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Consumption effects of an electricity decarbonization policy: Hong Kong

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Agenda

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- Key findings
- Main contributions
- Background
- Data description
- Regression results
- Effects on CO_2 emissions

Research questions

+ What is the estimated reduction in Hong Kong's total electricity demand due to the projected 40% electricity rate increase triggered by Hong Kong's adopted fuel mix policy?
+ What is the estimated increase in Hong Kong's town gas consumption due to the projected 40% electricity rate increase?
+ Are Hong Kong's electricity demands highly price-inelastic?

Key findings

+ Hong Kong’s retail demands for electricity and town gas are highly price-inelastic, with a -0.0194 aggregate electricity elasticity estimate, and a -0.1275 aggregate town gas elasticity estimate.
+ A 40% electricity rate increase reduces Hong Kong’s total electricity demand by only 0.81% and increases Hong Kong's total town gas consumption by 5.12%, chiefly because electricity and town gas are substitutes.
+ The decremental emissions of declining electricity consumption are weakened by the incremental emissions of rising town gas consumption. Therefore, the net impact is only a 0.24% reduction in Hong Kong's CO_2 emissions.
+ The electricity demands' low price responsiveness has two important policy implications:
  - Hong Kong's demand-side-management should rely more on energy-efficiency improvements than price-induced consumption reductions.
  - Restructuring Hong Kong's electricity industry to introduce wholesale competition should consider the potential for large electricity price spikes and market power abuse in connection to price-inelastic electricity demands.

Main contributions

+ First, it shows how to use the monthly tariff information to construct monthly energy price data by customer class that match the publicly available quarterly price data.
+ Second, it presents a constant-elasticity-of-substitution (CES) system of electricity and town gas demands to comprehensively estimate class-specific price elasticities. This formulation is applicable to cities and regions where aggregate data are available but disaggregate data are either unavailable or costly to collect.
+ Third, it documents the effects of monthly weather on Hong Kong's electricity and town gas consumption, after an extensive exploration of weather variables.
+ Finally, it documents small price elasticity estimates of -0.01 to -0.02 for Hong Kong's class-specific electricity demands and -0.06 to -0.23 for the related town gas demands.

Background

+ This presentation's empirics are based on Woo, C.K., A. Shiu, Y. Liu, X. Luo and J. Zarnikau (2018) "Consumption effects of an electricity decarbonization policy: Hong Kong," *Energy*, 144, 887-902.
+ Another application of the methodology can be found in Woo, C.K., Y. Liu, X. Luo, A. Shiu and J. Zarnikau (2017) "Consumption effects of electricity decarbonization: Evidence from California and the Pacific Northwest," *The Electricity Journal*, 30 (10), 44-49.
+ Both papers are motivated by decarbonization of electricity supply that uses low-carbon resources (e.g., new natural-gas-fired generation) and zero-carbon resources (e.g., hydro, solar and wind) to displace those with high CO_2 emissions (e.g., aging coal-and natural-gas-fired generation).

Three transformative events in the world's electricity industry

+ The first event is the market restructuring to introduce wholesale competition that has triggered extensive research in price behavior and dynamics, forward contracts and tolling agreements, derivatives and risk management, product differentiation, system operation, and integrated resource planning of generators.
+ The second event is large-scale renewable energy development, thanks to the global potential of solar and wind resources, as well as government policies such as feed-in-tariff (FIT), easy transmission access, renewable portfolio standard, low-cost financing, and tax subsidies.
+ The third event is deep decarbonization, underscored by China's aggressive pursuit of decarbonization through renewable energy development and carbon trading, which are a clean electricity future's critical components that have attracted extensive research attention.

Why Hong Kong?

+ Hong Kong is an international metropolis with a strong economic performance that could not have been possible *sans* a superbly reliable electricity supply.
+ Hong Kong is experiencing deteriorating air quality. The major source of local emissions, including CO2, is the 6,608MW of coal-fired generation that accounts for 52.3% of Hong Kong's 12,625MW of total generation capacity.
+ The Hong Kong government has recently made two important policy decisions that shape Hong Kong's electricity future. The first decision rejects reforming Hong Kong's electricity industry due to concerns of limited competition among the likely few sellers. The second decision adopts a fuel mix that will project a 40% electricity rate increase. Its acceptance from the public reflects the growing concerns of global warming and their willingness to pay for the cost of electricity decarbonization, see Cheng, Y.S., K.H. Cao, C.K. Woo, and A. Yatchew (2017) “Residential willingness to pay for deep decarbonization of electricity supply: contingent valuation evidence from Hong Kong,” *Energy Policy*, 109, 218-227.

Research relevancy in other regions

- The first case in point is California's newly enacted renewable portfolio standard, mandating that 50% of the state's electricity sales be met by 2030 by qualifying renewable resources such as solar, wind or geothermal.
- The second case is nuclear plant retirements in Europe in the wake of Japan's 2011 Fukushima disaster, as well as the vast development of renewable resources in Europe and North America.
- The third case is China's ambitious plan to cut its greenhouse gas emissions by reducing its consumption of coal, the dominant fuel used in China's electricity generation.

Data description

- We estimate retail electricity and town gas price elasticities for three major customer classes: residential, commercial and industrial.
- The Hong Kong government publishes the following data:
  - Monthly electricity and town gas consumption data by customer class from the Census and Statistics Department;
  - Quarterly utility-specific tariffs by customer class for electricity and town gas in the various issues of Hong Kong Energy Statistics Quarterly Report or Hong Kong Energy Statistics Annual Report published by the Census and Statistics Department;
  - Quarterly real GDP available in Hong Kong Economic Reports;
  - Monthly weather data published by the Hong Kong Observatory.
- We use a newly constructed sample of monthly data for the 192-month period of January 1981 to December 2016.

Regression model

+ After extensive trials of different functional forms and model specifications, we find that the following CES specification is an empirically plausible representation for our sample's Data Generation Process (DGP):

$$\Delta\ln(X_k / Y_k) = \alpha_k \, \Delta\ln(E_k/G_k) + \beta_k \, \Delta\ln(\mathrm{GDP}) + Z_k + \mu_k$$

  - X_k = electricity consumption (MWh) at price E_k ($/MWh) for customer class k = 1 for residential, 2 for commercial and 3 for industrial;
  - Y_k = town gas consumption (GJ) at price G_k ($/GJ);
  - Z_k = function of non-price drivers, including weather variables (ΔCDM and ΔHDM) and binary indicators;
  - μ_k = random error.

+ Coefficient $\alpha_k < 0$ measures the marginal effect of $\Delta\ln(E_k/G_k)$ on $\Delta\ln(X_k/Y_k)$.

+ Coefficient $\beta_k > 0$ measures the marginal effect of $\Delta\ln(GDP)$ on $\Delta\ln(X_k / Y_k)$.

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Regression results

Table 3
ITSUR regression results for the CES system; sample period = Jan-1981 – Dec-2016; adjusted R^2 in [ ]; clustered autocorrelation-heteroscedasticity-consistent standard errors in ( ); "***" = 1% significance, "**" = 5% significance, "*" = 10% significance.

Variable	Residential class: $j = 1$ [0.7888]	Commercial class: $j = 2$ [0.7769]	Industrial class: $j = 3$ [0.4267]
$\Delta\ln(E_j/G_j)$	−0.0861 (0.1944)	−0.2178* (0.1162)	−0.2400 (0.1983)
$\Delta\ln(\text{GDP})$	1.6455*** (0.2994)	0.3373** (0.1684)	0.0245 (0.2430)
ΔCDM	0.0288*** (0.0065)	0.0136*** (0.0028)	0.0022 (0.0039)
ΔHDM	0.0399*** (0.0085)	0.0047 (0.0044)	−0.0215*** (0.0063)

Note: For brevity, this table omits the estimates for the intercepts and coefficients of the binary indicators for months.

- The regressions have an empirically reasonable fit, with adjusted R^2 values of 0.43 to 0.79.
- The estimates for α_k are all negative and small in size, implying that electricity and town gas are substitutes and have low price responsiveness.
- The positive coefficient estimates for Δln(GDP) indicate that rising GDP tends to raise the consumption ratio.
- Coefficient estimates for ΔCDM and ΔHDM confirm Hong Kong's electricity and town gas demands move with weather.

Own-price elasticity estimates

Table 4
Own-price elasticity estimates based on ITSUR regression results; sample period = Jan-1981 – Dec-2016; standard errors in ( ); "***" = 1% significance, "**" = 5% significance, "*" = 10% significance.

Energy type	Residential	Commercial	Industrial	Aggregate
Electricity	−0.0214 (0.0482)	−0.0207* (0.0110)	−0.0113 (0.0093)	−0.0194 (0.0150)
Town gas	−0.0648 (0.1462)	−0.1972* (0.1052)	−0.2287 (0.1890)	−0.1275 (0.0985)

Note: The cross-price elasticity estimates are not shown here because the sum of the own-price and cross-price elasticity estimates is equal to zero, see Appendix C. The aggregate elasticity is the weighted average of the class-specific estimates, with each weight equal to the class-specific consumption share.

- Own-price elasticity of electricity demand of class k: $\varepsilon_k = \alpha_k \times [G_k Y_k/(E_k X_k + G_k Y_k)]$

- Hong Kong's electricity and town gas demands are highly price-inelastic.

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Calculation of consumption effects

- Step 1: Find the change in class *k*'s electricity consumption: $\Delta X_k = \varepsilon_k \times 40\% \times$ class *k*'s electricity consumption (MWh) in 2016. As $\varepsilon_k < 0$, $\Delta X_k < 0$.
- Step 2: Find the change in natural gas used in electricity generation (MMBtu) due to ΔX_k: $M_k = \Delta X_k \times$ heat rate (HR), where HR =7 MMBtu/MWh for a combined cycle gas turbine (CCGT). The total change in electricity generation's natural gas usage is $M = M_1 + M_2 + M_3$. The CO_2 emissions change due to M: $R_1 = M \times K_1$, where K_1 = CO_2 emissions of burning natural gas = 53.2 kg/MMBtu.
- Step 3: Find the change in class *k*'s town gas consumption: $N_k = h_k \times 40\% \times$ class *k*'s town gas consumption (GJ) in 2016. As the cross-price elasticity of natural gas consumption $h_k > 0$, $N_k > 0$. The total change in town gas consumption is $N = N_1 + N_2 + N_3$. The CO_2 emissions change due to N: $R_2 = N \times K_2$, where K_2 = CO2 emissions of burning town gas = 59.9 kg/GJ.
- Step 4: Find the net CO_2 emissions change $R = R_1 + R_2$.

Conclusion: Small net changes in CO_2 emissions

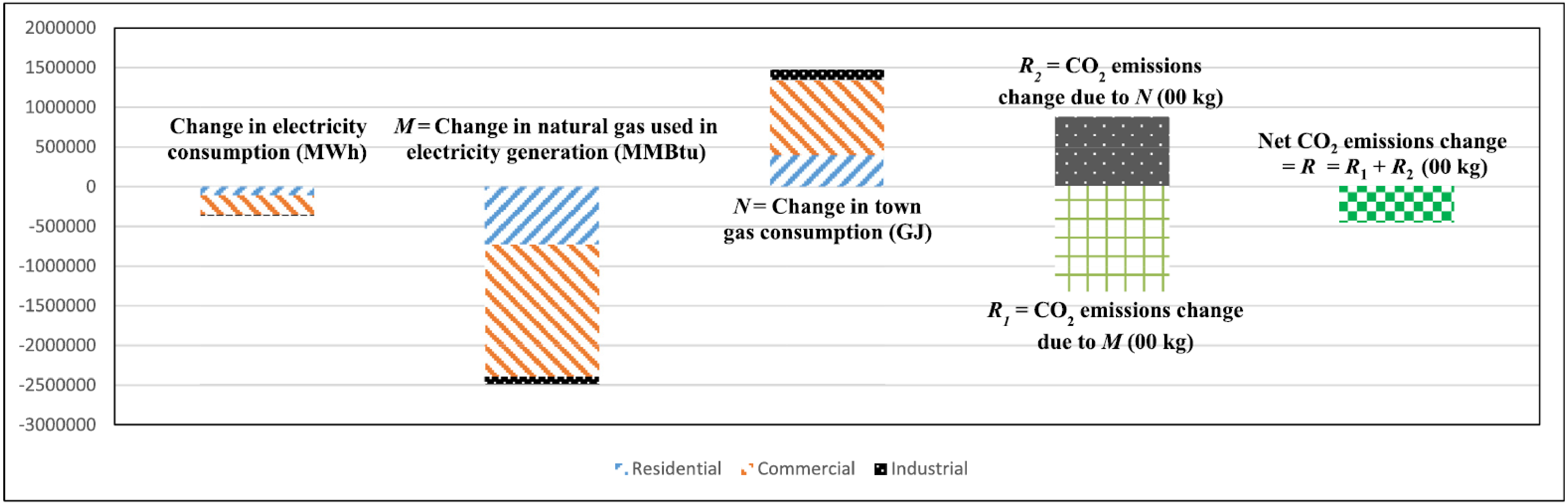

Fig. 2. The net change in CO_2 emissions due to the 40% electricity price increase based on the annual consumption data in 2016 under the expected price responsiveness scenario.

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- With 30+ years of industry experience, he has successfully participated in regulatory proceedings in California, Missouri, Texas, British Columbia, Alberta, Ontario, and Quebec.
- He has provided advice on electricity market reform in California, British Columbia, Alberta, Ontario, Quebec, Israel, Hong Kong, and Macau.
- He has published over 140 papers in such scholarly journals as *Energy*, *Energy Policy, The Energy Journal, Energy Economics, IEEE Transactions, Journal of Public Economics,* and *Quarterly Journal of Economics.*
- Recognized by *Who's Who in America*, he is a senior fellow of the United States Association for Energy Economics and an editorial board member of *Energy* (impact factor: 5.182), *Energy Policy* (impact factor: 4.599) and *The Energy Journal* (impact factor: 2.652).