Instrumental Variables Quantile Regression in Stata

Di Liu

StataCorp

Table of Contents

1. Motivation and Overview
2. Model and Example
3. Intuition and Simulations
4. IQR Estimator
5. Smooth Estimator
6. Summary

Motivation: Quantile regression with endogneity

- Beyond the mean: How would the participation in a 401(k) affect the lower-level, median, and upper-level conditional quantile of net wealth?
- Endogeneity: The participation in a 401(k) may depend on the unobservable saving preference that would also affect net wealth growth.
- IV: Conditional on income and other covariates, the eligibility of 401(k) can serve as an instrument (Poterba et al., 1995).

$$\text{Endogeneity} + \text{Quantile regression}$$
$$\Uparrow$$
$$\text{IV}$$

When is estimating $E(y|x)$ not adaquate?

Consider $E(y|x) = \beta_0 + \beta_1 x_1$, then

$$\beta_1 = E(y|x = a+1) - E(y|x = a)$$

Two senarios

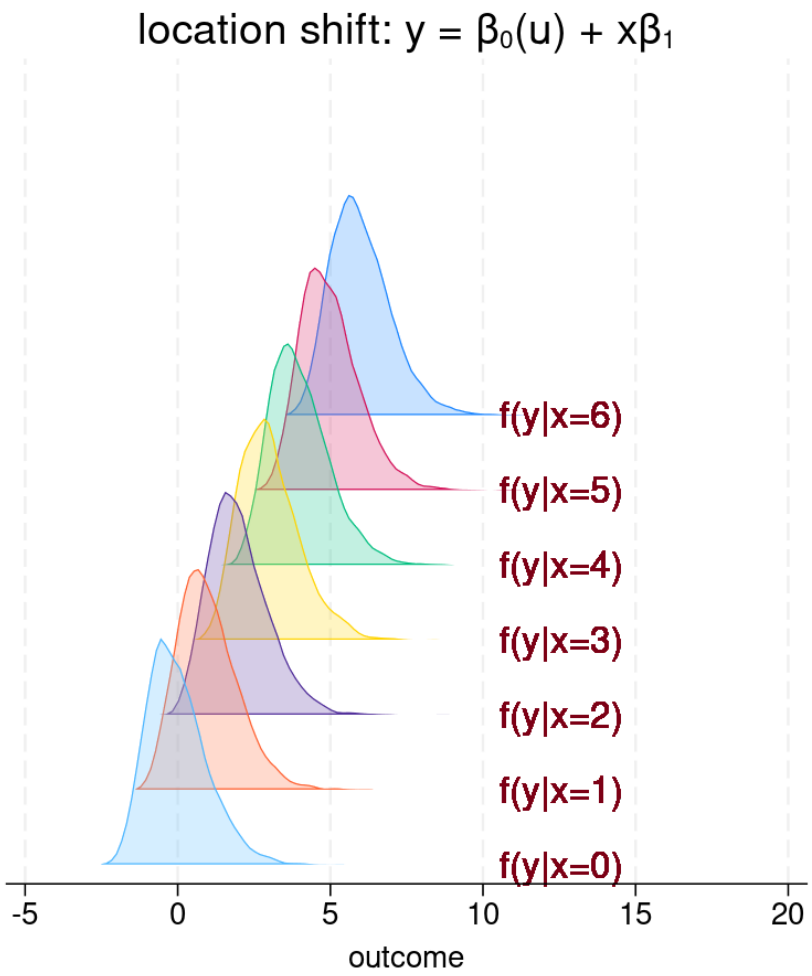
1. The conditional density $f(y|x = a+1)$ is only location-shifted relative to $f(y|x = a)$. Then

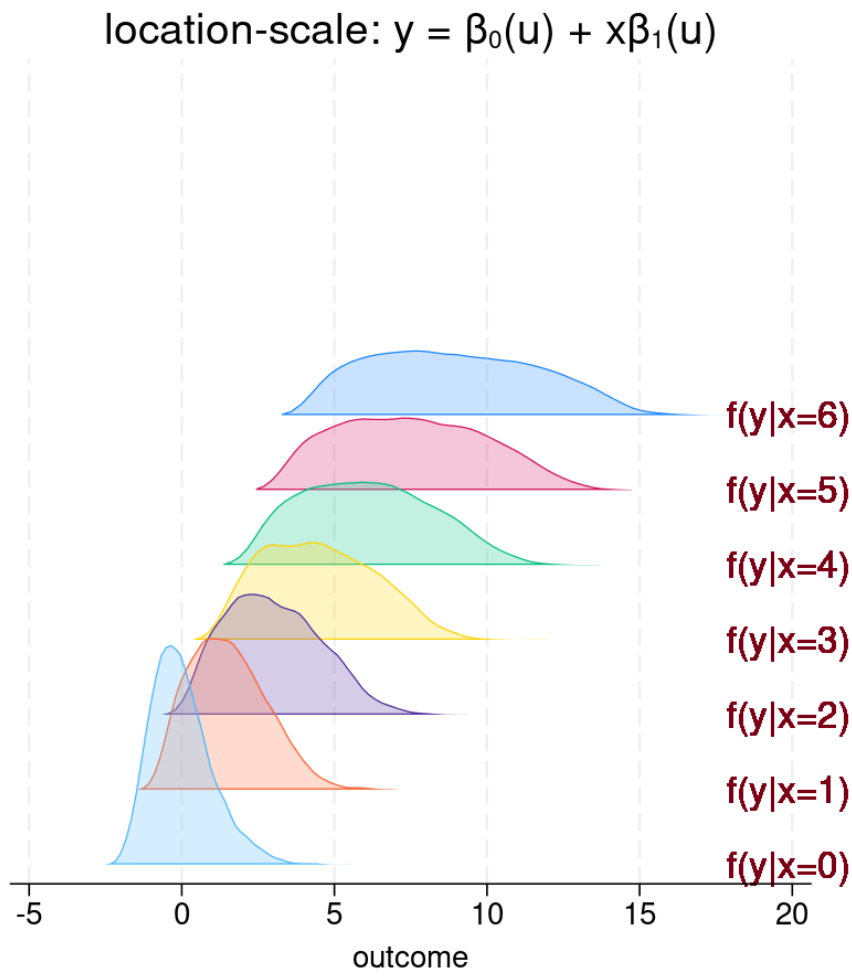
$$\beta_1 = Q(y|x = a+1, \tau) - Q(y|x = a, \tau)$$

2. The conditional density $f(y|x = a+1)$ is both location-shifted and scaled relative to $f(y|x = a)$. Then

$$\beta_1 \neq Q(y|x = a+1, \tau) - Q(y|x = a, \tau)$$

Beyond the mean





Overview of `ivqregress` toolbox (I)

We provide a suite of commands to estimate, visualize, make the inference, and diagnose the linear IV quantile regression models (IVQR).

- Estimation
  - `ivqregress iqr` implements the Inverse Quantile Regression estimator in Chernozhukov and Hansen (2006).
  - `ivqregress smooth` implements the Smoothed Estimating Equation estimator in Kaplan and Sun (2017).

Overview of `ivqregress` toolbox (II)

- Visualization
  - `estat coefplot` shows how the treatment effects vary at different conditional quantiles of outcome.
- Inference
  - `estat endogeffects` tests the hypothesis regarding the quantile process.
  - `estat dualci` provides the confidence interval robust to weak instruments (only after `ivqregress iqr`).
- Diagnosis
  - `estat waldplot` helps to visually inspect the convergence of the IQR estimator (only after `ivqregress iqr`).
- Standard post-estimation
  - `test`, `testnl`, `predict`, `margins`, ...

Table of Contents

1. Motivation and Overview
2. Model and Example
3. Intuition and Simulations
4. IQR Estimator
5. Smooth Estimator
6. Summary

Model

We can write the IV quantile regression model as a random-coefficients model (Chernozhukov and Hansen, 2008).

$$y = \mathbf{d}'\boldsymbol{\alpha}(u) + \mathbf{x}'\boldsymbol{\beta}(u) \qquad u|\mathbf{x},\mathbf{z} \sim \textit{Uniform}(0,1) \qquad (1)$$

$$\mathbf{d} = \delta(\mathbf{x},\mathbf{z},v) \qquad v \text{ statistically depends on } u \qquad (2)$$

$$\tau \to \mathbf{d}'\boldsymbol{\alpha}(\tau) + \mathbf{x}'\boldsymbol{\beta}(\tau) \qquad \text{is strictly increasing} \qquad (3)$$

Objective:

- The coefficients ($\boldsymbol{\alpha}(\tau)$ or $\boldsymbol{\beta}(\tau)$) summarize the marginal effects of covariates on the τ-th conditional quantile of outcome.
- Estimate the functions of $\boldsymbol{\alpha}(\tau)$ and $\boldsymbol{\beta}(\tau)$ at different τ's.

Example: 401(k) participation and net wealth

The IVQR model we want to estimate is

$$\texttt{asset} = \texttt{p401k} * \alpha(u) + \textbf{covariates}' * \beta(u)$$

where

- Outcome variable (`asset`) is the net financial assets.
- The participation in a 401(k) (`p401k`) may be endogenous.
- Conditional on income, the 401(k) eligibility can be used as an instrument.
- The ranking variable u is uniformly distributed conditional on `e401k` and covariates.

Objectives of analysis

- **Estimation:**
  - How does the 401(k) participation affect the lower-level, median, and upper-level conditional quantile of net financial assets? $\rightarrow$ Estimate $\alpha(\tau)$ when $\tau = 0.1, 0.2, \ldots, 0.9$.
- **Hypothesis of interest:**
  - No effect: The 401(k) participation does not affect net financial asset for all the estimated quantiles.
  - Constant effect: The 401(k) participation's treatment effect is constant for the different conditional quantiles of asset.
  - Dominance: The 401(k) participation is unambiguously beneficial for all the estimated quantiles of asset.
  - Exogeneity: The 401(k) participation is exogenous.

Define covariates

```
. describe
Contains data from assets2.dta
 Observations:         9,913                  Excerpt from Chernozhukov and
                                                Hanson (2004) Rev. of Economics
                                                and Statistics
    Variables:            12                  18 Jan 2022 08:19
```

Variable name	Storage type	Display format	Value label	Variable label
assets	float	%9.0g		Net total financial assets
age	byte	%9.0g		Age
income	float	%9.0g		Household income
familysize	byte	%9.0g		Household size
educ	byte	%9.0g		Years of education
pension	byte	%16.0g	lbpen	Pension benefits
married	byte	%11.0g	lbmar	Marital status
twoearn	byte	%9.0g	lbyes	Two-earner household
e401k	byte	%12.0g	lbe401	401(k) eligibility
p401k	byte	%9.0g		401(k) participation
ira	byte	%9.0g	lbyes	IRA participation
ownhome	byte	%9.0g	lbyes	Home owner

```
Sorted by: e401k
. global covariates income age familysize educ i.(married ira pension ownhome)
```

ivqregress

- **IQR estimator**

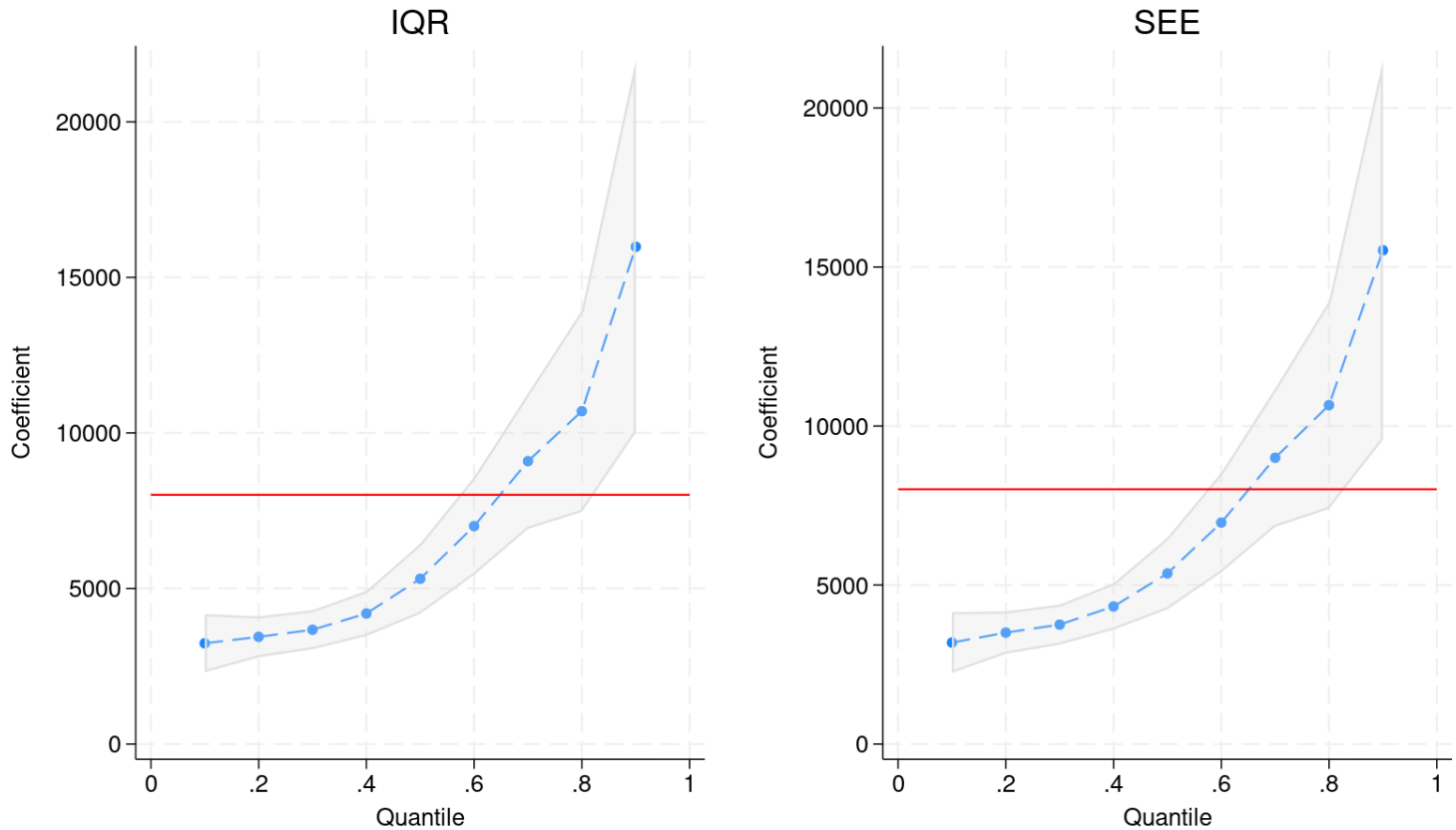
```
ivqregress iqr assets (i.p401k = i.e401k) $covariates   ///
          ,quantile(10(10)90)
```

- **Smooth estimator**

```
ivqregress smooth assets (i.p401k = i.e401k) $covariates ///
          ,quantile(10(10)90)
```

estat coefplot

- Visualize how the treatment effects vary at different conditional quantiles of outcome $\rightarrow$ plot the function $\alpha(\tau)$ or $\beta(\tau)$.



estat endogeffects

```
. estimates restore iqr
(results iqr are active now)
. estat endogeffects
```

Tests for endogenous effects — Replications = 100

Null hypothesis	KS statistic	95% critical value
No effect	11.271	2.481
Constant effect	5.395	2.524
Dominance	0.000	2.569
Exogeneity	4.146	2.809

Note: If the KS statistic < critical value, there is insufficient evidence to reject the null hypothesis. (KS = Kolmogorov-Smirnov)

```
.
. estimates restore smooth
(results smooth are active now)
. estat endogeffects
```

Tests for endogenous effects — Replications = 100

Null hypothesis	KS statistic	95% critical value
No effect	11.507	2.525
Constant effect	5.351	2.514
Dominance	0.000	2.661
Exogeneity	4.201	2.573

Note: If the KS statistic < critical value, there is insufficient evidence to reject the null hypothesis. (KS = Kolmogorov-Smirnov)

Table of Contents

1. Motivation and Overview
2. Model and Example
3. Intuition and Simulations
4. IQR Estimator
5. Smooth Estimator
6. Summary

IVQR model key moment condition

$$Pr(y \leq \mathbf{d}'\alpha(\tau) + \mathbf{x}'\beta(\tau)|\mathbf{x},\mathbf{z}) = \tau$$

$$\Downarrow$$

$$\mathbf{E}\left[\left(\tau - \mathbb{1}(y - \mathbf{d}'\alpha(\tau) - \mathbf{x}'\beta(\tau) \leq 0)\right)\Psi(\mathbf{x},\mathbf{z})\right] = 0$$

- The main difficulty is the indicator function $\mathbb{1}()$. The objective function is non-convex and non-smooth.
- In practice, $\Psi(\mathbf{x},\mathbf{z}) = (\Phi(\mathbf{x},\mathbf{z})', \mathbf{x}')'$, and $\Phi(\mathbf{x},\mathbf{z})$ is the linear projection of $\mathbf{d}$ on the space spanned by $\mathbf{x}$ and $\mathbf{z}$.
- $\Phi(\mathbf{x},\mathbf{z})$ can be regarded as transformed instruments for $\mathbf{d}$, so the over-identification can always be transformed into just-identification.

Nonconvex and non-smooth objective function

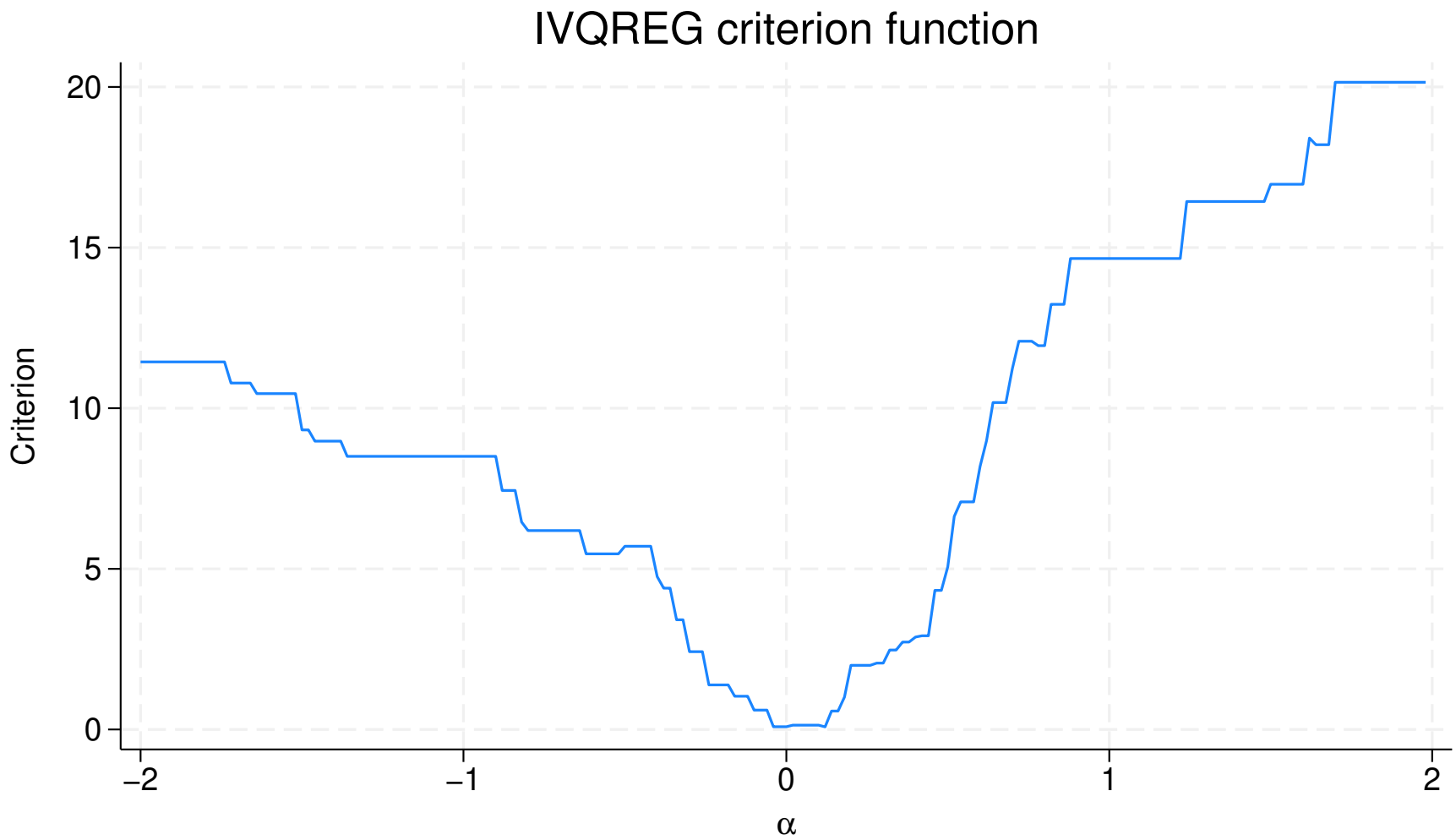


Figure: IVQREG GMM criterion function

Intuition behind IQR and Smooth estimators

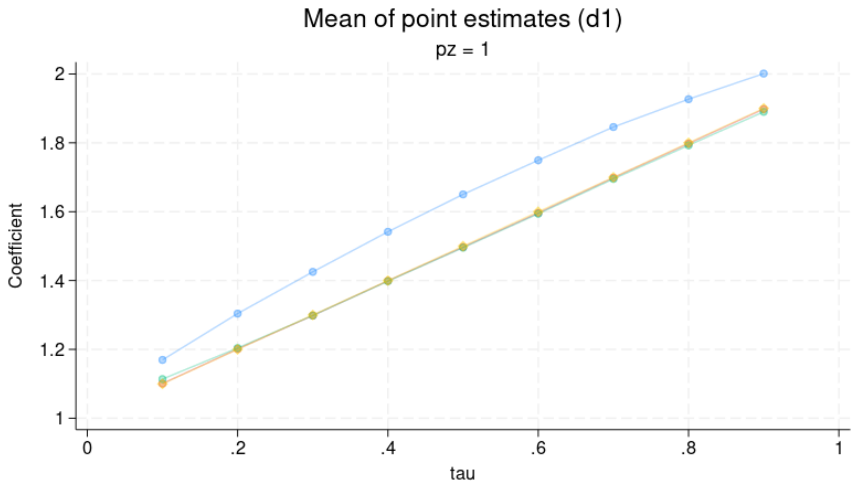
- **IQR** (Chernozhukov and Hansen, 2006 and 2008)
  - Reduce the $p = dim(\alpha) + dim(\beta)$ dimensional non-convex problem into one-dimensional non-convex problem.
  - Do a exhaustive grid search (in one dimension) over high quality of grid points.
  - The bounds for grid points are guarenteed to cover the true value with 95% probability.
  - Good for only one endogenous variable, but can compute the CI that is robust to the weak instrument.
- **Smooth** (Kaplan and Sun, 2017)
  - Smooth the indicator function by kernel method.
  - Solve a system of non-convex equation using `solvenl()`.
  - Good for more than one endogenous variables, but can not provide the CI robust to weak instrument.

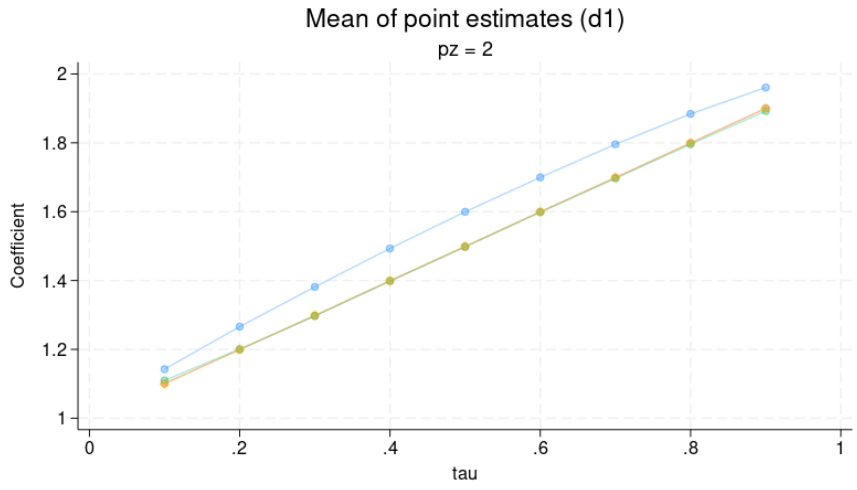
Simulation: DGP

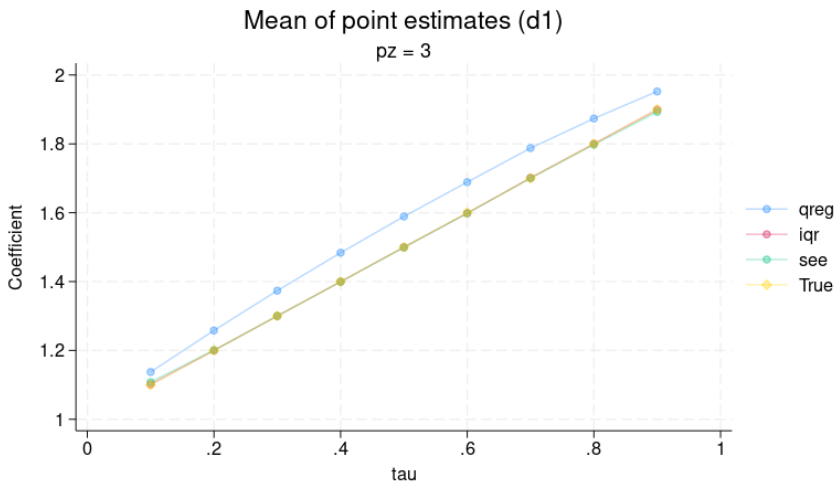
$$y = \mathbf{d}'\alpha(u) + \mathbf{x}'\beta(u)$$
$$\alpha(\tau) = \beta(\tau) = 1 + \tau$$

- u is uniformly distributed.
- **d** is a linear function of instrument **z** and it is correlated with u.
- **x** is exogenous.
- When $dim(\mathbf{d}) = 1$, $dim(\mathbf{z}) = 1$, 2 or 3, $N = 1000$. Run `qreg`, IQR, and Smooth.
- When $dim(\mathbf{d}) = 2$, $dim(\mathbf{z}) = 2$, 4, or 6, $N = 5000$. Run `qreg` and Smooth.
- Estimate coefficients when $\tau = 0.1, 0.2, \ldots, 0.9$.
- The number of repetitions is 2030.

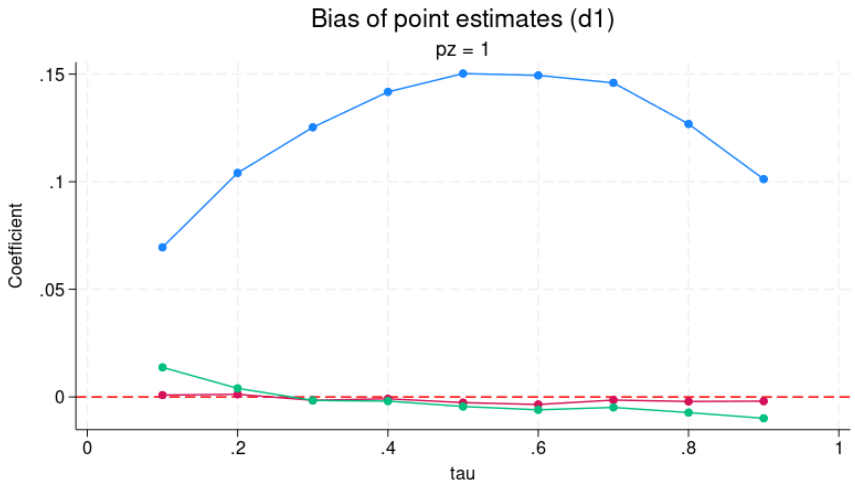
Simulation: dim(**d**) = 1 (mean of $\widehat{\beta}$)

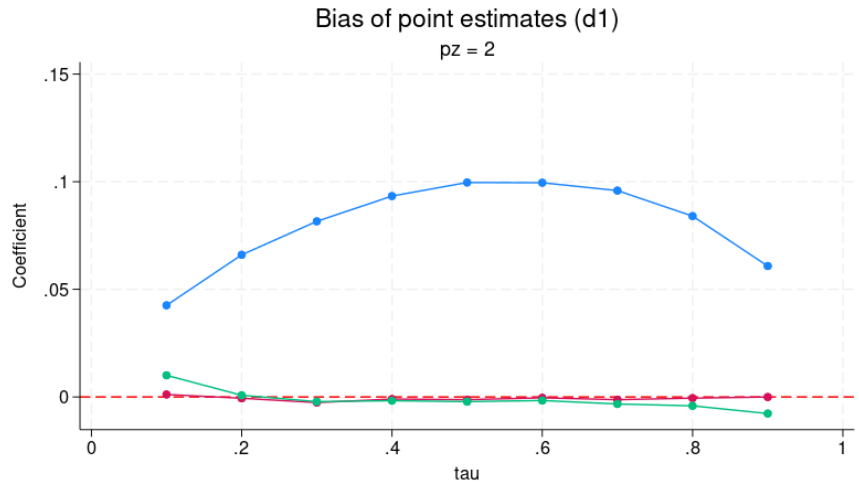


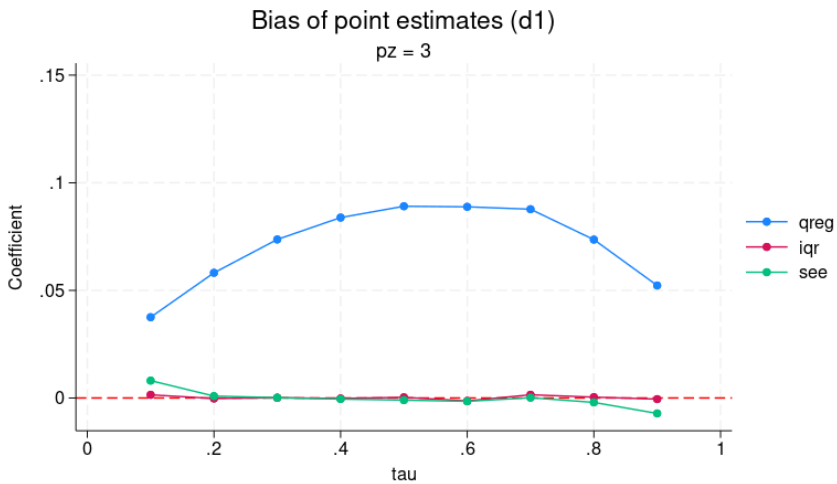




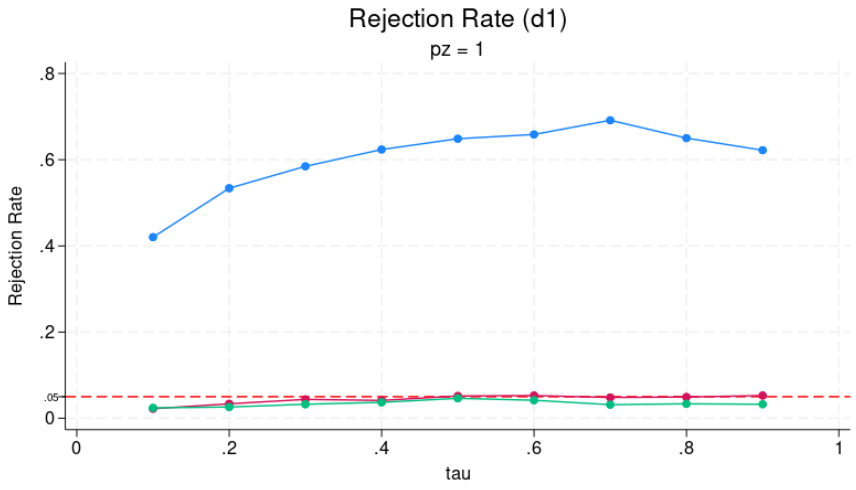
Simulation: dim(**d**) = 1 (bias)

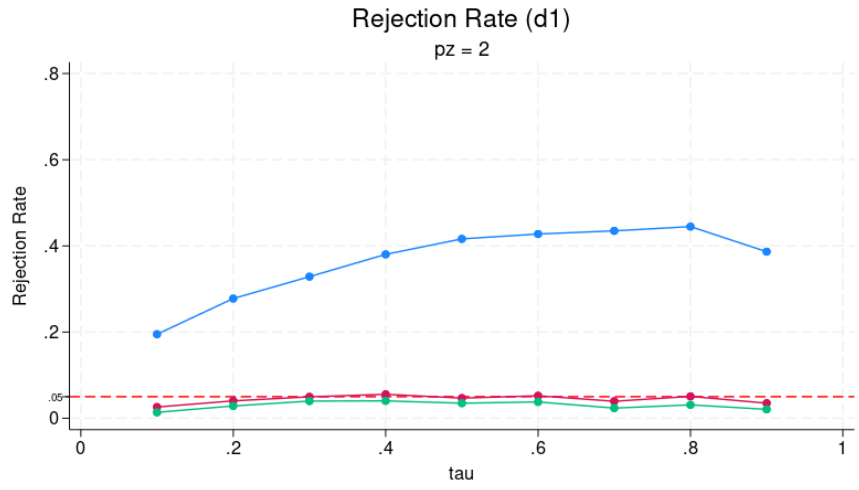


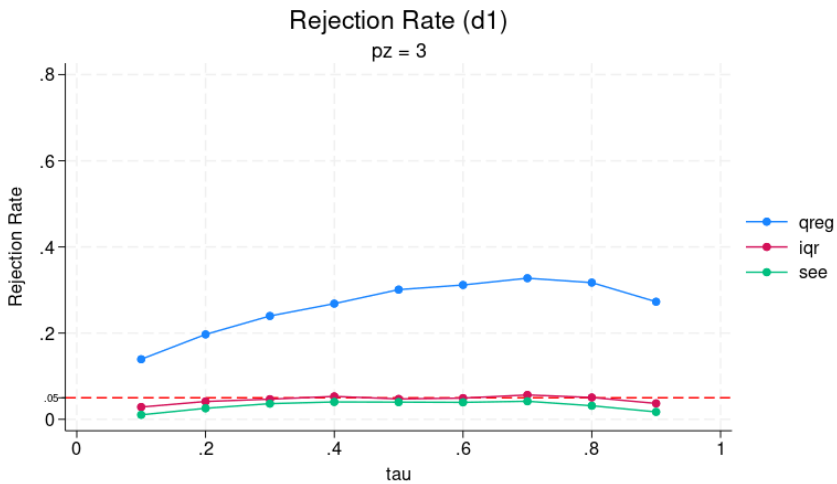




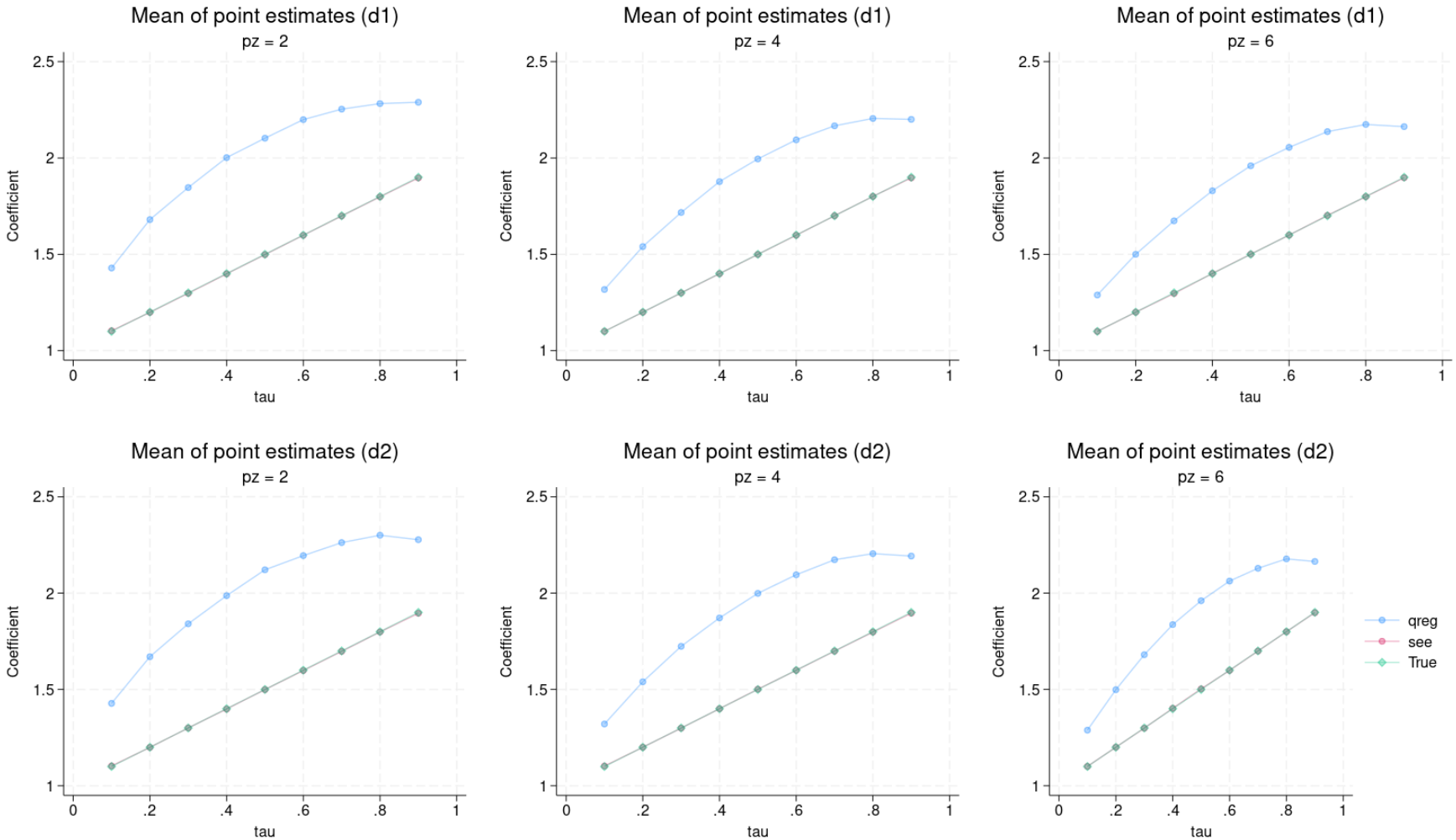
Simulation: dim(**d**) = 1 (rejection rate)



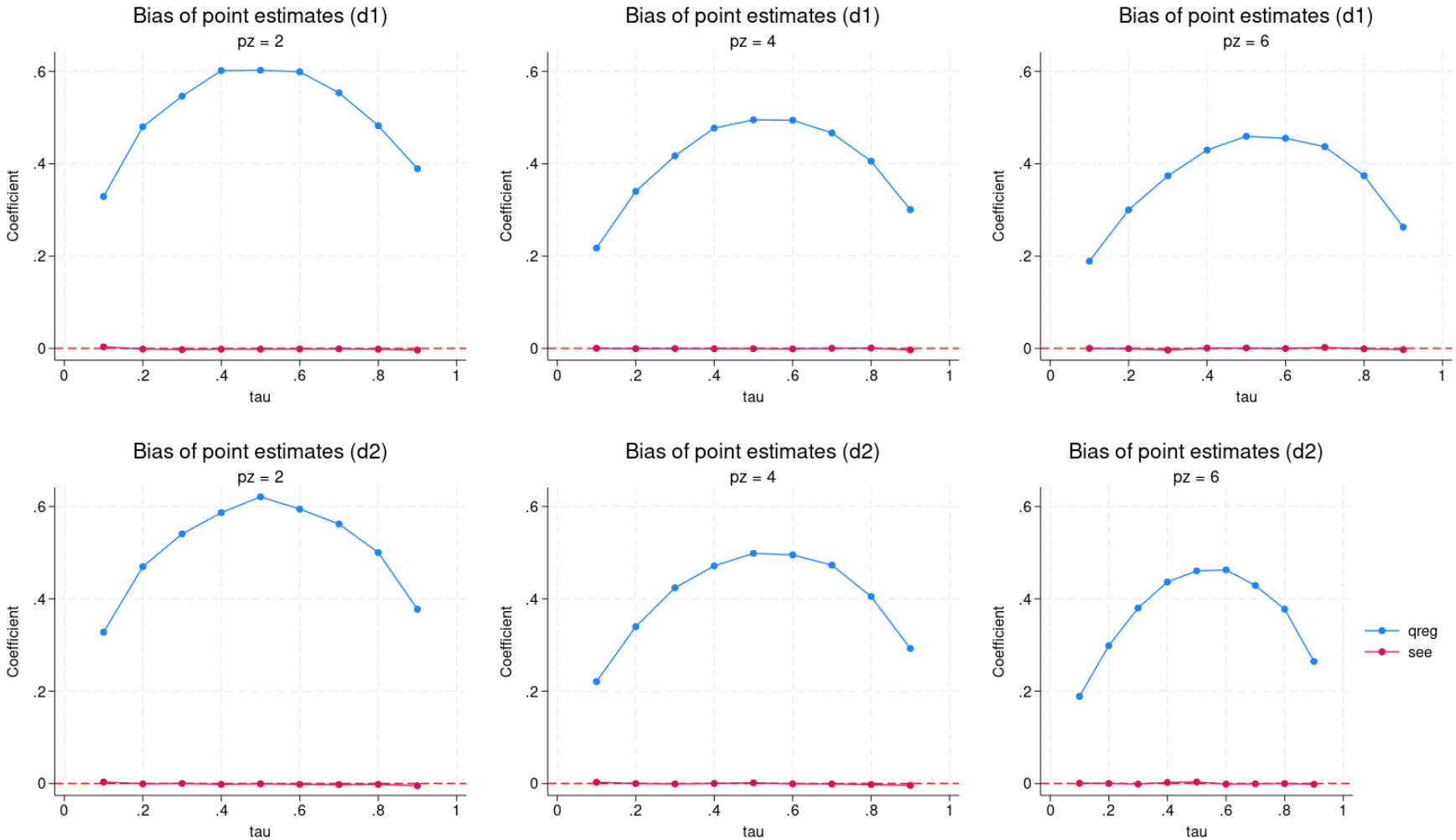




Simulation: dim(**d**) = 2 (mean of $\widehat{\beta}$)



Simulation: dim(**d**) = 2 (bias)



Simulation: dim(**d**) = 2 (rejection rate)

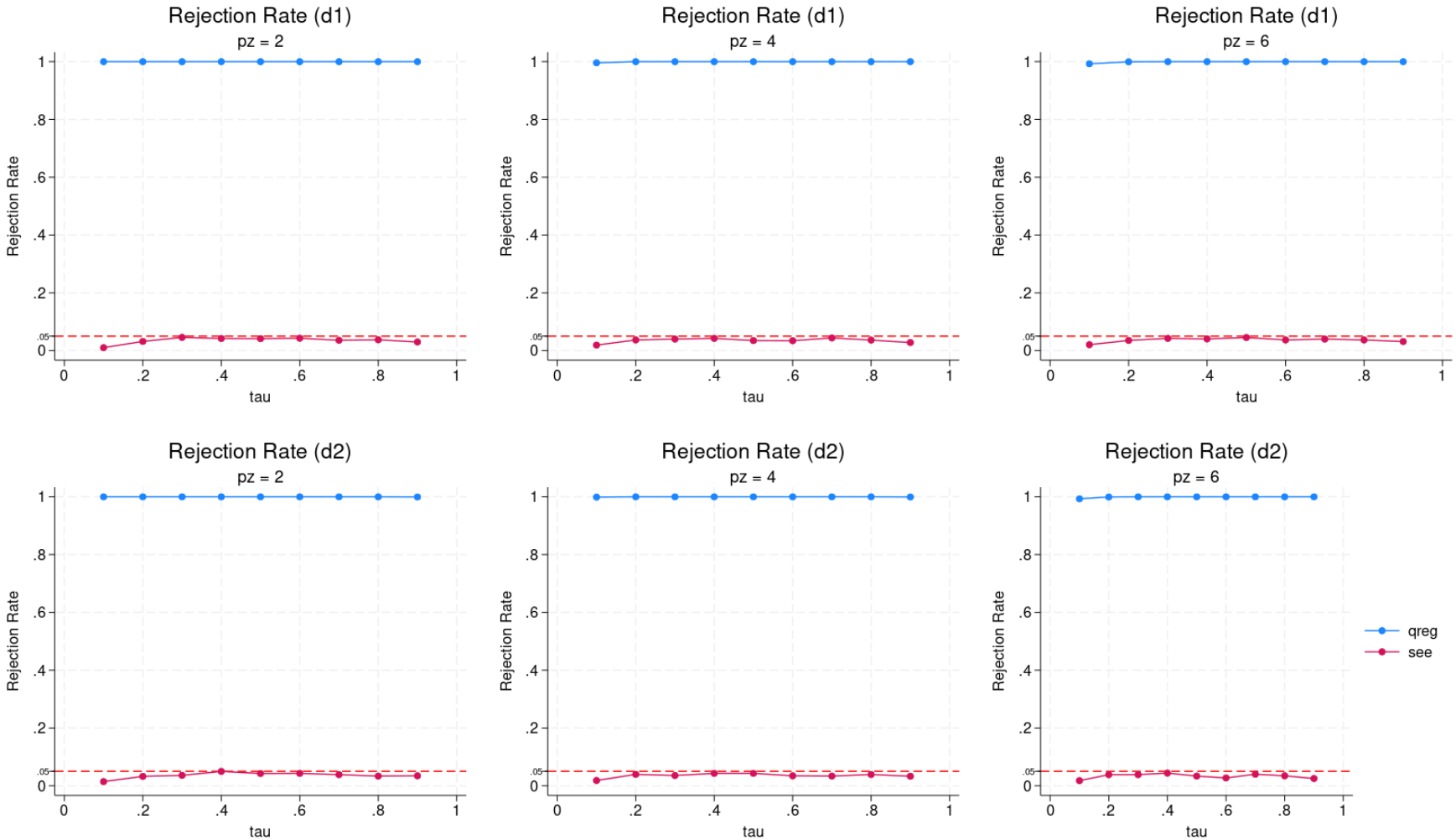


Table of Contents

1. Motivation and Overview
2. Model and Example
3. Intuition and Simulations
4. IQR Estimator
5. Smooth Estimator
6. Summary

Inverse quantile regression

QREG

$$\Downarrow$$

$$Pr(y \leq \mathbf{z}'\gamma(\tau) + \mathbf{x}'\beta(\tau)|\mathbf{x},\mathbf{z}) = \tau$$

$$\Downarrow$$

$$\min \sum_{i=1}^{N} \rho_\tau(y_i - \mathbf{z}_i'\gamma - \mathbf{x}_i'\beta)$$

$$\Downarrow$$

```
qreg y x z
```

IVQREG

$$\Downarrow$$

$$Pr(y \leq \mathbf{d}'\alpha(\tau) + \mathbf{x}'\beta(\tau)|\mathbf{x},\mathbf{z}) = \tau$$

$$\Updownarrow$$

$$Pr(y - \mathbf{d}'\alpha(\tau) \leq \mathbf{x}'\beta(\tau) + \mathbf{z}' * 0|\mathbf{x},\mathbf{z}) = \tau$$

$$\Downarrow$$

```
qreg y-d'α(τ) x z
```

IQR finds $\alpha(\tau)$ such that the coefficient on **z** is as close to zero as possible.

Constructing grid using dual CI

- Given a grid of $A = \{\alpha_1, \ldots, \alpha_J\}$, **IQR** finds $\alpha(\tau)$ such that the coefficient on **z** is as close to zero as possible, which is measured by the Wald statistic ($W_n(\boldsymbol{\alpha}(\tau))$).
- The grid points boundary must be more comprehensive than the dual CI, otherwise `ivqregress iqr` will error out.
- Dual CI means it covers the true value of $\alpha(\tau)$ with 95% probability (Chernozhukov and Hansen, 2008).

Dual CI

PROPOSITION

(Proposition 1 in Chernozhukov and Hansen[2008]) When $\alpha = \alpha(\tau)$,

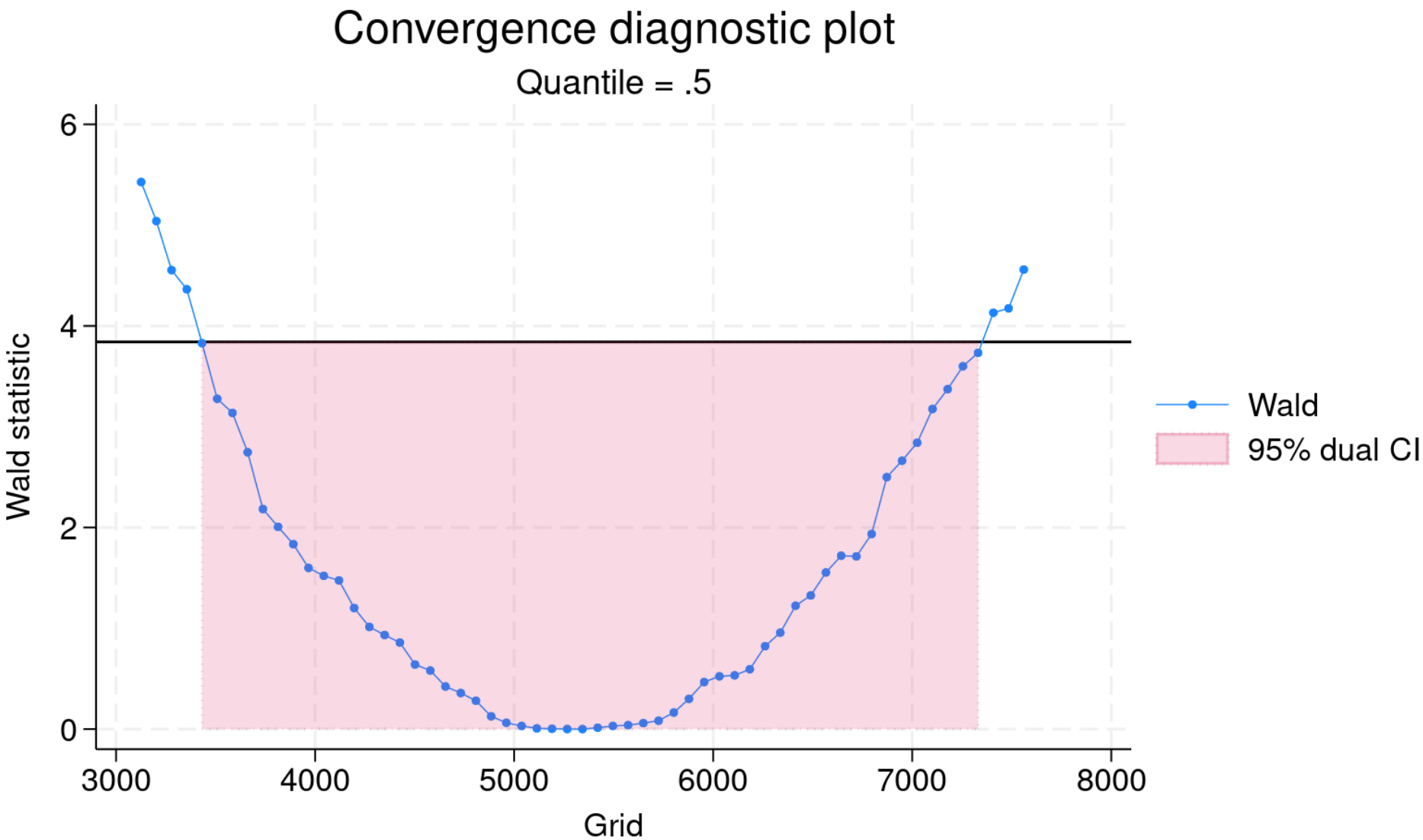
$$W_n[\alpha(\tau)] \rightarrow_d \chi^2(dim(\gamma))$$

and for the confidence region $CR_p[\alpha(\tau)] = \{\alpha \in A : W_n(\alpha) < c_p\}$, *where* $P(\chi^2(dim(\gamma)) < c_p) = p$,

$$P\{\alpha(\tau) \in CR_p[\alpha(\tau)]\} = P\{W_n[\alpha(\tau)] < c_p\} = p \tag{4}$$

$CR_p[\alpha(\tau)] = \{\alpha \in A : W_n(\alpha) < c_p\}$ covers the true value of α with probability approaching p.

estat waldplot

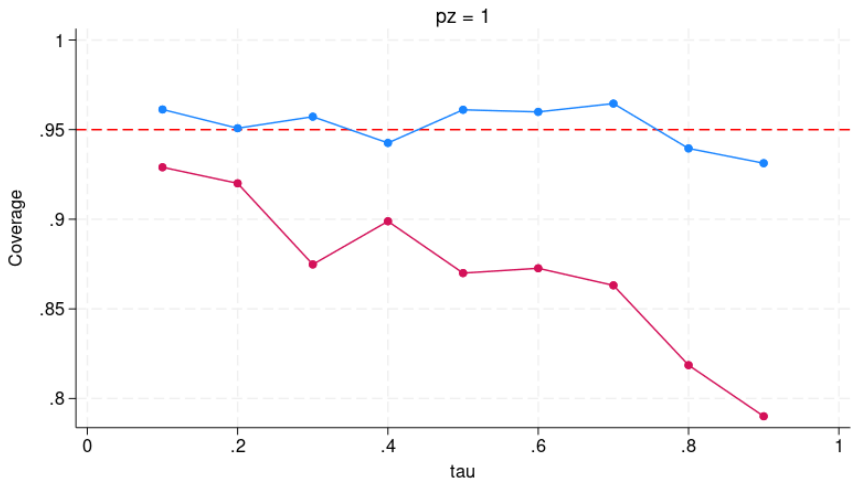


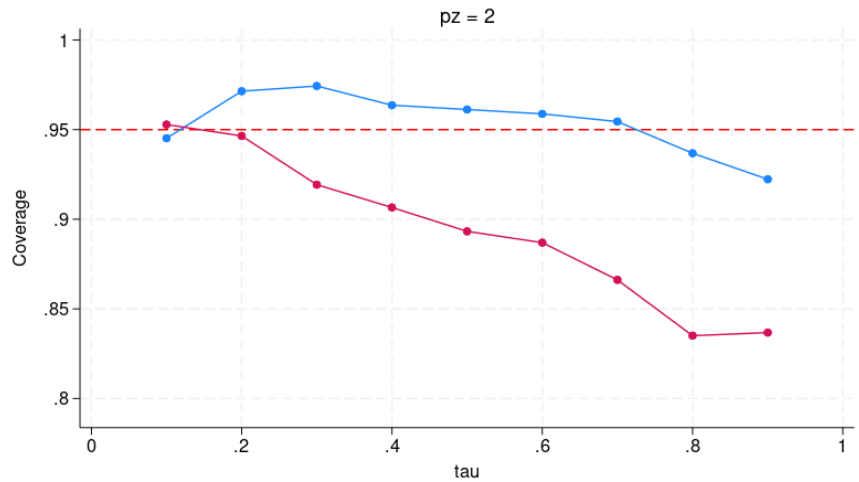
estat dualci

```
. estat dualci
Dual confidence interval                        Number of obs = 9,913
```

assets	Coefficient	Robust std. err.	z	P>|z|	Dual [95% conf.	interval]
p401k 1	5419.717	580.9771	9.33	0.000	3508.301	7407.591

Simulation: Dual CI coverage with weak instruments





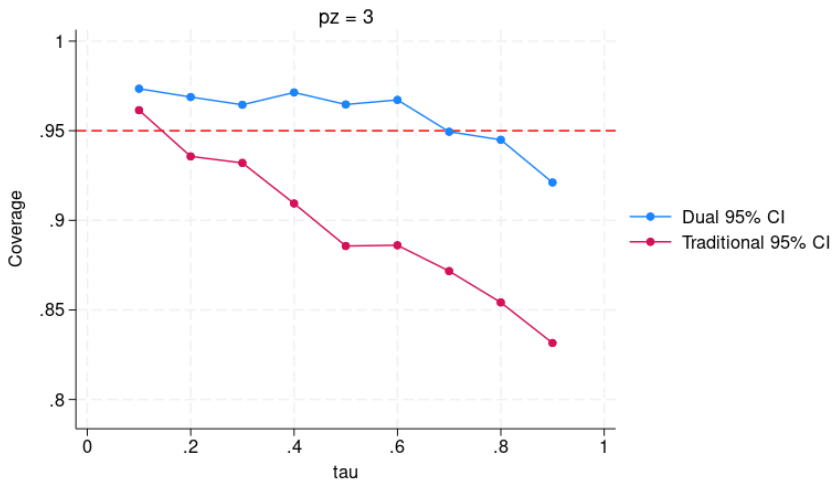


Table of Contents

1. Motivation and Overview
2. Model and Example
3. Intuition and Simulations
4. IQR Estimator
5. Smooth Estimator
6. Summary

Smoothed estimating equation estimator

$$\mathbf{E}\left[\left(\tau - \mathbb{1}\left(y - \mathbf{d}'\boldsymbol{\alpha}(\tau) - \mathbf{x}'\boldsymbol{\beta}(\tau)\right) \leq 0\right)\right) \Psi(\mathbf{x}, \mathbf{z})\Big] = 0$$

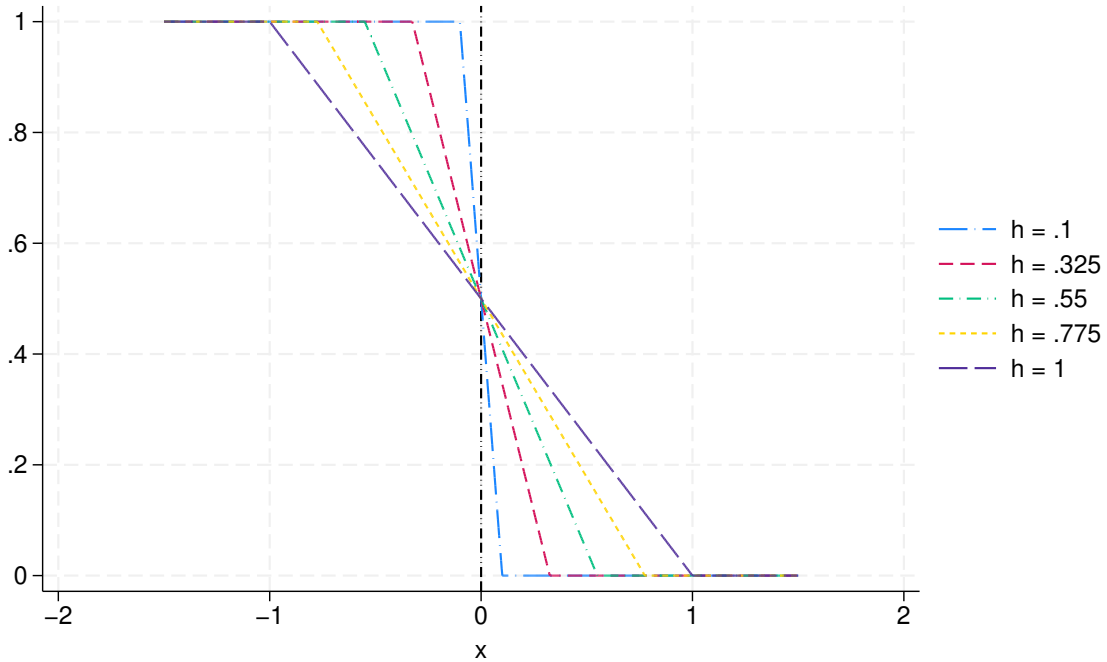
$$\Big\Downarrow \text{(smooth the indicator function by kernel)}$$

$$\mathbf{E}\left[\left(\tau - \widetilde{\mathbb{1}}\left(\frac{y - \mathbf{d}'\boldsymbol{\alpha}(\tau) - \mathbf{x}'\boldsymbol{\beta}(\tau)}{h}\right) \leq 0\right)\right) \Psi(\mathbf{x}, \mathbf{z})\Big] = 0$$

- Solve this system of non-linear equation by `solvenl()`.
- The Smooth estimator is first-order equivalent to the IQR estimator so that we can use the same variance-covariance estimator (de Castro et al., 2019).

Smoothed indicator function

$$\widetilde{\mathbb{1}}(v) = \begin{cases} 1 & \text{if } v \leq -1 \\ 0 & \text{if } v \geq 1 \\ \frac{1-v}{2} & \text{if } -1 < v < 1 \end{cases}$$



- The optimal bandwidth h^* is chosen to minimize the MSE of the estimating equation.
- `ivqregress` also requires that h^* result in a $\alpha(\tau)$ within the dual CI.

Table of Contents

1. Motivation and Overview
2. Model and Example
3. Intuition and Simulations
4. IQR Estimator
5. Smooth Estimator
6. Summary

Syntax of `ivqregress`

Inverse Quantile Regression estimator:

`ivqregress iqr` *depvar varlist*$_1$ (*varlist*$_2$ = *varlist*$_{iv}$) [`if`] [`in`] [, *options IQR_options*]

Smoothed Estimating Equation estimator:

`ivqregress smooth` *depvar varlist*$_1$ (*varlist*$_2$ = *varlist*$_{iv}$) [`if`] [`in`] [, *options smooth_optior*

where

- *varlist*$_1$ specifies the exogenous variables.
- *varlist*$_2$ specifies the endogenous variables. Only one continuous variable or one binary factor variable is allowed for the inverse quantile regression estimator.
- *varlist*$_{iv}$ specifies the instrumental variables.

Post-estimation

The following postestimation commands are of particular interest after `ivqregress`.

Commands	Description
`estat coefplot`	plot coefficients and their confidence intervals at different quantiles
`estat endogeffects`	process test of no effect, constant effect, stochastic dominance, and endogeneity
*`estat dualci`	provide the dual-confidence interval for the endogenous variables
*`estat waldplot`	plot Wald statistics corresponding to each grid point

Note :

- `estat waldplot` and `estat dualci` are allowed only after `ivqregress iqr`.

Summary

- We provide a suite of commands to estimate, visualize, and make the inference for the linear IVQR model.
- Two estimators: IQR and Smooth. Both are consistent, but the estimates may be different because they approximate the original estimating equation differently.
- IQR is widely used for the one endogenous variable case. It should be used as a benchmark because it provides the dual CI robust to the weak instrument.
- Smooth is suitable for the one or more endogenous variables case.

References

de Castro, L., A. F. Galvao, D. M. Kaplan, and X. Liu. 2019. Smoothed GMM for quantile models. *Journal of Econometrics* 213: 121–144.

Chernozhukov, V., and C. Hansen. 2006. Instrumental quantile regression inference for structural and treatment effect models. *Journal of Econometrics* 132(2): 491–525.

———. 2008. Instrumental variable quantile regression: A robust inference approach. *Journal of Econometrics* 142(1): 379–398.

Kaplan, D. M., and Y. Sun. 2017. Smoothed estimating equations for instrumental variables quantile regression. *Econometric Theory* 33(1): 105–157.

Poterba, J. M., S. F. Venti, and D. A. Wise. 1995. Do 401(k) contributions crowd out other personal saving? *Journal of Public Economics* 58(1): 1–32.

Appendix

Contents

1 `ivqregress iqr` **output** **2**

2 `ivqregress smooth` **output** **5**

1 ivqregress iqr output

```
. ivqregress iqr assets (i.p401k = i.e401k) $covariates, quantile(10(10)90)

Initial grid:
Quantile = 0.10: .........10.........20.........30 done
Quantile = 0.20: .........10.........20.........30 done
Quantile = 0.30: .........10.........20.........30 done
Quantile = 0.40: .........10.........20.........30 done
Quantile = 0.50: .........10.........20.........30 done
Quantile = 0.60: .........10.........20.........30 done
Quantile = 0.70: .........10.........20.........30 done
Quantile = 0.80: .........10.........20.........30 done
Quantile = 0.90: .........10.........20.........30 done

Adaptive grid:
Quantile = 0.10: .........10.........20.........30 done
Quantile = 0.20: .........10.........20.........30 done
Quantile = 0.30: .........10.........20.........30 done
Quantile = 0.40: .........10.........20.........30 done
Quantile = 0.50: .........10.........20.........30 done
Quantile = 0.60: .........10.........20.........30 done
Quantile = 0.70: .........10.........20.........30 done
Quantile = 0.80: .........10.........20.........30 done
Quantile = 0.90: .........10.........20.........30 done

IV quantile regression                          Number of obs =   9,913
Estimator: Inverse quantile regression          Wald chi2(81) = 5121.46
                                                Prob > chi2   =  0.0000
```

assets	Coefficient	Robust std. err.	z	P>|z|	[95% conf.	interval]
q10						
1.p401k	3240.08	475.6184	6.81	0.000	2307.885	4172.275
income	.0303072	.0123138	2.46	0.014	.0061725	.0544419
age	131.5908	15.13725	8.69	0.000	101.9223	161.2592
familysize	-329.2838	123.4665	-2.67	0.008	-571.2737	-87.29385
educ	-301.1635	52.02897	-5.79	0.000	-403.1384	-199.1885
married						
Married	-1504.648	380.0373	-3.96	0.000	-2249.508	-759.7886
ira						
Yes	7864.15	344.2198	22.85	0.000	7189.492	8538.809
pension						
Receives ..	63.88643	326.6017	0.20	0.845	-576.2412	704.0141
ownhome						
Yes	969.6861	300.4319	3.23	0.001	380.8503	1558.522
_cons	-7455.806	1192.112	-6.25	0.000	-9792.302	-5119.311
q20						
1.p401k	3446.347	334.4227	10.31	0.000	2790.89	4101.803
income	.0730526	.0083383	8.76	0.000	.0567097	.0893954
age	117.4232	10.09197	11.64	0.000	97.64336	137.2031
familysize	-311.518	77.31495	-4.03	0.000	-463.0525	-159.9835

educ	-198.8986	36.72851	-5.42	0.000	-270.8852	-126.9121
married						
Married	-1023.821	245.1418	-4.18	0.000	-1504.29	-543.3515
ira						
Yes	8728.335	389.1614	22.43	0.000	7965.593	9491.077
pension						
Receives ..	8.450874	211.6773	0.04	0.968	-406.429	423.3307
ownhome						
Yes	247.107	193.7332	1.28	0.202	-132.6031	626.817
_cons	-6064.723	762.7341	-7.95	0.000	-7559.654	-4569.791
q30						
1.p401k	3674.434	318.7578	11.53	0.000	3049.68	4299.188
income	.0900328	.0080609	11.17	0.000	.0742337	.1058319
age	106.4245	8.502461	12.52	0.000	89.76	123.089
familysize	-217.4507	57.05271	-3.81	0.000	-329.272	-105.6295
educ	-122.6666	32.44148	-3.78	0.000	-186.2508	-59.08249
married						
Married	-1021.046	209.9362	-4.86	0.000	-1432.513	-609.5787
ira						
Yes	11974.65	566.1735	21.15	0.000	10864.98	13084.33
pension						
Receives ..	-149.6646	187.9519	-0.80	0.426	-518.0435	218.7144
ownhome						
Yes	118.1594	157.3384	0.75	0.453	-190.2182	426.537
_cons	-5631.287	617.0855	-9.13	0.000	-6840.752	-4421.821
q40						
1.p401k	4196.127	369.6983	11.35	0.000	3471.532	4920.722
income	.1230721	.0104554	11.77	0.000	.1025799	.1435643
age	93.83839	7.963134	11.78	0.000	78.23093	109.4458
familysize	-225.3647	51.96267	-4.34	0.000	-327.2097	-123.5198
educ	-112.4069	30.98445	-3.63	0.000	-173.1353	-51.67845
married						
Married	-1191.624	211.8386	-5.63	0.000	-1606.82	-776.4277
ira						
Yes	16997.44	803.6711	21.15	0.000	15422.28	18572.61
pension						
Receives ..	-511.7032	194.9456	-2.62	0.009	-893.7895	-129.6168
ownhome						
Yes	102.3659	148.1471	0.69	0.490	-187.997	392.7288
_cons	-4787.913	553.4111	-8.65	0.000	-5872.579	-3703.247
q50						
1.p401k	5313.397	573.2818	9.27	0.000	4189.786	6437.009
income	.1577512	.0124889	12.63	0.000	.1332735	.1822289

age	99.96526	8.561923	11.68	0.000	83.1842	116.7463
familysize	-197.8251	54.36773	-3.64	0.000	-304.3838	-91.26627
educ	-96.43983	32.09465	-3.00	0.003	-159.3442	-33.53547
married						
Married	-1359.124	227.3366	-5.98	0.000	-1804.696	-913.5528
ira						
Yes	22629.61	1022.706	22.13	0.000	20625.15	24634.08
pension						
Receives ..	-693.8347	210.6176	-3.29	0.001	-1106.638	-281.0317
ownhome						
Yes	-30.29657	154.7265	-0.20	0.845	-333.555	272.9618
_cons	-4998.673	570.1315	-8.77	0.000	-6116.11	-3881.236
q60						
1.p401k	7006.205	801.4258	8.74	0.000	5435.439	8576.97
income	.2327564	.0174037	13.37	0.000	.1986458	.2668671
age	135.4321	11.38565	11.89	0.000	113.1166	157.7475
familysize	-262.5927	65.82424	-3.99	0.000	-391.6058	-133.5795
educ	-118.7153	40.43096	-2.94	0.003	-197.9585	-39.47208
married						
Married	-1716.762	269.9874	-6.36	0.000	-2245.927	-1187.596
ira						
Yes	30301.55	1241.557	24.41	0.000	27868.15	32734.96
pension						
Receives ..	-988.7325	261.4987	-3.78	0.000	-1501.261	-476.2044
ownhome						
Yes	-122.2135	193.9046	-0.63	0.529	-502.2595	257.8324
_cons	-6290.287	688.2098	-9.14	0.000	-7639.154	-4941.421
q70						
1.p401k	9093.469	1109.745	8.19	0.000	6918.408	11268.53
income	.3459585	.0226207	15.29	0.000	.3016228	.3902942
age	191.2876	16.53737	11.57	0.000	158.875	223.7003
familysize	-242.6605	86.05014	-2.82	0.005	-411.3157	-74.00534
educ	-143.4298	51.12786	-2.81	0.005	-243.6386	-43.22104
married						
Married	-2470.874	352.4949	-7.01	0.000	-3161.751	-1779.996
ira						
Yes	39365.32	1608.07	24.48	0.000	36213.56	42517.08
pension						
Receives ..	-1796.514	344.5429	-5.21	0.000	-2471.806	-1121.222
ownhome						
Yes	-4.058645	262.5795	-0.02	0.988	-518.7051	510.5878
_cons	-8637.647	928.462	-9.30	0.000	-10457.4	-6817.894
q80						

```
     1.p401k |   10699.12   1651.062     6.48   0.000     7463.098    13935.14
      income |   .5103271   .0293056    17.41   0.000      .4528892    .5677649
         age |   280.7892   24.10894    11.65   0.000      233.5366    328.0419
  familysize |  -400.8973   117.2019    -3.42   0.001     -630.6089   -171.1858
        educ |   -130.398   68.51364    -1.90   0.057     -264.6823    3.886266

     married |
     Married |  -2902.662   480.5005    -6.04   0.000     -3844.426   -1960.899

         ira |
         Yes |   48875.79   2297.873    21.27   0.000      44372.04    53379.54

     pension |
Receives ..  |  -3072.814   502.6944    -6.11   0.000     -4058.077   -2087.551

     ownhome |
         Yes |   235.2409   402.9808     0.58   0.559     -554.5869    1025.069
       _cons |  -11871.24   1257.402    -9.44   0.000      -14335.7   -9406.775
-------------+----------------------------------------------------------------
q90          |
     1.p401k |   15983.42   3046.028     5.25   0.000      10013.32    21953.53
      income |   .8247356   .0570029    14.47   0.000       .713012    .9364593
         age |   485.8734   48.99224     9.92   0.000      389.8504    581.8965
  familysize |  -646.4962    185.913    -3.48   0.001     -1010.879   -282.1134
        educ |    48.4205   106.2844     0.46   0.649     -159.8931    256.7341

     married |
     Married |  -3265.007   753.4701    -4.33   0.000     -4741.782   -1788.233

         ira |
         Yes |   68543.44   4952.261    13.84   0.000      58837.18    78249.69

     pension |
Receives ..  |  -4656.177   869.4887    -5.36   0.000     -6360.343    -2952.01

     ownhome |
         Yes |   400.1957   680.2776     0.59   0.556     -933.124    1733.515
       _cons |  -20594.85   2260.983    -9.11   0.000      -25026.3   -16163.41
------------------------------------------------------------------------------

Endogenous: 1.p401k
Exogenous:  income age familysize educ 1.married 1.ira 1.pension 1.ownhome
            1.e401k

. estimates  store iqr
```

2 ivqregress smooth output

```
. ivqregress smooth assets (i.p401k = i.e401k) $covariates, quantile(10(10)90)

Fitting smoothed IV quantile regression:

Quantile = .1:
Step 1: Bandwidth = 1327.0069    GMM criterion Q(b) = 9.224e-11
Step 2: Bandwidth = 1311.3131    GMM criterion Q(b) = 1.997e-10

Quantile = .2:
```

```
Step 1: Bandwidth = 1272.5204    GMM criterion Q(b) = 2.089e-10
Step 2: Bandwidth = 1237.7195    GMM criterion Q(b) = 3.115e-19

Quantile = .3:
Step 1: Bandwidth = 1504.4065    GMM criterion Q(b) = 5.407e-13
Step 2: Bandwidth = 1486.4224    GMM criterion Q(b) = 1.153e-10

Quantile = .4:
Step 1: Bandwidth = 1362.7753    GMM criterion Q(b) = 5.797e-17
Step 2: Bandwidth = 1362.6479    GMM criterion Q(b) = 2.271e-16

Quantile = .5:
Step 1: Bandwidth = 1302.9736    GMM criterion Q(b) = 2.617e-08
Step 2: Bandwidth = 6079.6881    GMM criterion Q(b) = 2.391e-12
Step 3: Bandwidth = 1438.3068    GMM criterion Q(b) = 9.212e-13

Quantile = .6:
Step 1: Bandwidth = 1533.5129    GMM criterion Q(b) = 2.663e-18
Step 2: Bandwidth = 1520.1182    GMM criterion Q(b) = 1.557e-19

Quantile = .7:
Step 1: Bandwidth = 2044.8617    GMM criterion Q(b) = 1.391e-10
Step 2: Bandwidth = 1977.2482    GMM criterion Q(b) = 1.825e-11

Quantile = .8:
Step 1: Bandwidth = 2503.7256    GMM criterion Q(b) = 3.623e-10
Step 2: Bandwidth = 2458.6714    GMM criterion Q(b) = 2.307e-10

Quantile = .9:
Step 1: Bandwidth = 3560.2178    GMM criterion Q(b) = 4.301e-12
Step 2: Bandwidth = 3529.3557    GMM criterion Q(b) = 2.929e-10

IV quantile regression                              Number of obs =   9,913
Estimator: Smoothed estimating equations            Wald chi2(81) = 4932.84
                                                    Prob > chi2   =  0.0000
```

assets	Coefficient	Robust std. err.	z	P>|z|	[95% conf.	interval]
q10						
1.p401k	3191.667	486.2193	6.56	0.000	2238.695	4144.639
income	.0318585	.0123707	2.58	0.010	.0076124	.0561046
age	128.9268	15.42632	8.36	0.000	98.69178	159.1618
familysize	-329.8374	125.4774	-2.63	0.009	-575.7687	-83.90615
educ	-289.8807	53.06713	-5.46	0.000	-393.8904	-185.8711
married						
Married	-1480.013	386.4611	-3.83	0.000	-2237.463	-722.5635
ira						
Yes	7914.049	342.9506	23.08	0.000	7241.878	8586.22
pension						
Receives ..	-5.356704	334.9869	-0.02	0.987	-661.919	651.2056
ownhome						
Yes	1043.279	308.722	3.38	0.001	438.1945	1648.363
_cons	-7631.313	1214.725	-6.28	0.000	-10012.13	-5250.496
q20						
1.p401k	3503.744	338.8383	10.34	0.000	2839.633	4167.854
income	.0737261	.0084716	8.70	0.000	.057122	.0903302

age	114.9688	10.38239	11.07	0.000	94.61965	135.3179
familysize	-277.8925	78.67289	-3.53	0.000	-432.0885	-123.6964
educ	-194.0516	37.98876	-5.11	0.000	-268.5082	-119.595
married						
Married	-1160.725	253.6528	-4.58	0.000	-1657.876	-663.5752
ira						
Yes	8799.905	388.3753	22.66	0.000	8038.703	9561.106
pension						
Receives ..	-33.33779	218.144	-0.15	0.879	-460.8921	394.2165
ownhome						
Yes	386.2308	201.4194	1.92	0.055	-8.543996	781.0057
_cons	-6264.968	792.0489	-7.91	0.000	-7817.356	-4712.581
q30						
1.p401k	3754.908	320.9631	11.70	0.000	3125.832	4383.984
income	.0939826	.0083408	11.27	0.000	.0776348	.1103303
age	103.8314	8.712147	11.92	0.000	86.75593	120.9069
familysize	-250.4947	59.95479	-4.18	0.000	-368.0039	-132.9855
educ	-134.7013	33.4085	-4.03	0.000	-200.1808	-69.22189
married						
Married	-1028.643	217.4311	-4.73	0.000	-1454.8	-602.4861
ira						
Yes	12008.63	563.5555	21.31	0.000	10904.08	13113.18
pension						
Receives ..	-179.5281	192.0513	-0.93	0.350	-555.9418	196.8855
ownhome						
Yes	195.7323	162.634	1.20	0.229	-123.0246	514.4891
_cons	-5536.814	637.1917	-8.69	0.000	-6785.686	-4287.941
q40						
1.p401k	4326.754	371.7419	11.64	0.000	3598.153	5055.354
income	.1288469	.0105877	12.17	0.000	.1080955	.1495983
age	99.89601	8.289602	12.05	0.000	83.64869	116.1433
familysize	-231.3411	53.94265	-4.29	0.000	-337.0668	-125.6155
educ	-114.4753	32.09266	-3.57	0.000	-177.3758	-51.57484
married						
Married	-1212.951	216.8328	-5.59	0.000	-1637.935	-787.966
ira						
Yes	16874.38	801.2841	21.06	0.000	15303.89	18444.86
pension						
Receives ..	-493.1742	198.6221	-2.48	0.013	-882.4663	-103.8821
ownhome						
Yes	105.4536	152.7777	0.69	0.490	-193.9852	404.8925
_cons	-5216.625	581.4362	-8.97	0.000	-6356.219	-4077.031
q50						

1.p401k	5364.468	573.3728	9.36	0.000	4240.678	6488.258
income	.1679934	.013419	12.52	0.000	.1416925	.1942942
age	113.6318	9.352867	12.15	0.000	95.30052	131.9631
familysize	-228.7766	57.61072	-3.97	0.000	-341.6916	-115.8617
educ	-102.2889	34.18527	-2.99	0.003	-169.2908	-35.28701
married						
Married	-1362.56	238.5988	-5.71	0.000	-1830.205	-894.9153
ira						
Yes	22402.04	1043.504	21.47	0.000	20356.81	24447.27
pension						
Receives ..	-713.996	220.476	-3.24	0.001	-1146.121	-281.8709
ownhome						
Yes	-12.71396	161.3703	-0.08	0.937	-328.994	303.5661
_cons	-5672.645	619.7049	-9.15	0.000	-6887.244	-4458.045
q60						
1.p401k	6964.18	799.1829	8.71	0.000	5397.811	8530.55
income	.2422267	.0180009	13.46	0.000	.2069457	.2775078
age	145.0532	11.88882	12.20	0.000	121.7515	168.3549
familysize	-271.8402	68.28584	-3.98	0.000	-405.678	-138.0024
educ	-128.4236	41.84504	-3.07	0.002	-210.4384	-46.40883
married						
Married	-1790.19	278.6729	-6.42	0.000	-2336.379	-1244.001
ira						
Yes	30029.76	1251.554	23.99	0.000	27576.76	32482.76
pension						
Receives ..	-1063.919	269.4261	-3.95	0.000	-1591.984	-535.8533
ownhome						
Yes	-79.57029	198.2018	-0.40	0.688	-468.0387	308.8981
_cons	-6708.442	714.0485	-9.39	0.000	-8107.951	-5308.932
q70						
1.p401k	9002.846	1108.915	8.12	0.000	6829.412	11176.28
income	.3555392	.0229067	15.52	0.000	.310643	.4004354
age	203.3279	17.59732	11.55	0.000	168.8378	237.818
familysize	-314.0023	89.13006	-3.52	0.000	-488.694	-139.3106
educ	-163.099	52.90533	-3.08	0.002	-266.7916	-59.40646
married						
Married	-2396.634	359.7017	-6.66	0.000	-3101.636	-1691.631
ira						
Yes	38962.04	1621.653	24.03	0.000	35783.66	42140.42
pension						
Receives ..	-1882.868	352.3168	-5.34	0.000	-2573.396	-1192.34
ownhome						
Yes	-19.74677	271.0796	-0.07	0.942	-551.053	511.5595
_cons	-8753.875	954.0692	-9.18	0.000	-10623.82	-6883.934

q80						
1.p401k	10658.02	1665.467	6.40	0.000	7393.765	13922.27
income	.5172628	.0298155	17.35	0.000	.4588255	.5757
age	293.9692	24.78395	11.86	0.000	245.3935	342.5448
familysize	-407.2737	119.8248	-3.40	0.001	-642.1259	-172.4214
educ	-131.0776	69.87187	-1.88	0.061	-268.0239	5.868784
married						
Married	-3077.77	491.0029	-6.27	0.000	-4040.118	-2115.422
ira						
Yes	48410.11	2296.042	21.08	0.000	43909.95	52910.27
pension						
Receives ..	-3049.023	515.0161	-5.92	0.000	-4058.436	-2039.61
ownhome						
Yes	272.4814	412.1642	0.66	0.509	-535.3457	1080.308
_cons	-12294.73	1284.692	-9.57	0.000	-14812.68	-9776.781
q90						
1.p401k	15525.23	3035.965	5.11	0.000	9574.848	21475.61
income	.8311508	.0574108	14.48	0.000	.7186277	.9436738
age	486.9876	51.61654	9.43	0.000	385.821	588.1541
familysize	-586.2617	193.5936	-3.03	0.002	-965.6983	-206.8252
educ	14.5293	110.8781	0.13	0.896	-202.7878	231.8464
married						
Married	-3877.165	781.2296	-4.96	0.000	-5408.347	-2345.983
ira						
Yes	67888.86	4902.106	13.85	0.000	58280.91	77496.81
pension						
Receives ..	-4829.506	898.9147	-5.37	0.000	-6591.346	-3067.665
ownhome						
Yes	715.6272	722.8727	0.99	0.322	-701.1773	2132.432
_cons	-19953.21	2326.698	-8.58	0.000	-24513.45	-15392.96

Endogenous: 1.p401k
Exogenous: income age familysize educ 1.married 1.ira 1.pension 1.ownhome 1.e401k

```
. estimates  store smooth
```