A HAZARD RATE ANALYSIS OF MIRANT'S GENERATING PLANT OUTAGES IN CALIFORNIA

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The California Electricity Crisis of 2000-2001 saw large increases in prices. The diagnosis of the causes includes poor market design, bad policy responses, and a perfect storm of market shocks. The possible role of market manipulation and the exercise of market power have been a focus of study and policy.

Market Power and Withholding

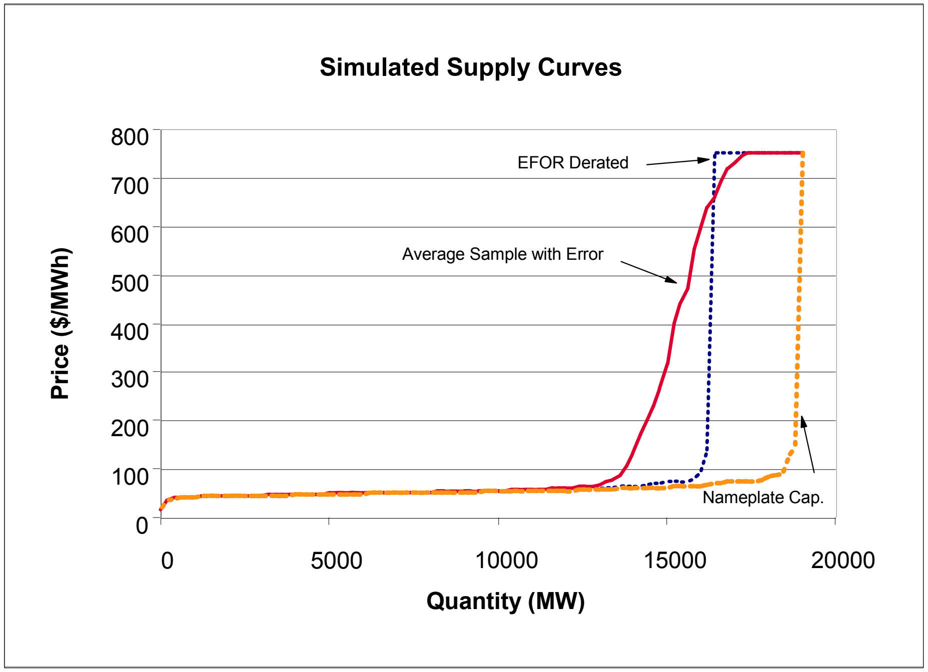
Reduce output, raise prices and profit on inframarginal production or contracts.

- **Economic Withholding.** Offering generation capacity at prices higher than both costs and the market clearing price.

- **Physical Withholding.** Removing generation from the market at any price by declaring an "outage" condition which makes the plant unavailable.

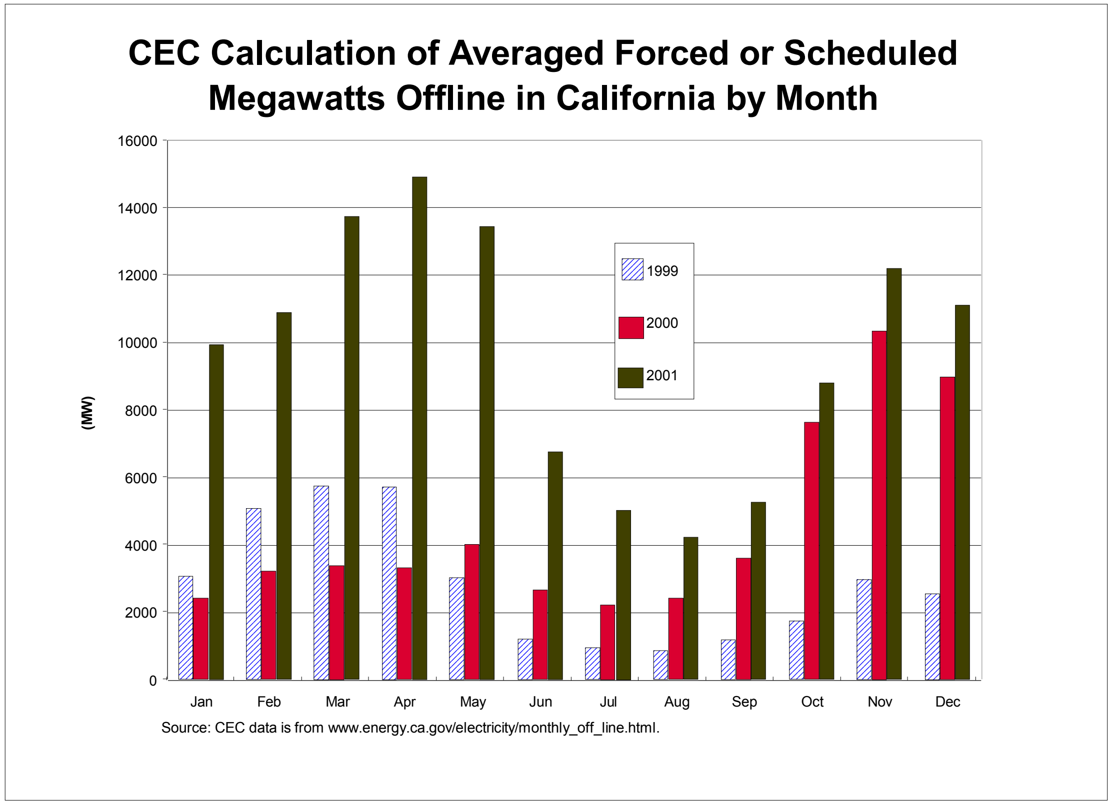
During shortage hours all capacity offered is taken to generate energy or provide reserves and there is no economic withholding. Physical withholding has been alleged to have occurred in California, but investigations have not found evidence of physical withholding. The lack of evidence may mean that no withholding occurred. Or it may be that it is difficult to prove that a declared outage is strategic and not real.

The principal evidence offered of the exercise of market power through withholding has been indirect in the form of counterfactual simulations with static single-price simulations. The methodology is problematic, and sensitive to assumptions. One key assumption of the counterfactual is the "non-strategic" outage rate.



Increasing the assumed outage rate by 5% (capacity weighted 13.7% to 18.7%) raises counterfactual demand weighted average price from $59 to $105 per MWh for a June 2000 simulation.

The California Crisis saw large outages of generating plants.



However, these data do not by themselves indicate strategic withholding. For example, the data include nuclear plants and other facilities owned or under contract to utilities who had incentives to lower prices.

Non-Utility Generators (NUGs), the focus of market power analyses, increased plant availability during the crisis. This controls for ownership, but not reserve shutdowns or other factors.

Average Hourly Capacity On-Line (MWs) – Selected California Utility and NUG Units, 1997-2001

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average Jan-Dec	Average Jan-May	Average Jun-Dec
	Regulated Utility Units														
1997	-	-	-	-	-	-	-	-	-	1,432	656	458	NM	NM	NM
1998	556	568	545	575	827	915	1,960	2,738	2,182	1,357	1,009	810	1,175	615	1,570
1999	780	1,009	1,300	1,166	1,481	2,256	2,773	2,687	1,976	2,605	1,530	1,351	1,749	1,150	2,172
2000	1,665	1,518	1,599	1,043	1,839	2,444	2,981	3,248	2,451	1,817	1,441	1,687	1,982	1,536	2,298
2001	1,800	1,870	1,639	1,447	1,859	1,894	2,116	2,520	2,178	1,755	1,173	1,135	1,783	1,722	1,826
	Non-Utility (NUG) Units														
1997	-	-	-	-	-	-	-	-	-	7,647	5,713	6,293	NM	NM	NM
1998	6,634	5,743	5,812	5,046	4,326	5,928	9,625	11,679	9,962	7,136	6,556	6,536	7,095	5,511	8,213
1999	6,981	6,582	5,710	6,380	5,688	7,254	8,566	8,709	7,774	11,591	7,437	6,828	7,468	6,261	8,320
2000	6,604	6,732	5,938	5,846	9,013	12,401	12,717	13,627	12,376	10,708	9,292	9,999	9,616	6,834	11,592
2001	10,742	10,729	10,537	10,197	10,116	11,535	12,518	13,402	11,730	9,948	8,114	9,240	10,738	10,461	10,933
	Total Regulated Utility and Non-Utility (NUG) Units														
1997	-	-	-	-	-	-	-	-	-	9,079	6,369	6,751	NM	NM	NM
1998	7,190	6,311	6,356	5,622	5,153	6,843	11,585	14,417	12,144	8,493	7,565	7,346	8,270	6,126	9,783
1999	7,761	7,591	7,010	7,545	7,169	9,509	11,339	11,396	9,750	14,196	8,967	8,179	9,217	7,411	10,492
2000	8,269	8,251	7,536	6,889	10,851	14,845	15,698	16,875	14,827	12,525	10,733	11,686	11,598	8,370	13,890
2001	12,542	12,599	12,177	11,644	11,975	13,430	14,634	15,922	13,908	11,703	9,288	10,374	12,521	12,183	12,759

Source: EPA CEMS Data. Capacity values come from EIA form 806, EIA Inventory of Nonutility Electric Power Plants in the United States 1999, and EIA Inventory of Utility Electric Power Plants in the United States 1999.

Note 1: This table reports the average hourly capacity, by month, of the generators that were online in the particular hour. Many units do not report CEMS data, and therefore must be excluded from this table. Units excluded due to lack of data: Alnor, Brawley, Coachella, Downieville, Ellwood, Glenarm, Kearny, Kern, Kings Beach, Long Beach, McClellan, McClure Mountainview, North Island, Oakland, Pebbly Beach, Portola, Redding Power, Rockwood, Walnut. Units included in this table are: Alamitos, Broadway, Contra Costa, Coolwater, El Centro, El Segundo, Encina, Etiwanda, Grayson, Harbor, Haynes, Humbolt Bay, Hunters Point (Partial - see note 2), Huntington Beach, Magnolia, Mandalay, Morro Bay, Moss Landing, Olive, Ormond Beach, Pittsburg, Potrero, Redondo Beach, Riverside, Scattergood, South Bay, Valley and Woodland.

Note 2: In this time period Hunters Point 3-6 reported hourly steam load output, but no hourly gross generation. These units are excluded from this table because it is unclear whether they were producing electricity.

The probability of being out of service is a function of time until failure and time out given a failure.

$$\pi = \mathrm{P}(out\ of\ \ service) = \frac{E\left(time\ out\right)}{E\left(time\ on\ line\right) + E\left(time\ out\right)}.$$

Outage rates could be a strategic choice. A counterfactual simulation assumption might be to use average outage rates from other plants and normal conditions.

$$\pi = \overline{\pi}_{Similar\ Plants,\ Pre-crisis}.$$

A modeling approach would recognize that more intense use of generating plants could increase the probability of failure. A model based on pre-crisis performance of the same plant provides a test of the counterfactual and an alternative assumption for simulations.

$$\pi = \pi_{\ Pre-crisis}\left(Utilization, Overhauls, \cdots\right).$$

A comparison of the predicted and actual performance during the crisis provides an estimate of the "strategic" crisis effect.

$$\Delta = \pi\left(\overline{Z}_{Crisis}, Crisis = 1\right) - \pi\left(\overline{Z}_{Crisis}, Crisis = 0\right).$$

OUTAGE HISTORY Mirant Plants

In 1999 Mirant acquired a number of power plants from PG&E, along with daily data back to 1994.

Actual and Assumed Outage Rates (%) for PG&E/Mirant Units

	NERC/ Joskow-Kahn (A)	Annual Forced Outage 1994-1999 (B)	Annual Total Outage 1994-1999 (C)	Summer Forced Outage 1994-1999 (D)	Summer Total Outage 1994-1999 (E)
Contra Costa 6	8.51	23.64	31.41	6.88	16.57
Contra Costa 7	8.51	4.33	13.84	2.69	5.18
Average	8.51	13.99	22.63	4.79	10.88
Pittsburg 5	8.51	14.63	25.73	9.53	10.34
Pittsburg 6	8.51	2.00	12.66	0.58	20.56
Pittsburg 7	8.71	8.57	21.84	6.41	7.58
Average	8.58	8.40	20.08	5.51	12.83
Potrero 3	6.70	5.58	17.25	3.76	9.89
Pittsburg 1	10.30	50.45	56.61	48.69	52.12
Pittsburg 2	10.30	43.12	52.35	23.96	26.45
Pittsburg 3	10.30	66.70	74.18	42.26	45.44
Pittsburg 4	10.30	25.77	39.83	12.93	20.99
Average	10.30	46.51	55.74	31.96	36.25

(A) NERC GADS data, 1995 - 1999 Generating Unit Statistical Brochure, available at www.nerc.com/~filez/gar.html
(B) Forced outage hours January 1, 1994-December 31, 1998/ (forced outage + on-line hours)
(C) [Forced outage hours January 1, 1994-December 31, 1998/ (forced outage + on-line hours)] + [(maintenance hours/total hours)]
(D) Forced outage hours June 1 - September 30, 1994-1998/ (forced outage + on-line hours)
(E) [Forced outage hours June 1 - September 30, 1994-1998/ (forced outage + on-line hours)] + [(maintenance hours/total hours)]

Data Sources: Mirant Outage Data and The files CAL_SISO_4_Gen_Sch2_yyQ#
from the CD "ISO Responses to Cal Parties First Set of DR, EL00-95 et al, Disk 2."

HAZARD RATE MODEL — Failures and Outage Duration

The extended data base covered 1994 through June 2001.

The data allow for estimation of a hazard rate model for failure times and outage durations. With predictions of expected values for each, we have estimates of the outage rates. The principal assumptions applied include:

- **Exclude Reserve Shutdowns.** Reserve shutdowns indicate periods when plants were not needed. These are not failures or outages and were treated as stopping the clock.
- **Exclude Major Overhauls.** These unusual events are for major changes such as installing new environmental equipment. These require scheduling by the Independent System Operator and could not be strategic decisions.
- **Exclude Deratings.** These are short duration partial outages. Would need a separate model of partial outages. On a national basis, these are small effects.
- **Combine Maintenance and Forced Outages.** The distinction between maintenance and forced outages is somewhat arbitrary. Treat all such outages as a single type.

A hazard rate or duration model characterizes the distribution of failure times.

The density function describes the time to failure of the equipment, $f(t)$. The cumulative distribution for the probability that equipment fails at or before time *t* is

$$F(t) = \int_0^t f(s)\,ds.$$

Given the cumulative failure distribution, the survival function is the probability that the equipment is still running at time *t*, as in

$$S(t) = 1 - F(t).$$

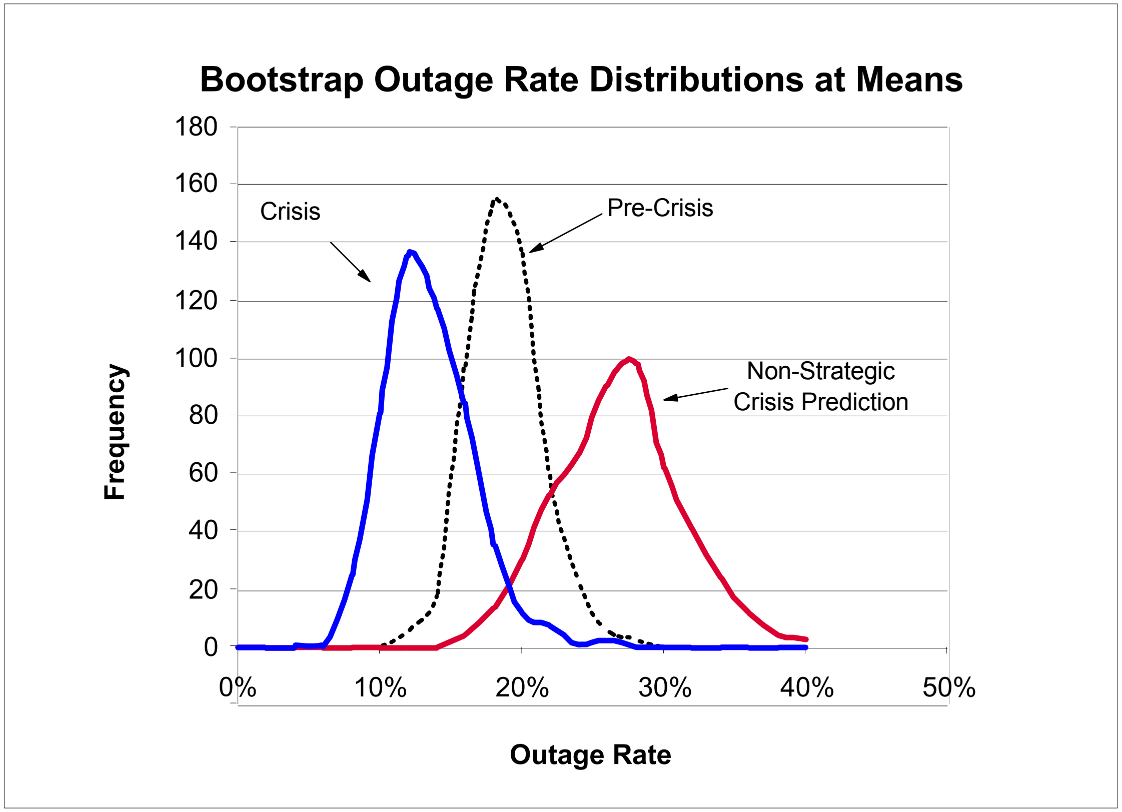
Given the survival function the hazard rate is

$$r(t) = \frac{f(t)}{S(t)}.$$

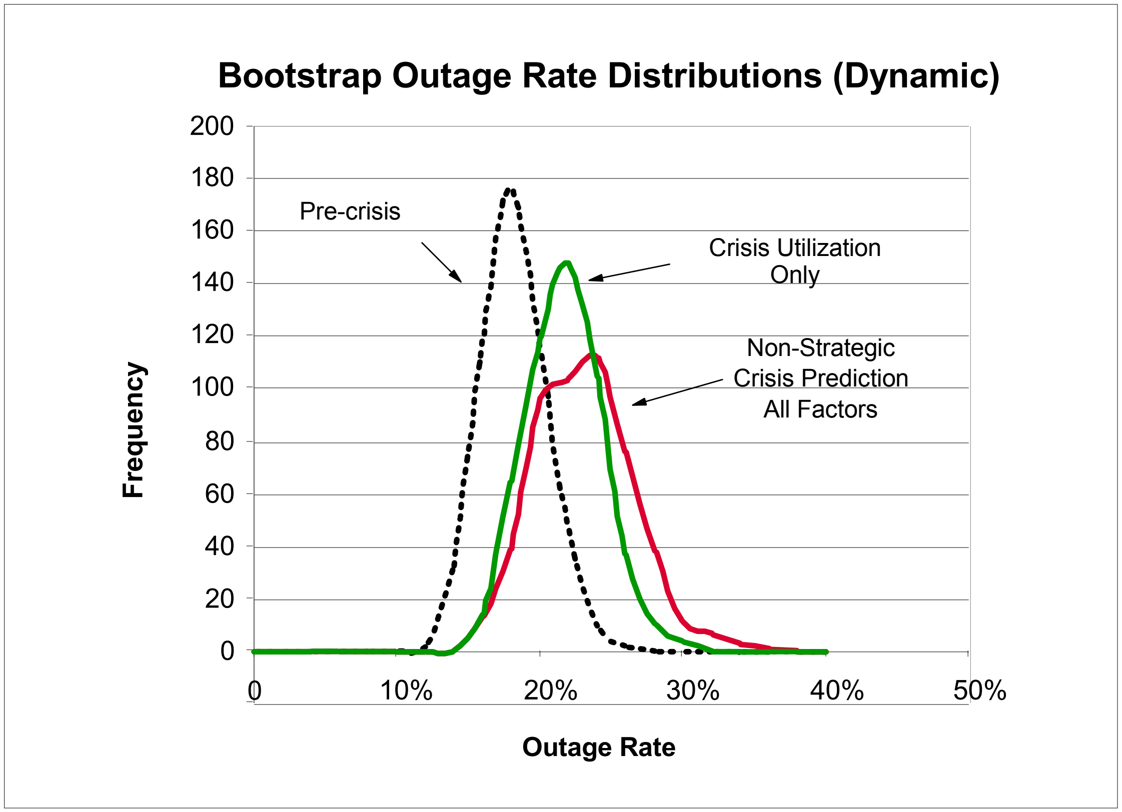
The hazard rate is essentially the rate at which failures occur at time *t* given that the equipment has not yet failed. A proportional hazard rate model characterizes the plant hazard rate as a base model scaled by the effects of external variables $\left(Z_i(t)\right)$, or

$$r_i(t) = r_0(t)\,e^{Z_i(t)\beta}.$$

Evaluated at plant sample means, the crisis period counterfactual prediction is for higher outage rates. The "strategic" effect of the crisis implies lower outage rates.



Integrating over the dynamic path of covariates provides alternative estimates of the counterfactual for (i) changes in utilization only and for (ii) all changes in the crisis covariates.



MIRANT OUTAGE RATES   Summary

The hazard rate model predicts that under the crisis period conditions failure times would have been shorter, outage durations longer, and outage rates higher. The actual Mirant performance during the crisis yielded significantly lower outage rates than the counterfactual prediction.

Mirant Plants					
Estimated Capacity Weighted Outage Rates					
	Point Estimate	**Point Estimate**	**Difference**	**Bootstrap Mean**	**Bootstrap Standard Error**
	$\pi\left(\bar{Z}_{Pre-crisis}, C=0\right)$	$\pi\left(\bar{Z}_{Crisis}, C=0\right)$	Δ	$\bar{\Delta}$	$s.e\left(\Delta\right)$
At Means: No Crisis Effect	18.75%	26.65%	7.90%	7.92%	3.50%
	$\pi\left(\bar{Z}_{Crisis}, C=0\right)$	$\pi\left(\bar{Z}_{Crisis}, C=1\right)$			
At Means: Crisis Effect	26.65%	12.65%	-14.00%	-13.31%	5.22%
	$\bar{\pi}\left(U_{Pre-crisis}, \bullet, C=0\right)$	$\bar{\pi}\left(\frac{\bar{U}_{crisis}}{\bar{U}_{Pre-crisis}} U_{Pre-crisis}, \bullet, C=0\right)$			
Dynamic: Incremental Utilization	17.36%	21.07%	3.71%	3.59%	0.84%
	$\bar{\pi}\left(Z_{Pre-crisis}, C=0\right)$	$\bar{\pi}\left(Z_{Crisis}, C=0\right)$			
Dynamic: Total No Crisis Effect	17.36%	19.80%	2.44%	4.88%	2.95%

Supporting papers and additional detail can be obtained from the authors. Scott Harvey is a Director with LECG, LLC. William W. Hogan is the Lucius N. Littauer Professor of Public Policy and Administration, John F. Kennedy School of Government, Harvard University and a Director of LECG, LLC. Todd Schatzki is a managing economist at LECG, LLC. This paper draws on work for the Harvard Electricity Policy Group and the Harvard-Japan Project on Energy and the Environment. The author are or have been consultants on electric market reform and transmission issues for Allegheny Electric Global Market, American Electric Power, American National Power, Australian Gas Light Company, Avista Energy, Brazil Power Exchange Administrator (ASMAE), British National Grid Company, California Independent Energy Producers Association, Calpine Corporation, Central Maine Power Company, Comision Reguladora De Energia (CRE, Mexico), Commonwealth Edison Company, Conectiv, Constellation Power Source, Coral Power, Detroit Edison Company, Duquesne Light Company, Dynegy, Edison Electric Institute, Edison Mission Energy, Electricity Corporation of New Zealand, Electric Power Supply Association, El Paso Electric, GPU Inc. (and the Supporting Companies of PJM), GPU PowerNet Pty Ltd., GWF Energy, Independent Energy Producers Assn, ISO New England, Maine Public Advocate, Maine Public Utilities Commission, Midwest ISO, Mirant Corporation, Morgan Stanley Capital Group, National Independent Energy Producers, New England Power Company, New York Independent System Operator, New York Power Pool, New York Utilities Collaborative, Niagara Mohawk Corporation, NRG Energy, Inc., Ontario IMO, Pepco, Pinpoint Power, PJM Office of Interconnection, PP&L, Public Service Electric & Gas Company, Reliant Energy, Rhode Island Public Utilities Commission, San Diego Gas & Electric Corporation, Sempra Energy, SPP, Texas Utilities Co, TransÉnergie, Transpower of New Zealand, Westbrook Power, Williams Energy Group, and Wisconsin Electric Power Company. Hallie Martin and John Jankowski provided research assistance. The views presented here are not necessarily attributable to any of those mentioned, and any remaining errors are solely the responsibility of the author. (Related papers can be found on the web at www.whogan.com).