FUZZY CLOCK:

DECISION-SPECIFIC TIMING INFORMATION

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WHAT IS THE ECONOMIC QUESTION?

How much timing information does a policy decision require?

- Recorded event time can differ from the latent time at which a response occurs.
- The required correction depends on the response query and the decision loss.
- The paper studies an additive recording clock under a common-mean response restriction.

WHY DO MEAN TIMING AND TIMING DISPERSION ANSWER DIFFERENT QUESTIONS?

- A clock that is one day late on average shifts the best scheduled date by one day.
- Two clocks with that same mean can have different variances and therefore different values of flexible delivery.
- A scheduling query needs the mean; a schedule-versus-flexibility query also needs the variance under quadratic loss.

WHAT IS OBSERVED, MAINTAINED, AND CHOSEN?

- Observed: moments of the recorded response path.
- Maintained or validated: moments of the recording clock and the common-mean bridge.
- Chosen: a schedule or provision mode under a declared timing loss.

HOW DOES QUADRATIC LOSS SEPARATE THE TWO TIMING QUESTIONS?

$$\frac{L(a;\tau)}{T_0} = V_\tau + (a - \bar{\tau})^2$$

- $\bar{\tau}$ determines the best scheduled date $a^\star$.
- V_τ is the minimum scheduled loss and the value of perfect timing flexibility.
- Clock moments recover these objects through the response-moment recursion.

WHY DO SCHEDULING AND FLEXIBILITY REQUIRE DIFFERENT MOMENTS?

Proposition (Scheduling and flexibility)
Under quadratic loss, mean displacement determines the best scheduled date, while timing variance determines the value of flexibility around that date.

The same clock can therefore support the date choice and change the comparison between rigid and flexible provision.

HOW DOES CLOCK BLUR ENTER THE POLICY QUERY?

Latent response

Additive recording clock

Recorded path and decision

WHY IS THE TIMING-INFORMATION HIERARCHY SHARP?

Theorem (Sharp timing-information hierarchy)
For any order r, clock laws can agree through moment $r - 1$ and differ at moment r. Within the stated clock and response classes, corresponding latent paths can produce the same recorded response and the same lower-order summary while having different rth latent-response moments.

The moment-transport recursion is therefore paired with a matching lower-order impossibility result.

WHAT IS THE MINIMUM INFORMATION FOR A POLYNOMIAL DECISION?

Proposition (Decision-specific timing hierarchy)
For polynomial timing loss, the moments entering expected loss determine the required clock summary. Lower-order summaries can preserve the scheduled-date ranking while changing minimum loss and the preferred provision mode.

The information requirement follows the decision functional rather than the full timing distribution.

WHICH TIMING SUMMARY IS SUFFICIENT FOR A DECLARED DECISION?

- List the response moments entering expected loss for the decision menu.
- Use the clock recursion to recover those moments from recorded responses and validated clock moments.
- The sharp hierarchy shows that the next omitted clock moment can change the next decision object.

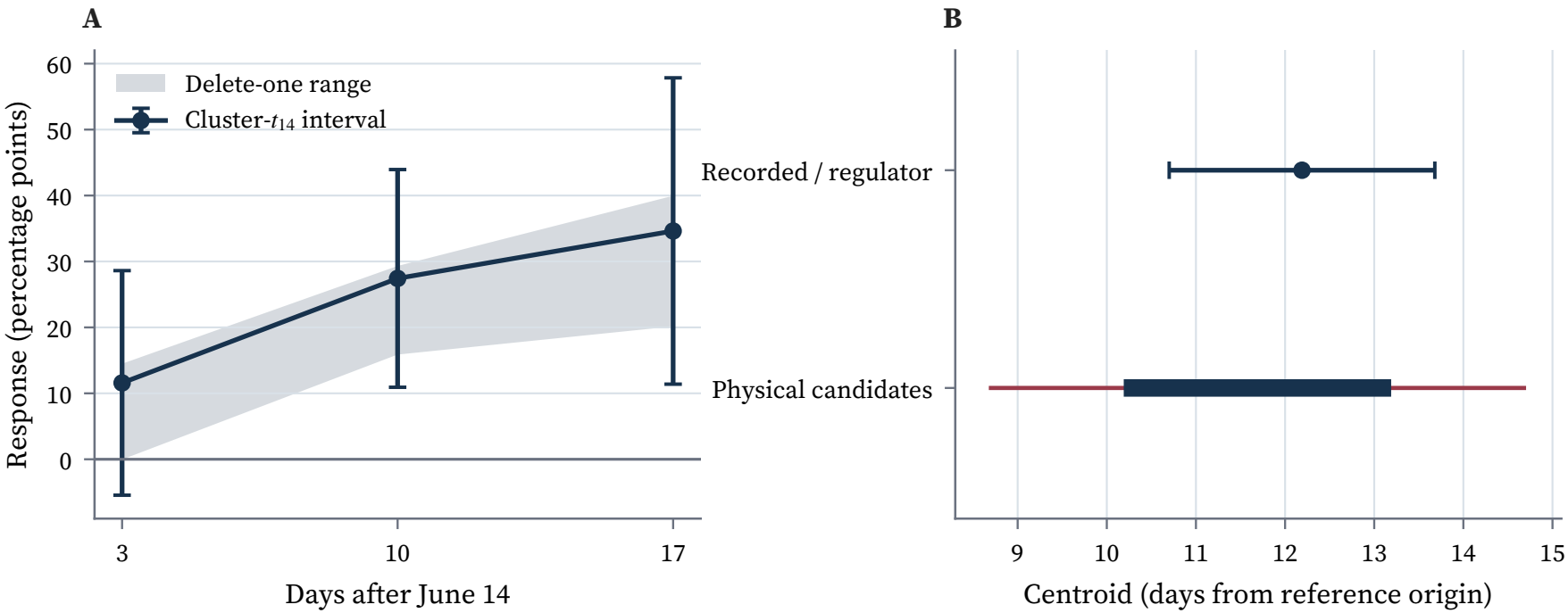
WHERE SHOULD TIMING VALIDATION EFFORT GO?

- The decision menu determines which response moments enter expected loss.
- The clock recursion maps those moments to a finite set of clock moments.
- The lower-order construction identifies the first omitted timing feature that can change the decision.

WHAT ARE THE THREE GAS CALCULATIONS?

- An estimated network response describes the recorded event-time path.
- A maintained clock translates recorded origins into candidate latent timing.
- An executable delivery rule maps the recovered query into storage or provision choices.

HOW DOES A RECORDED NETWORK RESPONSE ENTER THE CLOCK CALCULATION?



Network response and event-time translation in the main gas application.

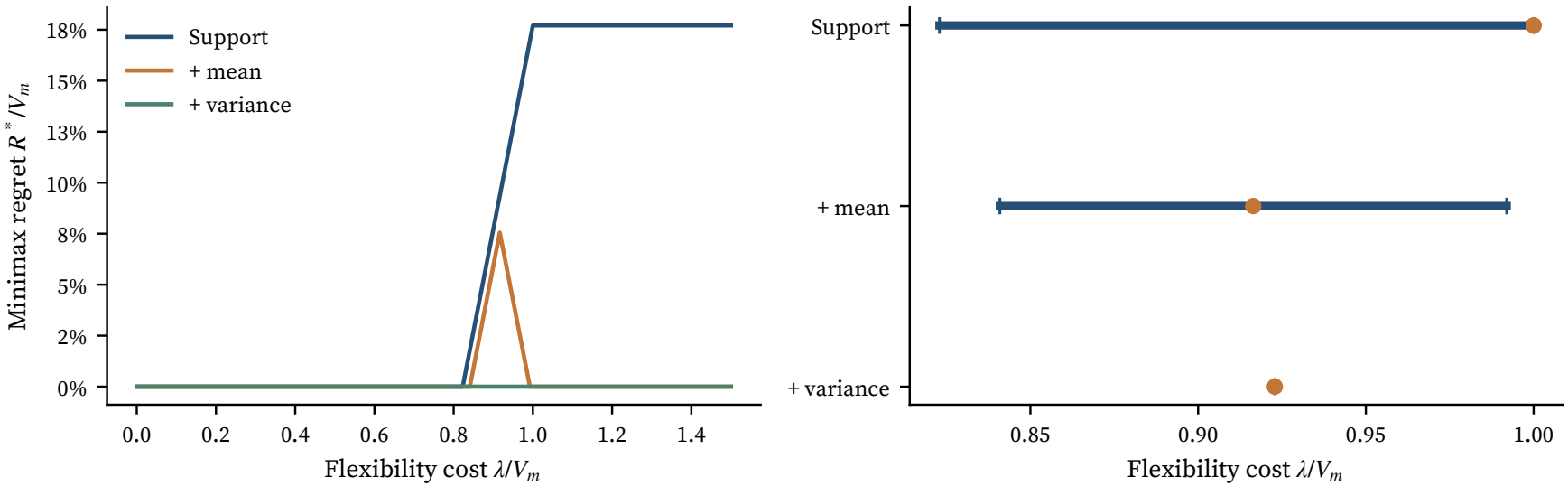
WHAT VALIDATION INPUTS SUPPORT THE CALCULATION?

- Clock moments may come from validation records, engineering constraints, or external calibration.
- Response-dependent recording requires cross-moments beyond the independent-clock recursion.
- Sampling uncertainty enters the downstream cost comparison through the estimated response and clock inputs.

How does the gas exercise keep three sources of uncertainty visible?

- Response uncertainty comes from the network-response estimation design.
- Timing uncertainty comes from the maintained or validated clock law.
- Decision uncertainty enters through storage costs, feasible delivery rules, and the downstream loss comparison.

HOW DOES MISSING CLOCK INFORMATION CHANGE POLICY REGRET?



Appendix validation-information ablation and execution regret.

WHAT DOES THE APPLICATION ESTABLISH?

- The response estimate, clock calibration, and delivery rule remain separate inputs.
- Information ablations show which timing summaries change recovered queries.
- Policy comparisons report the loss induced by using a coarser clock summary.

WHICH LITERATURES HELP PLACE THE QUESTION?

- Schennach (2004, 2007): nonlinear models with measurement error.
- Abbring and van den Berg (2003): nonparametric identification in duration models.
- Chernozhukov, Fern'andez-Val, and Melly (2013): target-specific counterfactual functionals.
- This paper asks which moments of a recording clock are sufficient for a stated timing decision.

WHICH PARTS OF THE GAS CALCULATION ARE CAUSAL?

- The network response inherits the empirical design used to estimate it.
- The latent-time translation is conditional on the maintained clock law.
- The provision comparison is conditional on the declared loss and feasible actions.

WHAT SHOULD THE READER CARRY FORWARD?

1. Timing information is decision specific.
2. Moment recursion gives both recovery and a sharp hierarchy.
3. A policy calculation should keep response, clock, and execution rule visible.

TECHNICAL APPENDIX

WHICH DEFINITIONS AND ASSUMPTIONS ORGANIZE THE PAPER?

- Assumption: Common-mean clock condition
- Definition: Query-identifying timing summary

HOW DO THE MAIN RESULTS BUILD ON ONE ANOTHER?

Sharp timing-information hierarchy

Decision-specific timing hierarchy

Scheduling and flexibility

WHICH FORMAL RESULTS SUPPORT THE ARGUMENT?

- Theorem: Sharp timing-information hierarchy
- Theorem: Minimum timing information for polynomial decisions
- Proposition: Interval-anchored causal contrast
- Proposition: Scheduling and flexibility
- Proposition: Moment transport recursion
- Proposition: Decision fiber and common bridges
- Corollary: Clock conservation

WHICH SCOPE CONDITIONS GOVERN THE CLAIMS?

- The network response inherits the empirical design used to estimate it.
- The latent-time translation is conditional on the maintained clock law.
- The provision comparison is conditional on the declared loss and feasible actions.