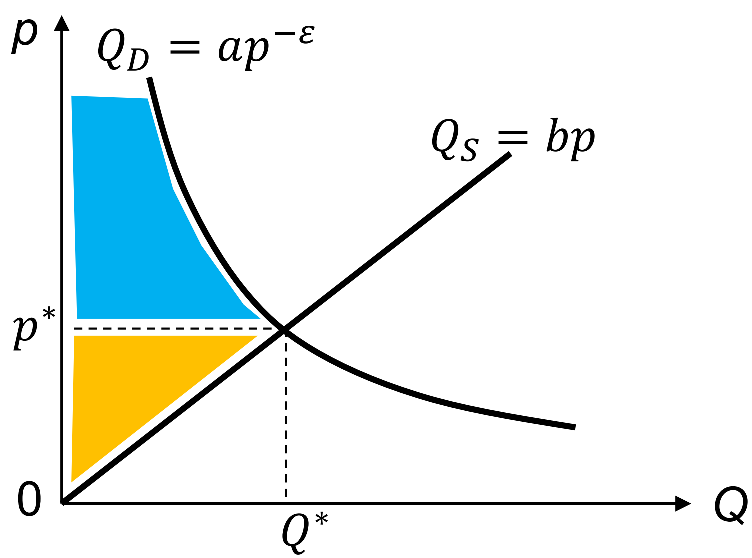
Surplus and social welfare

Consumer surplus (*CS*), Producer surplus (*PS*), and Social welfare (*W*)

$$CS = \int_{p^*}^{\bar{p}} ap^{-\varepsilon}\, dp$$

$$PS = b\int_{0}^{p^*} p\, dp$$

$$W = CS + PS$$



Equilibrium:

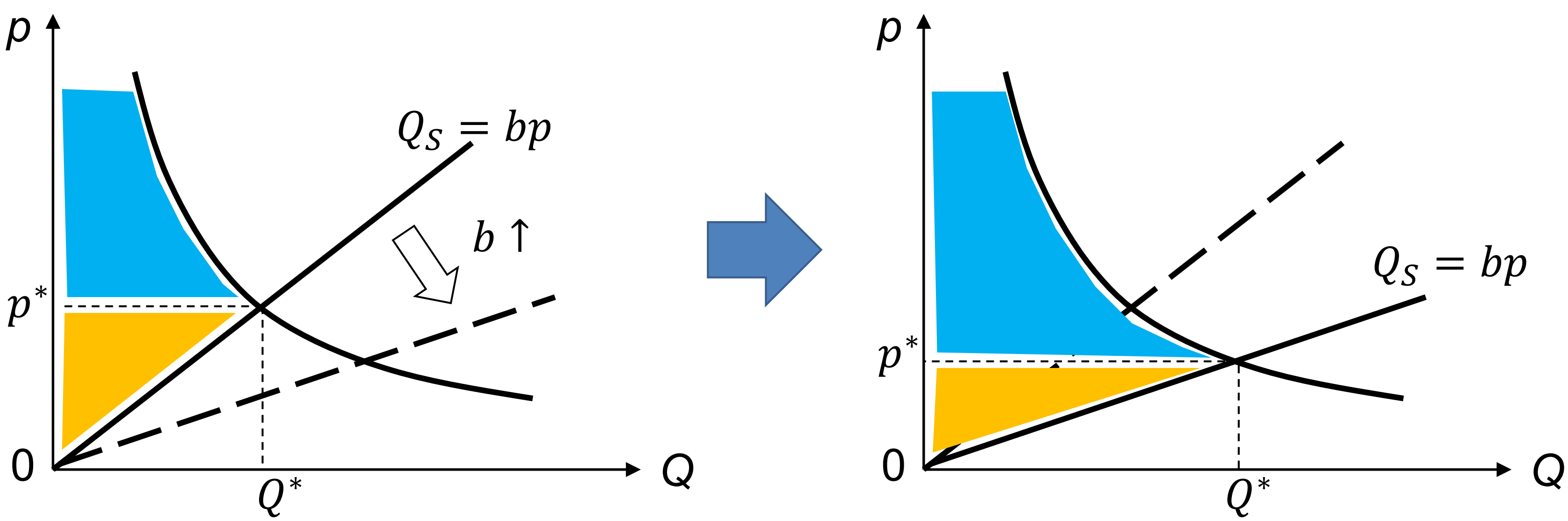
$$p^* = a^{\frac{1}{1+\varepsilon}} b^{\frac{-1}{1+\varepsilon}}$$

$$Q^* = a^{\frac{1}{1+\varepsilon}} b^{\frac{\varepsilon}{1+\varepsilon}}$$

Efficiency imp. & cost reduction

Efficiency improvement and/or cost reduction in the production of the good is described by the change in the slope of the marginal cost curve (that is identical to the supply curve).

Efficiency improvement = increase in b (b ↑)



Comparative statics

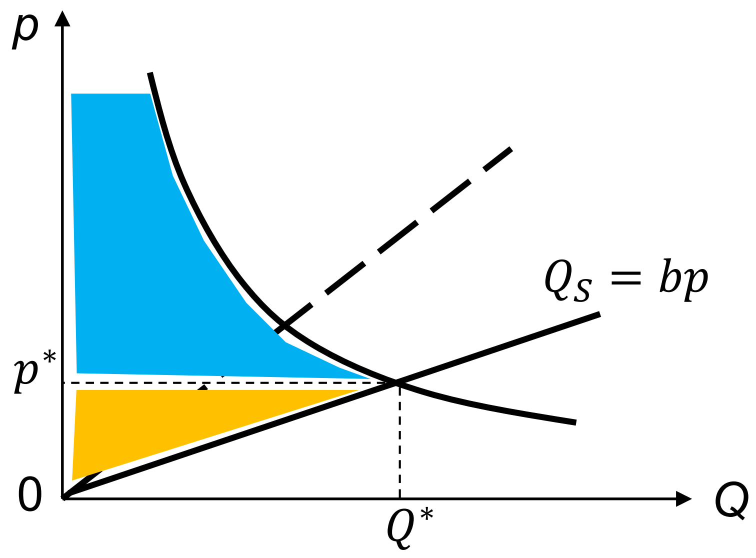
Eff. imp = inc. in b $(b \uparrow)$

$$\frac{dCS}{db} = \left(\frac{1}{1+\varepsilon}\right) a^{\frac{2}{1+\varepsilon}} b^{\frac{-2}{1+\varepsilon}} > 0 \ \forall b$$

$$\frac{dW}{db} \equiv \frac{dCS}{db} + \frac{dPS}{db} = \frac{1}{2} a^{\frac{2}{1+\varepsilon}} b^{\frac{-2}{1+\varepsilon}} > 0 \ \forall b$$

$$\frac{dPS}{db} = \frac{\varepsilon - 1}{2(1+\varepsilon)} a^{\frac{2}{1+\varepsilon}} b^{\frac{-2}{1+\varepsilon}}$$

$$\frac{dPS}{db} \begin{cases} > 0 \ \text{ for } \varepsilon > 1 \\ < 0 \ \text{ for } \varepsilon < 1 \end{cases}$$



Comparative statics, cont'd

Increase in b definitely improves CS and W.

i.e. The replacement to more efficient technology definitely benefits the consumer and the society as a whole.

However, effect on PS (producer surplus) is ambiguous:

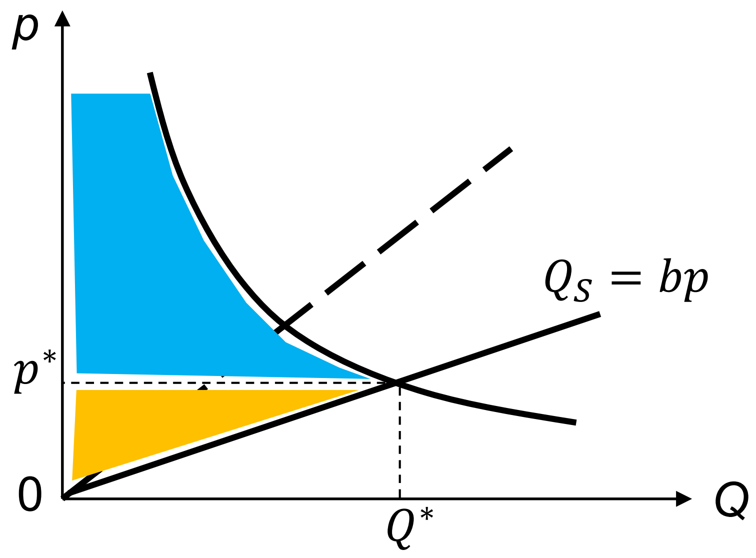
It can be either increased or decreased.

The divide is

whether ε (price elasticity of demand)

is greater than the unity or not.

$$\frac{dPS}{db}\begin{cases} > 0 \ \text{ for } \varepsilon > 1 \\ < 0 \ \text{ for } \varepsilon < 1 \end{cases}$$



Results

- It should be underlined that in the model, efficiency improvement / cost reduction technology requires no extra cost for the implementation.

  That is, free better technology is available to the producer.

So, why don't we adopt it? (but, a question is: who is "we"?)

- When $\varepsilon > 1$, producer surplus increases. Thus, all stake holders will be happy with the better technology. As a result, nobody is willing to stop it.
- In contrast, when $\varepsilon < 1$, producer surplus decreases, even though the sum of CS and PS is increasing. As a result, the producer (or the group of producers) has no motivation for the adoption of the better technology.

Results, cont'd

- The divide between "adopt" and "not-adopt" is entirely dependent on the price elasticity of demand, ε, which is a consumer-side parameter, not on the side of producer.

  It has nothing to do with producer's current technology and cost structure.

- On one hand, this seems a bit strange in that the efficient technology will always benefit the consumer and the society, but cannot be adopted due to the consumer themselves.

- On the other hand, the result seems quite reasonable: it should be a matter of shares of benefit. Since the total effect is always positive, "who can enjoy the great share" is important.

  This leads to an idea of necessity of governmental intervention that adjusts the shares by any public policy measures.

Policy implications

- For a good for which price elasticity of demand, ε, is small, efficiency improvement in production technology may not be autonomous.

  Note that typical goods of low demand elasticity are commodities with high-necessity for daily life.
  - Electricity is the typical one.
  - Most energy services may also be examples of this type.
  - Another example outside the energy sector may includes telephone network: Technology development in this sector has been on-going on especially methods of radio-wave after digitalization. 5G is now available, but the shift is not so swift, compared to that of 4G from 3G.

- Thus, for such necessary goods, any governmental intervention may be needed for efficiency improvement to be promoted.

Conclusions

Research question:

Even if the market is perfect, and even if there is no extra cost needed for deployment after R&D, is it still possible that adoption of technology for efficiency improvement and/or cost reduction is hindered and face any obstacles?

- Answer: Yes, it is.
- Why?— It is due to the nature of the necessary commodity-goods. The improvement benefits the society and the consumer, but may not suffice for the increase in the necessity.

- The promotion may not be autonomous, thus any policy measures will be needed for such cases.