Smart Contracts, IoT Sensors and Efficiency: Automated Execution *vs.* Better Information

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SMART CONTRACT REVOLUTION?

- blockchain $\rightarrow$ smart contracts will make the business landscape more decentralized and democratic
- Szabo (1996): the car lease example
- it is *said* that smart contracts will
  - make contracting complete
  - allow us to get rid of courts
  - ... escrow, and other trusted enforcers
  - enable complete decentralization (dao's)
  - democratization of industries
- what are the benefits of smart contracts, really?
  - build a model

WHAT IS A SMART CONTRACT?

- computer program
- upon a trigger, *automatically* executes an agreement between the parties to the contract

- *key characteristic*: **does not allow reneging**, due to automated execution
- *key limitation*: the "trigger" and the "agreement" need to be well specified so they can be respectively digitally verified and executed
  - *caution*: not every agreement lends itself to smart-contracting
- *key dependency*: identifying and digitally verifying "trigger" occurrence requires appropriate sensors, typically connected digital sensors (IoT)

SMART CONTRACTS vs. SENSORS

- benefits of smart contracts often confused with those of digital sensors
- *though* the two technologies that can be implemented separately

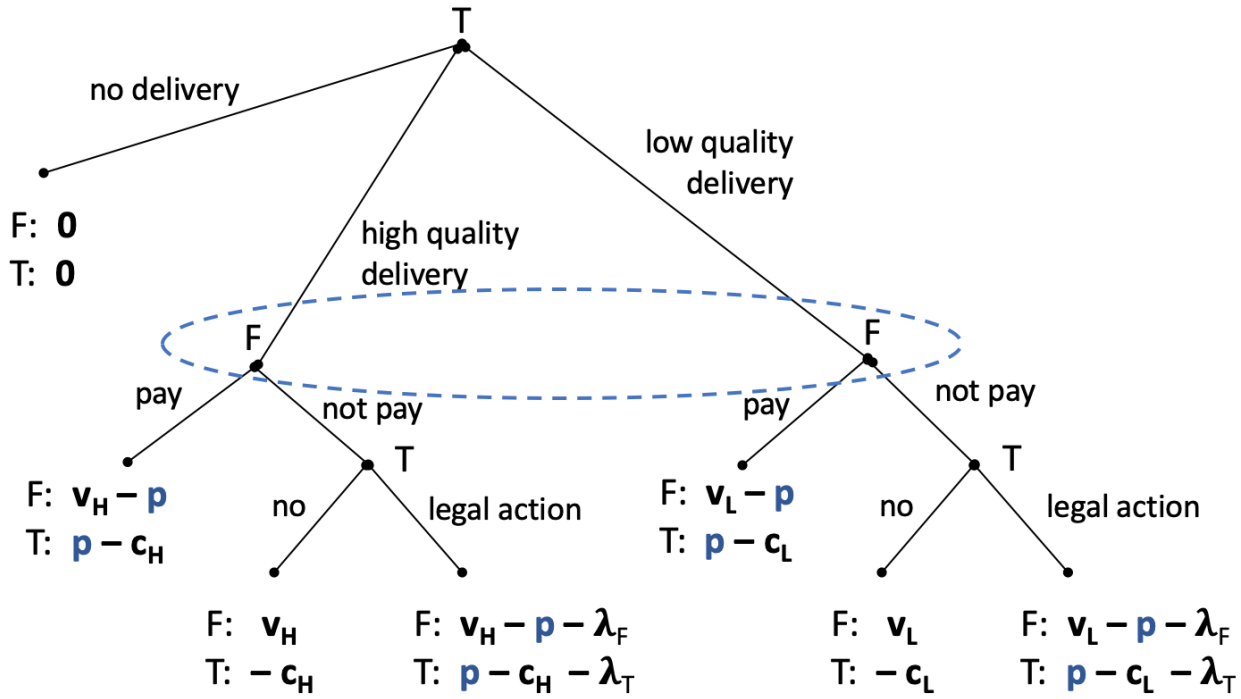
- we build a simple model to carefully separate effect of smart contracts and sensors
  - sensors expand the state space
  - smart contracts restrict the strategy space
- each has a different effect on the efficiency of a contract

SIMPLE MODEL: FRUIT SHIPMENT

- F contracts with T for the transportation of *fruit* at price p
- fruit properly refrigerated: F obtains v_H and T incurs c_H
- fruit not refrigerated, F obtains $v_L < v_H$ and T incurs $c_L < c_H$
- we assume that $v_H - c_H > v_L - c_L > 0$, i.e.,
  - it's always socially beneficial to trade
  - surplus created by high quality delivery is larger
- if the fruit is not shipped at all, both parties obtain 0
- after delivery, F should pay T
- **if a dispute is brought to a court**
  - F and T bear the cost λ_F and λ_T of legal action
  - the courts are always fair, and they are able to enforce performance of the contract terms in full

CONTRACT

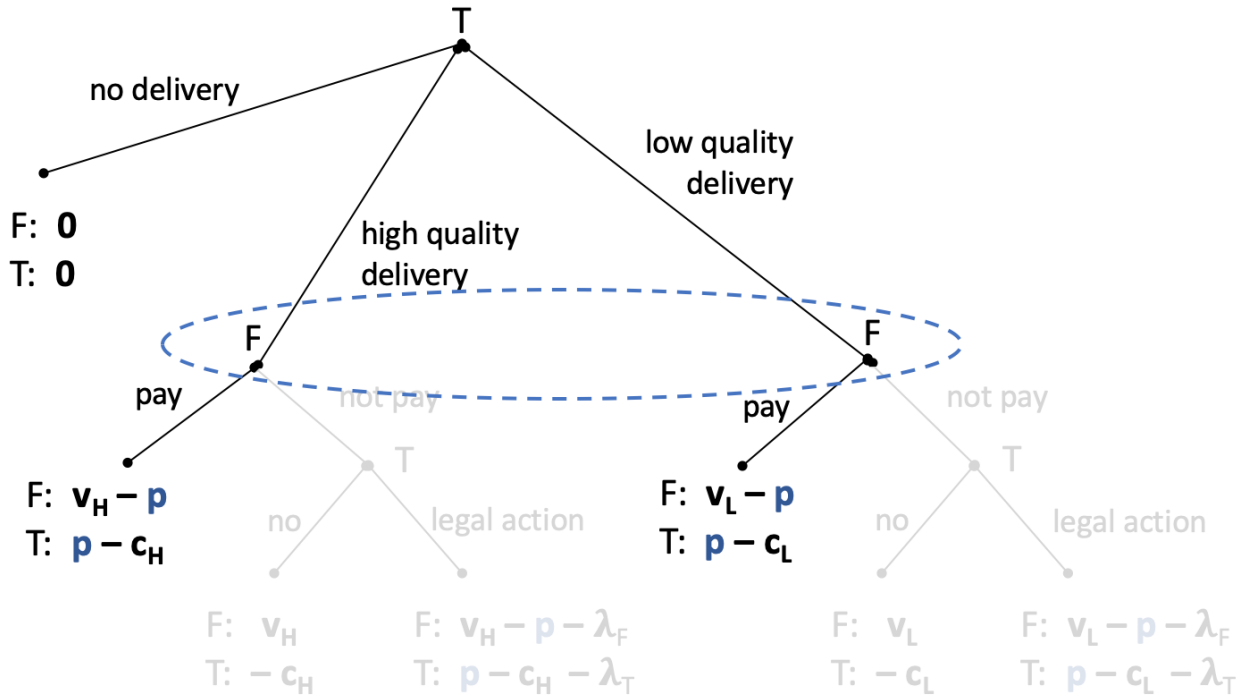
- refrigeration not observable to F (or verifiable to a court)
- payment (F to T) and the fact the fruit was delivered both verifiable



- the equilibrium trading is never efficient:
  - for $\lambda_T > v_L$, no contracting $\Longrightarrow$ 0 profits and social welfare
  - for $\lambda_T \leq v_L$, only low quality delivery is contracted and executed

ADDING SMART CONTRACT (ONLY)

- with smart contract, payment occurs automatically upon delivery
  - F no longer has a choice between "pay" or "not pay"

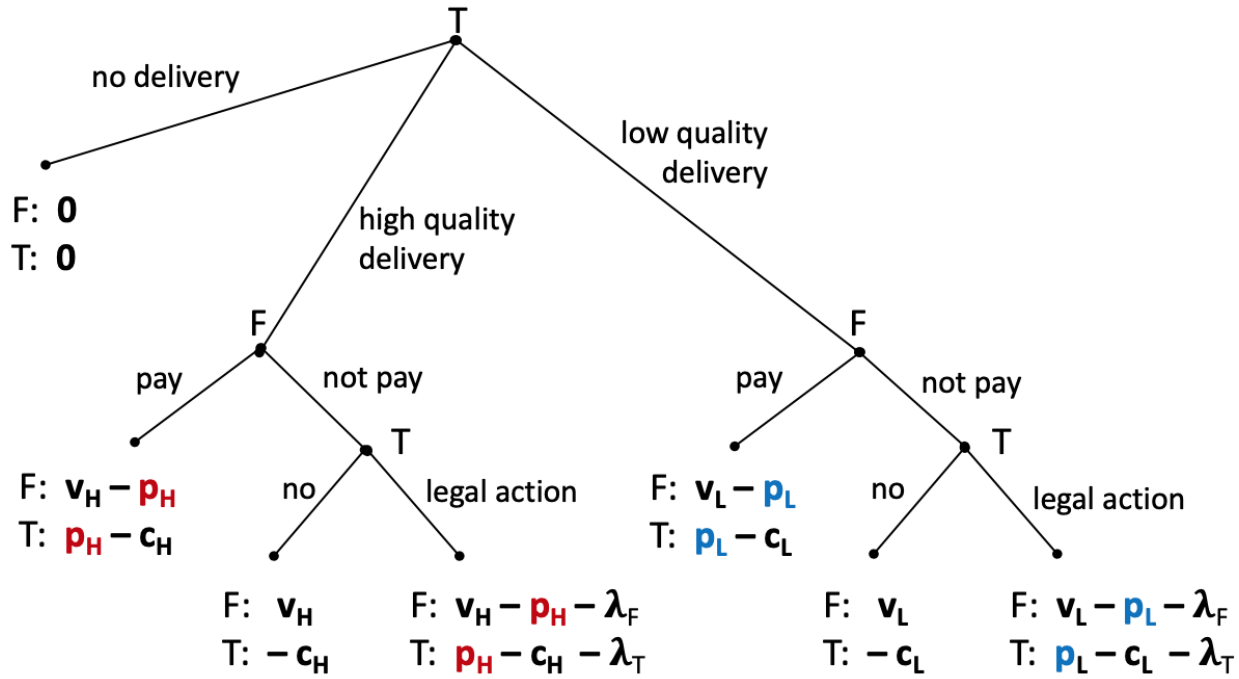


- in equilibrium
  - low quality delivery is contracted and executed whenever $c_L < v_L$

smart contract increases contracting space by $v_L \in (c_L, \lambda_T)$, but does not increase efficiency of trade

ADDING SENSORS (ONLY)

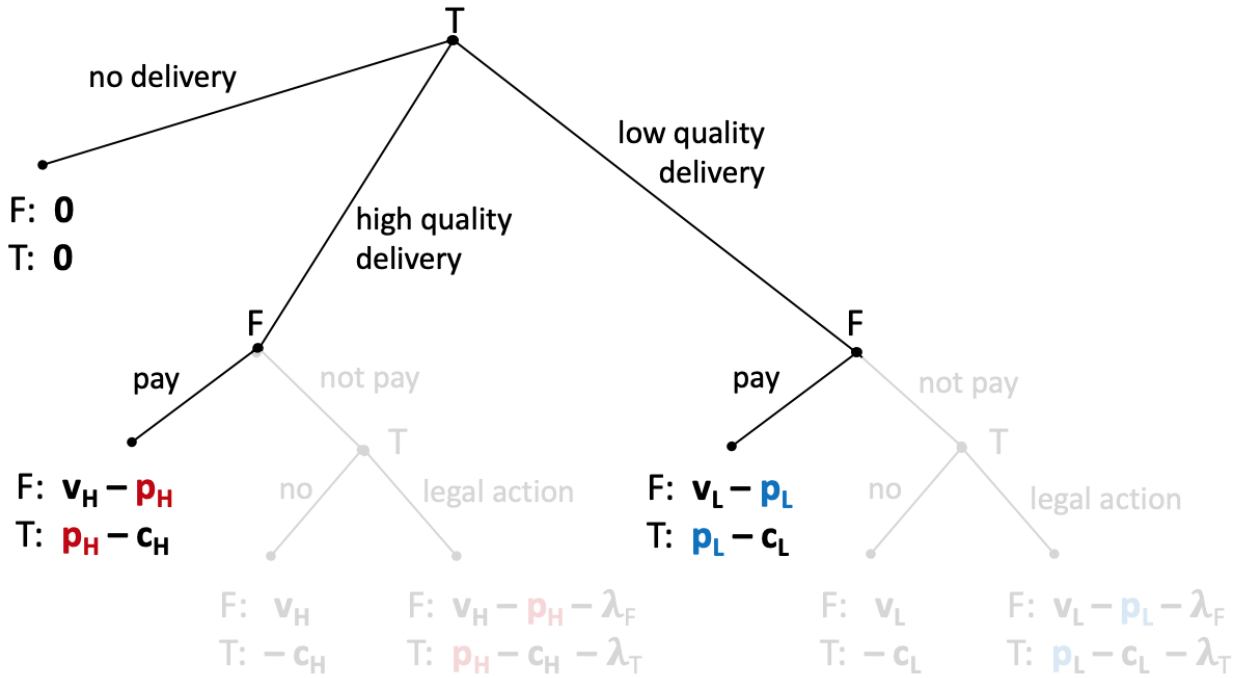
- sensors allow F (and the court) to distinguish between "refrigerated" and "not-refrigerated" shipment



- in equilibrium
  - for $\lambda_T > v_H$, no contracting $\implies$ 0 profits and social welfare
  - for $\lambda_T \leq v_H$, high quality delivery is contracted and executed
    - ★ social welfare $v_H - c_H > 0$ (efficient contracting)

sensors allow for efficient trade, and extend contracting region (somewhat)

ADDING SENSORS AND SMART CONTRACT



contracting in equilibrium is fully efficient

- *high quality delivery is contracted and executed whenever* $c_H < v_H$

DIFFERENT EFFECTS ON CONTRACTING

smart contracts and sensors affect the interactions differently:

- *sensors* **increase** *the state space over which the parties can contract*
- *smart contracts* **reduce** *strategy space*

SMART CONTRACT	SENSORS: NO	SENSORS: YES
NO	low-quality for $\lambda_T < v_L$	high-quality for $\lambda_T < v_H$
YES	low-quality for $c_L < v_L$	high-quality for $c_H < v_H$ (efficient)

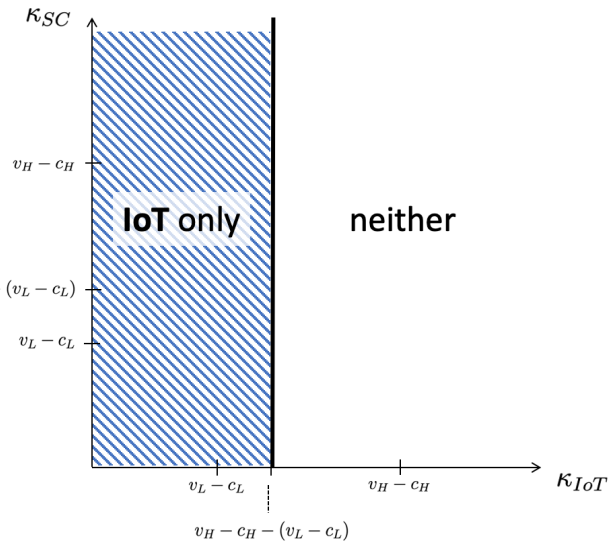
effect on the contracting efficiency

- smart contracts make contracting possible when it was not
- sensors increase efficiency of contracting when it occurs

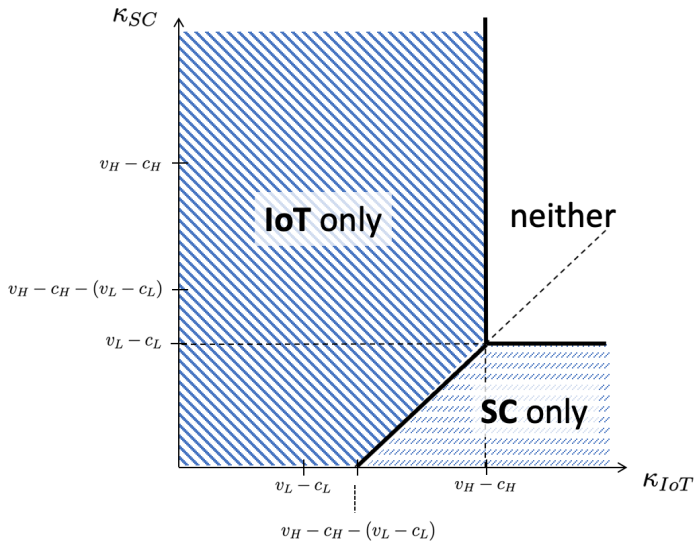
SOCIALLY OPTIMAL ADOPTION

social optimality of implementation depends on κ_{SC}, κ_{IoT} and λ_T

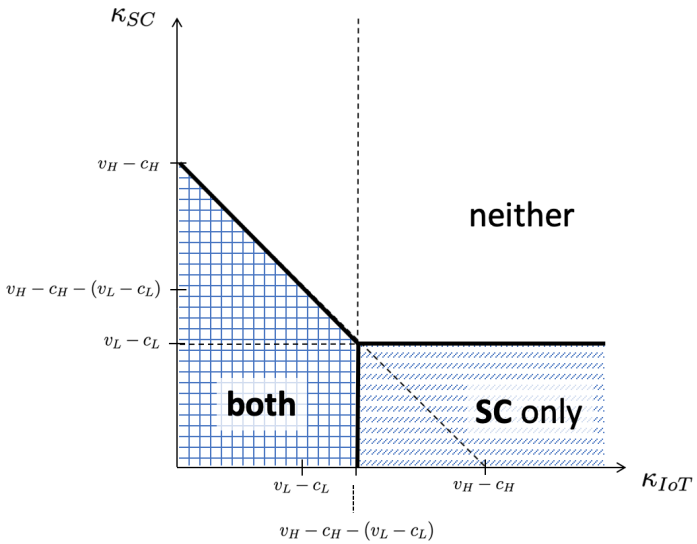
- sometimes adding the second technology brings no benefit
- sometimes implementation beneficial only if together



$\lambda_T < v_L$



$\lambda_T \in (v_L, v_H)$



$\lambda_T > v_H$

INCENTIVES TO ADOPT

- **smart contracts**

  when $\lambda_T < v_L$ and T has low bargaining power, F has incentives to impose smart contracts, which lowers social welfare, because it allows T to capture more surplus

- **sensors**

  when T has low bargaining power, also worse off with sensors (or sensors and smart contracts), even if social surplus increases

  - incentives to sabotage sensors

SMART CONTRACTS vs SENSORS

- carefully separating the effects of smart contracts and IoT
  - sensors **increase** the state space over which we can contract
  - smart contracts **reduce** strategy space

- **social optimality of adoption:** since both technologies can be implemented separately, we derive conditions when it's better to implement only smart contract, only IoT, and when both

- **incentives to adopt:** both technologies have potential to increase surplus, but there may be conflicting incentives for adoption

THANK YOU!