Technology Adoption and Adaptation to Climate Change — A Case-Based Approach

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Ani Guerdjikova (Cergy)

May 18, 2011
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- developing more resistant crop varieties;

Barriers to adaptation:

- financial constraints;
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- incomplete understanding of the process of climate change;
- specificity of local conditions;
- difficulties in forecasting agents' reaction to an increase in ambiguity.

No available insurance against ambiguity due to:

- incomplete markets;
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The Model

- Finite community of farmers of size $I$. 

Technologies (crops): $A = f^{OA}$; $A_N$: traditional, "old" technology; $A_N$: alternative, "new", crop.

Outputs: $R = f_{\bar{r}}^{gr}$.

Information is given in form of a data set summarizing all past choices and outcomes: $D = (a_i^t, r_i^t)_{i = 1}^{2}$. 

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Evaluation of technology $a$ by agent $i$ given data set $D$:

$$V^i(a; D) = \alpha_i \max_{p \in H^i_a(D)} u \cdot p + (1 - \alpha_i) \min_{p \in H^i_a(D)} u \cdot p$$
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- $u$ — utility function with $u(\bar{r}) = 1$, $u(r) = 0$. 

$$H^{i}_{a}(D) = \gamma T + (1 - \gamma T) \sum_{r \in \Delta} f_{D}(a; r) \delta_{r}$$

- $\gamma$ — perceived ambiguity of a data-set of length $T$.
- $\Delta$ — the set of all possible probability distributions on $R$.
- $f_{D}(a; r)$ — frequency with which $(a; r)$ is observed in data set $D$.
- $\delta_{r}$ — probability distribution concentrated on $r$. 

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Optimists and Pessimists

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  - assign a weight of 1 to the best probability distribution in $H_{\alpha}^i(D)$;

- Pessimists: $\alpha_p = 0$, share $(1-\omega)$
  - assign a weight of 1 to the worst probability distribution in $H_{\alpha}^i(D)$;
  - interpret the lack of evidence as failure;
  - choose the technology with the highest number of successes:
    $$a_p(D) = \inf_{a_N} \inf_{r} D(a_N;r) < \inf_{a_O} \inf_{r} D(a_O;r)$$
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  \[
  a^o (D) = \begin{cases} 
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Two regimes of returns for the old technology:

Regime 1 — before climate change:

\[ \Pr_{fr}^{\text{og}} = q > \frac{1}{2} \]

Regime 2 — after climate change:

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\[ \Pr_{fr}^{\text{ng}} = q > \frac{1}{2} \]

Agents are unaware of the regime change and do not know the probabilities of success for the two technologies.
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- Regime 1 — before climate change:
  \[ \Pr \{ \bar{r} \mid a_O \} = q > \frac{1}{2} \]

- Regime 2 — after climate change:
  \[ \Pr \{ \bar{r} \mid a_O \} = 1 - q < \frac{1}{2} \]
  \[ \Pr \{ \bar{r} \mid a_N \} = q > \frac{1}{2} \]
Two regimes of returns for the old technology:

- Regime 1 — before climate change:
  \[ \Pr \{ \tilde{r} \mid a_O \} = q > \frac{1}{2} \]

- Regime 2 — after climate change:
  \[ \Pr \{ \tilde{r} \mid a_O \} = 1 - q < \frac{1}{2} \]
  \[ \Pr \{ \tilde{r} \mid a_N \} = q > \frac{1}{2} \]

Agents are unaware of the regime change and do not know the probabilities of success for the two technologies.
Defining Steady States

- A steady state is defined by a tuple of limit frequencies \((\phi^*_N; \phi^*_p)\), with which agents of type \(i \in \{o; p\}\) hold the new technology.

- These limit frequencies give rise to limit frequencies of observations in the data:

  \[
  f (a_N; \bar{r}) = \left[ \omega \phi^*_N + (1 - \omega) \phi^*_p \right] q \\
  f (a_O; \bar{r}) = \left[ \omega (1 - \phi^*_N) + (1 - \omega) (1 - \phi^*_p) \right] (1 - q)
  \]

- In the steady state, the limit frequencies \(\phi^*_N\) and \(\phi^*_p\) have to be optimal given the generated limit frequencies of observations:

  \[
  \phi^*_p = \begin{cases} 
  1, & f (a_N; \bar{r}) > f (a_O; \bar{r}) \\
  [0; 1] & f (a_N; \bar{r}) = f (a_O; \bar{r}) \\
  0, & f (a_N; \bar{r}) < f (a_O; \bar{r})
  \end{cases} \\
  \phi^*_N = \begin{cases} 
  1, & f (a_N; r) < f (a_O; r) \\
  [0; 1] & f (a_N; r) = f (a_O; r) \\
  0, & f (a_N; r) > f (a_O; r)
  \end{cases}
  \]
If $\omega > 1 - q$, the unique steady-state is given by: $\phi^*_{N} = \frac{\omega + q - 1}{\omega}$, $\phi^*_{P} = 1$.
If $\omega \leq 1 - q$, the system has three steady-states:
Stability of Steady States and Welfare

If $\omega \leq 1 - q$, the steady states are ordered in terms of average expected payoffs:

$$(\phi_{N}^{o} = 0; \phi_{N}^{p} = 1) \succ (\phi_{N}^{o} = 1; \phi_{N}^{p} = \frac{1-\omega-q}{1-\omega}) \succ (\phi_{N}^{o} = 1; \phi_{N}^{p} = 0).$$
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The payoff in the steady state $(\phi^o_N = 0; \phi^p_N = 1)$ is larger than the payoff in the unique steady state for $\omega > 1 - q$ and is maximized at $\omega = 0$. 
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$$
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$$

The payoff in the steady state $(\phi^*_o = 0; \phi^*_p = 1)$ is larger than the payoff in the unique steady state for $\omega > 1 - q$ and is maximized at $\omega = 0$.

However, when $\omega$ is close to 0 and the initial state of the economy is $(\phi^o_N = 0; \phi^p_N = 0)$, the economy converges with high probability to the worst steady state, $(\phi^*_o = 1; \phi^*_p = 0)$. 
If $\omega \leq 1 - q$, the steady states are ordered in terms of average expected payoffs:

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The payoff in the steady state $(\phi^*_N = 0; \phi^*_N = 1)$ is larger than the payoff in the unique steady state for $\omega > 1 - q$ and is maximized at $\omega = 0$.

However, when $\omega$ is close to 0 and the initial state of the economy is $(\phi^*_N = 0; \phi^*_N = 0)$, the economy converges with high probability to the worst steady state, $(\phi^*_N = 1; \phi^*_N = 0)$.

Hence, the optimal share of optimists is between $(0; 1)$.
Consider an economy with a low share of optimists, $\omega \leq 1 - q$. 
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Assume that the initial state is $(\phi_N^o = 0; \phi_N^p = 0)$ and there are $T$ observations of $a_O$ with frequency of success $f_D (a_O; \bar{r}) \in (1 - q; q)$. 
Consider an economy with a low share of optimists, \( \omega \leq 1 - q \).

Assume that the initial state is \( (\phi^o_N = 0; \phi^p_N = 0) \) and there are \( T \) observations of \( a_O \) with frequency of success \( f_D (a_O; \bar{r}) \in (1 - q; q) \).

An effective policy stimulating early adoption will provide incentives to the pessimists to switch to the new technology so that the economy could transition to the optimal steady state \( (\phi_*^o = 0; \phi_*^p = 1) \).
A subsidy $G$ is paid to everyone who adopts in the first period.
Subsidies for Early Adopters

- A subsidy $G$ is paid to everyone who adopts in the first period.
- An effective subsidy will induce pessimists to choose $a_N$, hence it has to contain an "ambiguity premium".
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Subsidies for Early Adopters

- A subsidy $G$ is paid to everyone who adopts in the first period.
- An effective subsidy will induce pessimists to choose $a_N$, hence it has to contain an "ambiguity premium".
- The government cannot distinguish between optimists and pessimists, hence, the subsidy, if effective, will be received by everyone in the society.
- It follows that the effective subsidy might be prohibitively costly, i.e., the price of inducing pessimists to choose the new technology might exceed the increase in expected returns.
Providing Additional Information

The government provides an additional data set $\tilde{D}$ of length $\tilde{T}$ with $\frac{\tilde{T}}{2}$ observations of $a_O$ and $\frac{\tilde{T}}{2}$ observations of $a_N$. The data set $\tilde{D}$ is representative of the performance of the two technologies:

$$f_{\tilde{D}}(a_O; \bar{r}) = \gamma_t \sum_{r} R_T f_{\tilde{D}}(a_0; r) + \tilde{s} $$

The relevance of the information in $\tilde{D}$ is $\tilde{s}_t(0; 1)$.

Given the data set $D[\tilde{D}$, the beliefs of agent $i$ about technology $a$ are:

$$H_i a_{D[\tilde{D}]} = \gamma_t \sum_{r} R_T f_{\tilde{D}}(a_0; r) + \tilde{s} \tilde{s} $$

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May 18, 2011  
Economics of Adaptation to Climate Change
Providing Additional Information

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- The data set $\tilde{D}$ is representative of the performance of the two technologies:

$$f_{\tilde{D}}(a_O; \bar{r}) = \frac{(1 - q)}{2}, \quad f_{\tilde{D}}(a_N; \bar{r}) = \frac{q}{2}.$$
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Providing Additional Information

- The government provides an additional data set \( \tilde{D} \) of length \( \tilde{T} \) with \( \frac{\tilde{T}}{2} \) observations of \( a_O \) and \( \frac{\tilde{T}}{2} \) observations of \( a_N \).
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- The relevance of the information in \( \tilde{D} \) is \( \tilde{s} \in (0; 1) \).
- Given the data set \( \tilde{D} \), the beliefs of agent \( i \in \{o, p\} \) about technology \( a \) are:

\[
H^i_a(D \cup \tilde{D}) = \left[ \gamma_{T'} + (1 - \gamma_{T'}) \frac{\sum_{r \in R} [Tf_{D}(a'; r) + \tilde{s}\tilde{T}f_{\tilde{D}}(a'; r)]}{T + \tilde{s}\tilde{T}} \right]
\]

\[
+ (1 - \gamma_{T'}) \frac{\sum_{r \in R} [Tf_{D}(a; r) + \tilde{s}\tilde{T}f_{\tilde{D}}(a; r)] \delta_r}{T + \tilde{s}\tilde{T}}.
\]
Stimulating Adoption by Providing Additional Information

- Pessimists and optimists differ w.r.t. their willingness to purchase additional information.
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If $\frac{sT}{2}$ is sufficiently large, i.e., the additional data is either sufficiently relevant or has sufficiently many observations, then:
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If $\frac{s\tilde{T}}{2}$ is sufficiently large, i.e., the additional data is either sufficiently relevant or has sufficiently many observations, then:

- pessimists will be willing to pay a strictly positive amount to obtain $\tilde{D}$;
Stimulating Adoption by Providing Additional Information

- Pessimists and optimists differ w.r.t. their willingness to purchase additional information.
- For a given frequency of observations,
  - optimists prefer to decide based on a shorter data set;
  - pessimists prefer to decide based on a longer data set.
- If $\frac{s \bar{T}}{2}$ is sufficiently large, i.e., the additional data is either sufficiently relevant or has sufficiently many observations, then:
  - pessimists will be willing to pay a strictly positive amount to obtain $\tilde{D}$;
  - pessimists will switch to the new technology upon obtaining $\tilde{D}$. 
Pessimists and optimists differ w.r.t. their willingness to purchase additional information.

For a given frequency of observations,
- optimists prefer to decide based on a shorter data set;
- pessimists prefer to decide based on a longer data set.

If \( \frac{s\tilde{T}}{2} \) is sufficiently large, i.e., the additional data is either sufficiently relevant or has sufficiently many observations, then:
- pessimists will be willing to pay a strictly positive amount to obtain \( \tilde{D} \);
- pessimists will switch to the new technology upon obtaining \( \tilde{D} \).

The behavior of optimists will remain unchanged and they will not be willing to purchase the additional data.
Conclusion

- A model of technology adoption triggered by climate change.
- Characterized and described the stability properties of the steady states.
- Discussion of the welfare properties and identification of the role of different types of agents in the process of innovation.
- Evaluation of two possible policies designed to stimulate innovation.