Can Hong Kong Price-manage Its Cross-harbor Tunnel Congestion?

Motivation

As is common in major cities of the industrialized world, Hong Kong is prone to severe traffic jams, despite the 11 million passenger journeys made each day on its public transport system. With 329 licensed vehicles for every km of road, Hong Kong drivers experience daily congestion delays, especially at the Cross Harbor Tunnel (CHT) which links Kowloon and Hong Kong Island and the two principal commercial centers of the territory that span Victoria Harbor. By contrast, traffic is relatively light at the Eastern Harbor Crossing (EHC) and the Western Harbor Crossing (WHC), which offer motorists alternative routes.

In 2013, the Hong Kong Special Administrative Region (HKSAR) Government issued a consultation paper, seeking public comments on three toll-change proposals that would raise the CHT’s tolls and lower the EHC’s tolls. The WHC’s tolls would remain unchanged due to its congested connecting roads. It is expected that the change in tolls can help relieving the CHT’s congestion.

This proposal prompts us to investigate whether its implementation is likely to be effective in affecting the tunnels’ usage patterns, or whether the usage patterns of the three tunnels is price-responsive. We examine the price responsiveness of Hong Kong’s three cross-harbor tunnels, and in particular, we (i) calculate own-price and cross-price elasticities by vehicle type and (ii) examine whether the tunnels are substitutes in the driver’s daily tunnel-choice decisions.

Topic Keywords

Congestion; Road pricing; Traffic demand estimation.

Major Research Question

Can Hong Kong price-manage its cross-harbor-tunnel congestion?

Key Questions to be Answered

- What are Hong Kong’s cross-harbor tunnels? How congested are these tunnels?
- How many vehicle-specific tolls are there?
- What is price management of congestion? What is the empirical evidence required for price management?
- Are tunnel crossings price-sensitive?
- Is the existing evidence sufficient to support the Hong Kong Government’s proposal of changing the tunnel tolls? If not, what’s missing?
- Do we need new evidence? If “yes”, how can we update the empirical evidence? What is the data availability? What is the analysis plan? What is the expected result?
- What is the new evidence? Is it as expected? Is it different from the old evidence? Does it support the Government’s proposal?
- What is the final answer to the main question: “yes” or “no”??
Methodology and Data

We use monthly crossing data available from the HKSAR’s Transport Department to estimate demand equations of Hong Kong’s cross-harbor tunnel usage of different vehicle types. The results can then be used to calculate the disaggregate and aggregate elasticities.

A “disaggregate” price elasticity estimate measures the price responsiveness of a particular vehicle type using a particular tunnel and an “aggregate” price elasticity estimate summarizes the price responsiveness of all vehicles using a particular tunnel.

A given vehicle type’s demand equation of tunnel j

\[ N_{jt} = \beta_{jj} + \sum_{k \neq j} \beta_{jk} \left( \frac{P_{kt}}{P_{jt}} \right)^{1/2} + \psi_j Y_t + \phi_j t, \quad (1) \]

where
- \( N \) represents monthly crossings;
- \( j \) or \( k \) represents a particular tunnel;
- \( P \) represents toll cost;
- \( Y \) represents Hong Kong’s monthly real GDP; and
- \( t \) represents monthly index that captures the time trend’s effect of non-toll costs, \( t = 1, \ldots, T \).

\( N_{jt} \) linearly depends on \( \left( \frac{P_{kt}}{P_{jt}} \right)^{1/2}, Y_t \) and \( t \) in equation (1).

There are three simple steps to calculate the disaggregate price elasticities for each vehicle type:

**S1:** Estimate equation (1) for each vehicle type separately using Ordinary Least Squares (OLS). The key estimate obtained is \( \beta_{jk} \).

**S2:** Take natural log of equation (1) and apply differentiation to obtain the own-price and cross-price elasticity formulae.

**S3:** Substitute the \( \beta_{jk} \) estimate (obtained from the estimated regression of equation (1)), \( P_{kt}, P_{jt} \) and \( N_{jt} \) into the required elasticity formulae to calculate the own-price and cross-price elasticities.

**S4:** Divide the sum of own-price and cross-price elasticities over the sample period by the number of months in the sample period to obtain the vehicle-specific monthly total usage’s average own-price and cross-price elasticities.
A given vehicle type’s disaggregate price elasticities for monthly total usage of tunnel \( j \)

(1) The vehicle type’s own-price elasticity (this measures how a change of tunnel \( j \)’s toll affects the tunnel crossings of the vehicle type for tunnel \( j \)) in month \( t \):

\[
\eta_{jjt} = \frac{\partial \ln N_{jt}}{\partial \ln P_{jt}} = -\frac{1}{2} \sum_{k \neq j} \beta_{jk} \left( \frac{P_{kt}}{P_{jt}} \right)^{1/2} / N_{jt}
\]

When \( \beta_{jk} \geq 0 \), \( \eta_{jj} \leq 0 \), suggesting that this vehicle type has a downward-sloping demand curve for tunnel \( j \).

(2) Vehicle-specific monthly total usage’s average own-price responsiveness:

\[
\eta_{jj} = \frac{\sum_t \eta_{jjt}}{T}, \text{ the equally-weighted average of } \eta_{jjt}
\]

(3) The vehicle type’s cross-price elasticity (this measures how a change of the tunnel \( k \)’s toll affects the tunnel crossings of the vehicle type for tunnel \( j \)) in month \( t \):

\[
\eta_{jkt} = \frac{\partial \ln N_{jt}}{\partial \ln P_{kt}} = \frac{1}{2} \beta_{jk} \left( \frac{P_{kt}}{P_{jt}} \right)^{1/2} / N_{jt} \text{ for } k \neq j
\]

When \( \beta_{jk} \geq 0 \), \( \eta_{jkt} \geq 0 \), suggesting that tunnels \( j \) and \( k \) are substitutes for the drivers of a particular vehicle type.

(4) The vehicle-specific monthly total usage’s average cross-price responsiveness:

\[
\eta_{jk} = \frac{\sum_t \eta_{jkt}}{T}, \text{ the equally-weighted average of } \eta_{jkt}
\]
A tunnel j’s aggregate usage elasticities

To compute an aggregate elasticity, we first use the index $m$ to denote a vehicle type.

$$E_{jk} = \text{percent change in tunnel } j\text{'s aggregate usage due to a one-percent change in tunnel } k\text{'s nine vehicle-specific tolls:}$$

$$E_{jk} = \frac{\sum_m \sum_t \eta_{jkt} W_{jmt}}{T},$$

where $\eta_{jkt}$ = vehicle type m’s $\eta_{jkt}$ value and $W_{jmt}$ = vehicle type m’s share of tunnel j’s aggregate usage in month t.

Data

We used 156 monthly observations for the 13-year period of 2000 to 2012 on harbor crossings for our model estimation. We considered three cross-harbor tunnels and nine vehicle types (including private cars, taxis, motorcycles, light buses, single-decked buses, double-decked buses, light goods vehicles, medium goods vehicles, and heavy goods vehicles). The followings show the data required and the source:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_{1t}$</td>
<td>Monthly vehicle-specific crossings: Eastern Harbor Crossing (EHC)</td>
<td>Monthly Traffic and Transport Digest, various issues, Transport Department, HKSAR.</td>
</tr>
<tr>
<td>$N_{2t}$</td>
<td>Monthly vehicle-specific crossings: Cross Harbor Tunnel (CHT)</td>
<td>Same as above</td>
</tr>
<tr>
<td>$N_{3t}$</td>
<td>Monthly vehicle-specific crossings: Western Harbor Crossing (WHC)</td>
<td>Same as above</td>
</tr>
<tr>
<td>$P_{1t}$</td>
<td>Monthly vehicle-specific tolls (HK$/crossing): Eastern Harbor Crossing (EHC)</td>
<td>Annual Transport Digest, various issues, Transport Department, HKSAR; and <a href="http://www.westernharbourtunnel.com/en/about4.html">http://www.westernharbourtunnel.com/en/about4.html</a>. When a toll changes in the midst of a month, the monthly toll is the average of the daily tolls.</td>
</tr>
<tr>
<td>$P_{2t}$</td>
<td>Monthly vehicle-specific tolls (HK$/crossing): Cross Harbor Tunnel (CHT)</td>
<td>Same as above</td>
</tr>
<tr>
<td>$P_{3t}$</td>
<td>Monthly vehicle-specific tolls (HK$/crossing): Western Harbor Crossing (WHC)</td>
<td>Same as above</td>
</tr>
<tr>
<td>$Y_t$</td>
<td>Monthly real GDP (2011 HK$M)</td>
<td>Hong Kong Monthly Digest of Statistics, Census and Statistics Department, Hong Kong SAR. Since the HKSAR Government only publishes quarterly real GDP and quarter-end employment, we first derive the monthly employment figures by linear extrapolation. Then, we estimate the monthly GDP as (a) quarterly GDP times (b) monthly share of the quarterly total employment-days = monthly employment * monthly number of calendar days.</td>
</tr>
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Conclusion

Based on the 2000-2012 monthly tunnel crossings by nine vehicle types, we show that Hong Kong can price-manage its cross-harbor-tunnel congestion, since the three tunnels are found to be substitutes with discernible price responsiveness. The toll changes proposed by the Transport and Housing Bureau (2013) are estimated to reduce crossings via the CHT by as much as 19.6%.

Taken together, these findings imply that the HKSAR Government can implement a pricing policy for effective transportation demand management of Hong Kong’s three cross-harbor tunnels.

References


