Supplementary methods and complete revised comparisons

Online Resource 1 for Within group policy detail and predictive recovery in regional innovation assessment

S1 Feature construction and exact nesting

The raw data contain 31 regions and eleven retained tool counts. Add c at the original-tool level. Primary K indexes P3/P5; F indexes P2/P6/P9; D is P1; S indexes P4/P7/P8/P10/P11. Coarse features are Helmert ILRs of four arithmetic sums. Within-group Helmert ILRs have dimensions 1, 2 and 4, in K/F/S order. No within-group coordinate is supplied by singleton D. Quantity is ln(1+raw total), never smoothed. The source-category sensitivity uses supply P2/P3/P4/P5, demand P1, environment P6/P7/P8/P9/P10/P11. Its dimensions are two coarse and eight fine coordinates. Four-group recovery simulations are not interpreted as simulation results for the source partition. For a d-part vector, Helmert coordinate j assigns 1/sqrt[j(j+1)] to each of its first j log parts and -j/sqrt[j(j+1)] to log part j+1, for j=1,...,d-1. Each block is centered and divided by sqrt(mean of column training variances). The augmented path with infinite fine penalty equals the entire coarse path to numerical tolerance. Infinite coarse penalty need not remove fine information. These are nested predictors, not claims of causal or geometrically orthogonal separation between amalgamation coordinates and within-group coordinates.

S2 Complete empirical comparisons

The primary benchmark includes quantity without penalization. In the quantity-penalized sensitivity, quantity moves into the common coarse block and the no-block benchmark consequently contains capacity and lagged outcome only. This changes the quantity baseline but leaves the coarse-to- augmented comparison exactly nested. All models tune inside the outer training data. Alternative partitions and sensitivities are exploratory checks, not alternative headline selections.

Table S1 All nested empirical increments

Outcome	Variant	Holdout	Coarse RMSE	Augmented RMSE	MSE change %
Contracts	Primary	Province	0.3345	0.4068	+48.0
Contracts	Primary	Macroregion	0.3412	0.4055	+41.3
Contracts	c=0.25	Province	0.3363	0.3667	+18.9
Contracts	c=0.25	Macroregion	0.3412	0.3667	+15.5
Contracts	c=1	Province	0.3306	0.3974	+44.5
Contracts	c=1	Macroregion	0.3412	0.3989	+36.7
Contracts	Quantity penalized	Province	0.3367	0.4222	+57.2
Contracts	Quantity penalized	Macroregion	0.3283	0.4191	+62.9
Contracts	Source categories	Province	0.3346	0.3977	+41.3
Contracts	Source categories	Macroregion	0.3412	0.4049	+40.9
Grants	Primary	Province	0.1278	0.1330	+8.3
Grants	Primary	Macroregion	0.1580	0.1486	-11.6

Outcome	Variant	Holdout	Coarse RMSE	Augmented RMSE	MSE change %
Grants	c=0.25	Province	0.1281	0.1337	+9.0
Grants	c=0.25	Macroregion	0.1583	0.1507	-9.3
Grants	c=1	Province	0.1278	0.1419	+23.3
Grants	c=1	Macroregion	0.1580	0.1463	-14.3
Grants	Quantity penalized	Province	0.1196	0.1250	+9.4
Grants	Quantity penalized	Macroregion	0.1501	0.1445	-7.3
Grants	Source categories	Province	0.1279	0.1385	+17.2
Grants	Source categories	Macroregion	0.1582	0.1490	-11.3

Positive changes mean deterioration. Every comparison retains identical coarse features. Full baseline, MAE, bias, prediction and penalty outputs are supplied in Online Resource 2.

S3 Block losses and case diagnostics

Table S2 Macroregional losses in the primary design

Outcome	Block	Coarse MSE	Augmented MSE	Difference
Contracts	East	0.0999	0.2488	0.1490
Contracts	Central	0.2006	0.2006	0.0000
Contracts	West	0.1095	0.1095	0.0000
Contracts	Northeast	0.0309	0.0309	0.0000
Grants	East	0.0218	0.0218	0.0000
Grants	Central	0.0322	0.0322	0.0000
Grants	West	0.0269	0.0192	-0.0077
Grants	Northeast	0.0133	0.0144	0.0011

Mean squared log errors within each block. Overall loss weights each province equally. East/Central/West/Northeast contain 10/6/12/3 provinces.

Table S3 Outcome-triggered complete deletion refits

Outcome	Excluded	Holdout	Coarse RMSE	Augmented RMSE	MSE change %
Contracts	Hainan	Province	0.3043	0.3320	+19.0
Contracts	Hainan	Macroregion	0.3506	0.3734	+13.4
Grants	Xinjiang	Province	0.1209	0.1261	+9.0

Outcome	Excluded	Holdout	Coarse RMSE	Augmented RMSE	MSE change %
Grants	Xinjiang	Macroregion	0.1392	0.1344	-6.8

Each row uses thirty regions and refits all scaling, inner tuning and outer predictions. Cases were selected after primary losses were inspected. These exploratory diagnostics are neither prespecified validation nor grounds for removing observations from the main analysis.

S4 Known-signal simulation and reference models

The mean is X beta plus sigma sqrt[q/(1-q)] g. X has five columns; sigma uses residual sum of squares divided by 26. g is the first K, F or S within-group coordinate, residualized against [X,C] on the fixed real design and normalized to RMS one. Coarse inner products are checked numerically and published. This full-design operation defines the generating direction; it has no access to synthetic y. The fine model can represent the direction together with X and C. The matched oracle retains C but knows g. The ideal oracle knows both g and that coarse coefficients are zero. Oracles are unavailable knowledge references, not attainable predictors. Their gap from the augmented method is conditional on these stipulations. There are 28 domain/noise/direction/q scenarios: two domains, two noise regimes, and seven cases per regime (shared null plus three directions at q=0.25/0.50). Each has 500 repetitions and three reported procedures. Thus 84 summary rows and 42,000 synthetic method-replicate records are supplied. Normal variance is sigma squared. Wild noise is sigma times HC2-adjusted residual magnitudes normalized to RMS one and independent equiprobable signs; variance is known by construction. Noise draws are shared across methods, directions and q within a regime. Seed is 20261026. These are synthetic outcomes, not additional observed regions. Both success measures use a 5% MSE reduction against the identical coarse procedure. Expected independent-outcome MSE at each province is (prediction-known mean)^2 plus known variance. Monte Carlo SE of a success proportion p is sqrt[p(1-p)/500]. Neither loss is a causal measure. Validation MSE is a noisy comparison of procedures, whereas synthetic expected MSE refers to the known fixed design and generating mechanism.

Table S4a Full recovery probabilities for validation MSE

Outcome	Noise	Direction	q	Fine	Matched	Ideal
Contracts	normal	null	0	8.4 (1.2)	8.8 (1.3)	31.8 (2.1)
Contracts	normal	K	0.25	33.0 (2.1)	76.6 (1.9)	80.2 (1.8)
Contracts	normal	K	0.5	66.6 (2.1)	98.6 (0.5)	99.4 (0.3)
Contracts	normal	F	0.25	40.8 (2.2)	79.8 (1.8)	85.0 (1.6)
Contracts	normal	F	0.5	80.0 (1.8)	99.4 (0.3)	99.6 (0.3)
Contracts	normal	S	0.25	36.4 (2.2)	79.4 (1.8)	86.2 (1.5)
Contracts	normal	S	0.5	81.6 (1.7)	100.0 (0.0)	100.0 (0.0)
Contracts	wild	null	0	15.2 (1.6)	4.2 (0.9)	16.4 (1.7)
Contracts	wild	K	0.25	25.0 (1.9)	58.2 (2.2)	63.2 (2.2)
Contracts	wild	K	0.5	58.8 (2.2)	100.0 (0.0)	100.0 (0.0)
Contracts	wild	F	0.25	32.2 (2.1)	42.8 (2.2)	49.2 (2.2)
Contracts	wild	F	0.5	64.0 (2.1)	96.4 (0.8)	97.8 (0.7)
Contracts	wild	S	0.25	44.4 (2.2)	97.8 (0.7)	98.0 (0.6)

Outcome	Noise	Direction	q	Fine	Matched	Ideal
Contracts	wild	S	0.5	86.6 (1.5)	100.0 (0.0)	100.0 (0.0)
Grants	normal	null	0	7.0 (1.1)	5.4 (1.0)	31.4 (2.1)
Grants	normal	K	0.25	30.0 (2.0)	78.6 (1.8)	83.8 (1.6)
Grants	normal	K	0.5	61.8 (2.2)	99.2 (0.4)	99.8 (0.2)
Grants	normal	F	0.25	45.8 (2.2)	80.4 (1.8)	85.8 (1.6)
Grants	normal	F	0.5	82.2 (1.7)	100.0 (0.0)	100.0 (0.0)
Grants	normal	S	0.25	36.2 (2.1)	79.6 (1.8)	86.4 (1.5)
Grants	normal	S	0.5	80.2 (1.8)	99.8 (0.2)	100.0 (0.0)
Grants	wild	null	0	10.6 (1.4)	12.0 (1.5)	30.0 (2.0)
Grants	wild	K	0.25	22.2 (1.9)	59.4 (2.2)	71.2 (2.0)
Grants	wild	K	0.5	55.4 (2.2)	100.0 (0.0)	100.0 (0.0)
Grants	wild	F	0.25	41.2 (2.2)	80.6 (1.8)	85.6 (1.6)
Grants	wild	F	0.5	80.2 (1.8)	100.0 (0.0)	100.0 (0.0)
Grants	wild	S	0.25	36.2 (2.1)	90.4 (1.3)	94.4 (1.0)
Grants	wild	S	0.5	84.2 (1.6)	100.0 (0.0)	100.0 (0.0)

Table S4b Full recovery probabilities for expected independent-outcome MSE

Outcome	Noise	Direction	q	Fine	Matched	Ideal
Contracts	normal	null	0	0.0 (0.0)	0.0 (0.0)	17.2 (1.7)
Contracts	normal	K	0.25	27.0 (2.0)	92.8 (1.2)	94.8 (1.0)
Contracts	normal	K	0.5	78.4 (1.8)	100.0 (0.0)	100.0 (0.0)
Contracts	normal	F	0.25	47.0 (2.2)	96.4 (0.8)	97.6 (0.7)
Contracts	normal	F	0.5	96.4 (0.8)	100.0 (0.0)	100.0 (0.0)
Contracts	normal	S	0.25	40.4 (2.2)	97.4 (0.7)	98.8 (0.5)
Contracts	normal	S	0.5	93.6 (1.1)	100.0 (0.0)	100.0 (0.0)
Contracts	wild	null	0	0.2 (0.2)	0.0 (0.0)	12.6 (1.5)
Contracts	wild	K	0.25	8.2 (1.2)	98.2 (0.6)	99.0 (0.4)
Contracts	wild	K	0.5	75.6 (1.9)	100.0 (0.0)	100.0 (0.0)
Contracts	wild	F	0.25	29.2 (2.0)	81.6 (1.7)	87.0 (1.5)
Contracts	wild	F	0.5	98.8 (0.5)	100.0 (0.0)	100.0 (0.0)

Outcome	Noise	Direction	q	Fine	Matched	Ideal
Contracts	wild	S	0.25	32.0 (2.1)	100.0 (0.0)	100.0 (0.0)
Contracts	wild	S	0.5	97.6 (0.7)	100.0 (0.0)	100.0 (0.0)
Grants	normal	null	0	0.0 (0.0)	0.2 (0.2)	17.8 (1.7)
Grants	normal	K	0.25	21.8 (1.8)	95.4 (0.9)	97.6 (0.7)
Grants	normal	K	0.5	71.0 (2.0)	100.0 (0.0)	100.0 (0.0)
Grants	normal	F	0.25	53.4 (2.2)	96.0 (0.9)	97.2 (0.7)
Grants	normal	F	0.5	97.4 (0.7)	100.0 (0.0)	100.0 (0.0)
Grants	normal	S	0.25	42.0 (2.2)	96.2 (0.9)	97.8 (0.7)
Grants	normal	S	0.5	94.6 (1.0)	100.0 (0.0)	100.0 (0.0)
Grants	wild	null	0	0.0 (0.0)	0.0 (0.0)	18.4 (1.7)
Grants	wild	K	0.25	13.8 (1.5)	91.0 (1.3)	94.4 (1.0)
Grants	wild	K	0.5	76.8 (1.9)	100.0 (0.0)	100.0 (0.0)
Grants	wild	F	0.25	45.4 (2.2)	96.0 (0.9)	97.2 (0.7)
Grants	wild	F	0.5	98.8 (0.5)	100.0 (0.0)	100.0 (0.0)
Grants	wild	S	0.25	35.8 (2.1)	99.8 (0.2)	100.0 (0.0)
Grants	wild	S	0.5	97.8 (0.7)	100.0 (0.0)	100.0 (0.0)

All entries are percent (Monte Carlo SE in percentage points). Fine denotes seven-coordinate augmentation; matched knows the direction and retains coarse features; ideal omits zero coarse terms. Null uses K as an irrelevant oracle direction. Rates are not empirical statistical power. Complete relative losses are in the CSV files.

S5 Benchmark increments in the earlier non-nested audit

Table S5 Policy increments under each earlier benchmark

Outcome	Holdout	Representation	Capacity delta	Lag delta	Difference
Contracts	Province	quantity	0.0043	0.0026	-0.0017
Contracts	Province	summaries	0.0049	0.0049	0.0000
Contracts	Province	groups	0.0000	0.0038	0.0038
Contracts	Province	tools	0.0000	0.0483	0.0483
Contracts	Macroregion	quantity	0.0068	0.0001	-0.0067
Contracts	Macroregion	summaries	0.1622	0.0156	-0.1466
Contracts	Macroregion	groups	0.1662	0.0030	-0.1632
Contracts	Macroregion	tools	0.0000	0.0000	0.0000

Outcome	Holdout	Representation	Capacity delta	Lag delta	Difference
Grants	Province	quantity	0.0024	0.0003	-0.0021
Grants	Province	summaries	0.0000	0.0000	0.0000
Grants	Province	groups	0.0000	0.0000	0.0000
Grants	Province	tools	0.0134	0.0017	-0.0117
Grants	Macroregion	quantity	0.0137	0.0000	-0.0137
Grants	Macroregion	summaries	0.0000	0.0000	0.0000
Grants	Macroregion	groups	0.0000	0.0000	0.0000
Grants	Macroregion	tools	-0.0063	0.0002	0.0065

These reproduce historical, non-nested V3 procedures only. A large fall in baseline RMSE is not a large change in policy increment. Positive deltas mean policy augmentation is worse. There are no independent-fold inference tests.

S6 Sources and historical extensions

The dictionary covers every raw and derived column, including later outcomes retained for historical reproducibility. The code for the revised primary analysis uses 2019 and 2020 outcomes only. Historical frozen-level, document-volume, full deletion and old simulations are archived separately in legacy_v3.zip; their old model names and success scales must not be pooled with revised results. They do not independently replicate this new nested comparison. Source registry entries cite tables and public URLs; source publications and copyrighted images are not redistributed. The source figure supplies document volumes but not policy names, dates, amendments or coding reliability. No implementation corpus is claimed. The 2022 printed-yearbook residual and separate initial contract release remain disclosed in the archived source audits. Their compilation differences are not assigned a cause. Regional outcome attribution is a substantive unresolved boundary, not corrected by numerical agreement or exact code reproduction.

S7 Reproduction and exploratory status

Run nested_analysis.py --repetitions 500, then case_audit.py. The former overwrites results with all primary and sensitivity models and simulation outputs. The latter appends case diagnostics after full refits. Python and NumPy suffice. Case diagnostics require the first script. Cached linear prediction operators depend only on training covariates; outcome-dependent tuning is repeated separately for each synthetic outcome. Direct-fit checks compare six predictions across two domains. Exact coarse-family nesting is asserted. Plans describe the sequence of design additions. The procedure is retrospective, not preregistered.

Run verify_inputs.py to validate and export primary input views, and audit_legacy.py to reproduce Table S5. Optional figures are recreated by make_figures.py. DATA_DOCUMENTATION.txt and REPRODUCTION_REPORT.json document data boundaries and this revision’s reproduction checks. The legacy archive is separately anonymised.