Beyond the Iceberg Hypothesis: Opening the Black Box of Transport Costs

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Motivation

- Trade costs: A central role in international economic analysis
  - Declining over the second half of the 20^{th} century (Jacks et al., 2008, Novy, 2013)
  - But still significant: Average international trade costs = a 74% markup over production costs (Anderson & Van Wincoop, 2004)
- What exactly are "trade costs"?
  - Transaction costs, policy costs, time costs, and transport costs *per se*
- Transport costs: A sizeable share of international trade costs
  - Account for 21% of international trade costs (Anderson & Van Wincoop, 2004)
  - Elasticity of trade wrt freight costs = -3 (Behar & Venables, 2011)

$\Rightarrow$ If much trade policy barriers have been removed, the transport cost component of trade costs remains sizeable

The paper: On international transport costs

Motivation (cont')

- Standard modeling of trade costs: As an ad-valorem tax-equivalent
  - As a constant percentage of the producer price per unit traded
  - $\Leftrightarrow$ The "iceberg cost" hypothesis (Samuelson, 1954)
- Yet... A debated question
- Wouldn't trade costs rather exhibit an additive structure ?
- The structure (additive vs iceberg) of transport costs, far from being anecdotal
  - Additive trade costs, an important role in shaping the pattern of trade flows (the Alchian & Allen (1964) conjecture)
  - A bunch of empirical papers in support of the additive hypothesis: Martin (2012), Hummels & Skiba (2004), Irrarazabal et al. (2015)
  - With strong normative implications: Sorensen (2014), Irrarazabal et al. (2015)

$\Rightarrow$ Trade costs are likely to display an additive component, but precisely... by how much?

One objective of the paper: Provide an answer to this question

Our paper

- An empirical decomposition of the structure of transport costs
- Quantitatively assess the size and the importance of the additive component in international transport costs
  - Exploit the differences between export and imports prices (by transport mode, ocean and air)
  - From the US imports flows, on a yearly basis from 1974 to 2013
- Our contribution to the literature
  - Confirm the literature about the importance of the additive component of trade costs (Martin, 2012, Hummels & Skiba, 2004)
  - But, we quantify it
  - Over a large spectrum of time (1974 to 2013) and distinguishing between air and sea transport

⇒ A broad view of the magnitude of additive costs in international trade over time

Three questions, three answers

- What is the size of the iceberg and the additive trade costs?

$\Rightarrow$ Provide a quantitative measure of both

  - Iceberg cost: 2.5% and 3.2% of the export price in air and ocean transport (mean value over 1974-2013)
  - Additive cost: 1.8% and 2.9% of the export price

- What do we lose by skipping the additive part of transport costs?

$\Rightarrow$ We lose much

  - With the additive term included, the ad-valorem component reduces by a factor of 2
  - With the additive term taken into account, a significantly better "goodness-of-fit"

- How have international transport costs evolved over time?
  - Transport costs *per se* have fallen since 1985, by 40%
  - When additive costs are included, not much difference between air and sea transport, $\neq$ Hummels (2007) and Behar & Venables (2011)

Plan of the talk

- Data Sources
- Empirical Methodology
- Assessing the importance of the additive component in transport costs
  - Measure both the ad-valorem and the additive components
  - Goodness-of-fit evaluation
- Characterizing the trends of transport costs
- Conclusion

Data sources

- Our measure of international transport costs: The difference between the export price and the import price
- Database: US Imports of Merchandise database ▸ More
  - The export (fas) price, $\widetilde{p}$: the price for one kg of merchandise at the country export gate
  - The import (cif) price, p: the price for one kg of merchandise at the entry in the US
  - Yearly basis, from 1974 to 2013, HS 10 digit classification level, by transport mode (air or vessel)

$\Rightarrow$ Our dependent variable: The ratio $p/\widetilde{p}$

  - At the 3-digit classification level
  - Estimation at the 4-digit level on some selected years as robustness
  - Approximatively 200 products (3 digits), from around 200 countries
    - Around 600-700 products at the 4-digit level

Empirical specification (1)

The estimated equation

- Relate the import price p to the export price $\widetilde{p}$ given both additive (per-kg) costs t and ad-valorem costs τ:

$$p = \tau \widetilde{p} + t, \qquad \text{with} \quad \tau \geq 1, \quad t \geq 0$$

- For product k, from country i
- Rewrite to get:

$$\frac{p_{ik}}{\widetilde{p}_{ik}} - 1 = \tau_{ik} - 1 + \frac{t_{ik}}{\widetilde{p}_{ik}}$$

$\Rightarrow$ Estimate this equation for each year over 1974-2013 (at the $k =$ 3-digit classification level)

  - Notice the equation is also year- and mode (air or vessel)- specific

Empirical specification (2)

The estimation strategy

- Two assumptions (as in Irrarazabal et al., 2015)
  - Both iceberg and additive costs are separable between the origin country i and the product k dimensions
  - Separability in a multiplicative manner for ad-valorem costs and additive manner for per-kg costs

  $\Leftrightarrow$ Write t_{ik} and τ_{ik} as:

$$\tau_{ik} = \tau_i \times \tau_k, \qquad t_{ik} = t_i + t_k \tag{1}$$

- Given the constraint $\frac{p_{ik}}{\widetilde{p}_{ik}} - 1$, the error term should be always positive and multiplicative

$\Rightarrow$ The estimated equation becomes:

$$\frac{p_{ik}}{\widetilde{p}_{ik}} - 1 = \left(\tau_i \times \tau_k - 1 + \frac{t_i + t_k}{\widetilde{p}_{ik}}\right) \times \exp(\epsilon_{ik})$$

  - With ϵ_{ik} following a normal law centered on 0.

- Taking logs, we finally estimate the following equation

$$\ln\left(\frac{p_{ik}}{\widetilde{p}_{ik}} - 1\right) = \ln\left(\tau_i \times \tau_k + \frac{t_i + t_k}{\widetilde{p}_{ik}} - 1\right) + \epsilon_{ik} \tag{2}$$

- A non-linear equation (due to the additive costs) $\rightarrow$ Estimation using non-linear squares More
- How to characterize the importance of additive costs relatively to iceberg?

$\Rightarrow$ Estimate Equation (2) constraining $t = 0$

  - For each year and by transport mode, estimate two equations, depending on additive costs included or not

- When additive costs are included:

$$\ln\left(\frac{p_{ik}}{\widetilde{p}_{ik}} - 1\right) = \ln\left(\tau_i \times \tau_k - 1 + \frac{t_i + t_k}{\widetilde{p}_{ik}}\right) + \epsilon_{ik} \tag{3}$$

- When assuming iceberg costs only

$$\ln\left(\frac{p_{ik}}{\widetilde{p}_{ik}} - 1\right) = \ln(\tau_i \times \tau_k - 1) + \epsilon_{ik}^{ice} \tag{4}$$

- From which we re-built:
  - With additive costs:

$$\widehat{\tau}_{ik}^{adv} = \widehat{\tau}_i \times \widehat{\tau}_k, \qquad \widehat{t}_{ik}^{add} = \widehat{t}_i + \widehat{t}_k$$

  - With only iceberg costs:

$$\widehat{\tau}_{ik}^{ice} = \widehat{\tau}_i \times \widehat{\tau}_k$$

- Taking the average over the product-country dimension, we finally get (by year and transport mode):
  - When additive costs are included: $\widehat{\tau}^{adv}$, $\widehat{\tau}^{add}$
  - With only iceberg costs: $\widehat{\tau}^{ice}$

Decomposing transport costs: Additive vs Iceberg

Result 1: Provide estimates for the size of both the ad-valorem and the additive components of transport costs

- Transport costs expressed in percent of the export price, average values over 1974-2013 ▸ More

# digit	3 digits		4 digits (*)	
Mode	Vessel	Air	Vessel	Air
With only Ad-Valorem Trade Costs ($\widehat{\tau}^{ice}$)				
Mean	**5.8**	**5.1**	6.0	4.9
Median	5.1	4.2	5.2	3.7
With Additive & Ad-Valorem Trade Costs				
Ad-valorem term ($\widehat{\tau}^{adv}$)				
Mean	**3.2**	**2.5**	3.3	2.4
Median	2.8	1.8	2.8	1.6
Additive term ($\widehat{t}^{add}$)				
Mean	**2.9**	**1.8**	2.8	1.9
Median	1.9	0.7	1.7	0.8
# obs.	29279	28207	29317	27680
# origin country	188	191	188	189
# products	230	211	666	567

Comments

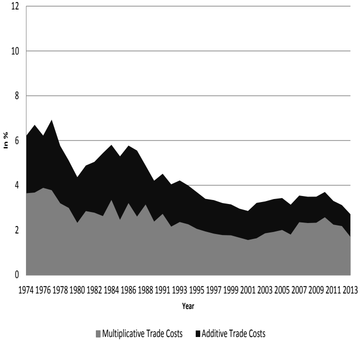
- An important magnitude of overall transport costs
  - Over 1974-2013, correspond to a mean increase of the export price by 5.8% for ocean shipping, by 5.1% for air transport
- When decomposing the structure of transport costs: A sizeable additive component
  - Additive costs amount to 2.9% of the export price in ocean shipping, 1.8% in air transport
- Omitting the additive term substantially biases the iceberg component upwards
  - The ad-valorem cost reduces by a factor of 2 when additive transport costs are included in the estimation
  - 3.2% and 2.5% as mean values in vessel and air respectively (in presence of additive costs)

More on the importance of additive transport costs

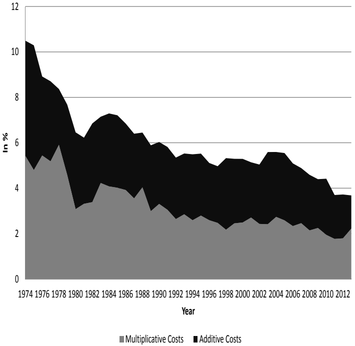
- Using the time dimension of our database, study the shares of both ad-valorem and additive components in total transport costs

More on this figure later

(a) Air



(b) Vessel



Comments

- The size of transport costs is larger for ocean shipping than from air transport
  - On average over the period (Table 1) and on a yearly basis (Figure 1) More
- A sizeable share of the additive component in total transport costs
  - 48.2% in average for ocean, 42.3% for air
  - A decreasing share of additive costs over time for air transport
  - Roughly constant for ocean shipping

⇒ **Result 2**: Additive costs, an important dimension of international transport costs

- Further investigate the robustness of this result

The role of additive costs: Goodness-of-fit evaluations

- Provide a more systematic diagnosis about the importance of additive costs
- By comparing the goodness-of-fit of the regressions
  - Obtained under Specification (4) (no additive costs)
  - vs Specification (3) (with additive costs)
- Various measures of goodness of fit
  - The R^2 (the larger the value, the better the fit)
  - Standard Error of Regression (SER) (the smaller the value, the better the fit)
  - The log-likelihood function and two derived measures
    * The Akaike Information Criterion (the lower AIC, the better the fit)
    * The log-likelihood ratio test (H_0: both models are equivalent)

Goodness of fit comparison

- Air, 3 digit - level, selected years

Year	1980	1990	2000	2010	2013	Mean stat
R^2						
Term I only	0.27	0.25	0.32	0.42	0.34	0.31
Terms A & I	0.65	0.63	0.64	0.51	0.46	0.60
SER						
Term I only	0.86	0.81	0.84	0.86	0.92	0.85
Terms A & I	0.71	0.67	0.70	0.79	0.85	0.73
AIC criteria						
Term I only	41171.0	60715.6	87492.6	102297.6	88191.9	70498.1
Terms A & I	35738.4	52098.9	74954.9	95887.1	80873.7	62285.0
Log-likelihood						
Term I only	-20253.5	-29977.8	-43341.3	-50746.8	-43692.9	-34888.6
Terms A & I	-17263.2	-25393.5	-36788.4	-47277.5	-39751.9	-30508.3
LL ratio	5980.6	9168.7	13105.7	6938.6	7882.1	8760.69
nb of restrictions	369	393	426	426	427	402
p-value	0.00	0.00	0.00	0.00	0.00	0.00

Notes: SER = Standard Error of regression; AIC = Akaike Information Criterion. R^2 between the log of predicted ratio and the log of the observed ratio. For the LL ratio test, the number of restrictions is equal to the number of parameters estimated, i.e., the number of partner countries plus the number of products. The mean statistics is calculated as the average value over all years.

Goodness of fit comparison (cont')

- Vessel, 3 digit - level, selected years

Year	1980	1990	2000	2010	2013	Mean stat
R^2						
Term I only	0.415	0.456	0.401	0.350	0.339	0.39
Terms A & I	0.575	0.590	0.571	0.491	0.462	0.56
SER						
Term I only	0.62	0.59	0.65	0.74	0.76	0.66
Terms A & I	0.53	0.51	0.55	0.66	0.68	0.57
AIC criteria						
Term I only	33010.3	51142.6	71365.9	84789.9	88191.9	57848.6
Terms A & I	28067.3	43664.7	60475.9	76161.3	80873.7	49682.3
Log-likelihood						
Term I only	-16129.1	-25169.3	-35263.9	-41998.9	-43692.9	-28534.3
Terms A & I	-13353.7	-21171.4	-29491.0	-37418.7	-39751.9	-24151.3
LL ratio	5550.96	7995.88	11545.98	9160.56	7882.15	8766.0
nb of restrictions	395	411	436	424	427	417
p-value	0.00	0.00	0.00	0.00	0.00	0.00

Notes: SER = Standard Error of regression; AIC = Akaike Information Criterion. R^2 between the log of predicted ratio and the log of the observed ratio. For the LL ratio test, the number of restrictions is equal to the number of parameters estimated, i.e., the number of partner countries plus the number of products. The mean statistics calculated as the average value over all years.

Comments

- **Result 2 (confirmed)**: Including the additive component improves the fit of the model, whatever the considered criterion or the transport mode
  - On average over the period, the R^2 doubles for air transport, increases by 50% for vessel (also on a yearly basis)
- A decrease in the quality of fit strongly after 2000, for both transport modes
- Contrasted results between air and ocean transports
  - Ad-valorem costs have more explanative power in ocean shipping than in air transport
    - On average, account for 39% of the variance of the cif-fab ratio, vs 31% in Air
  - But their explanatory power seems to have decreased over time
    - A roughly constant contribution of the additive component to the goodness of fit over time

  $\neq$ For Air: The decreasing role of the explanatory power of the additive component over the recent years (consistent with Figure 1)

$\Rightarrow$ Go deeper in the analysis of the time-trends

Decomposing transport costs: Characterizing the trends

- Coming back to Figure 1 ▸ Go: Downward trend in overall transport costs, for both air and ocean shipping
  - Considering 1980 as starting date, a 1.5- 2 percentage points decrease in Air, a 2-3 percentage point decrease in Vessel
- Does it mean a decrease in transport costs *per se*? Not necessarily
- The change in overall transport costs over time: Depend on the evolution of per product- per partner costs, but also on the composition of trade flows
  - Over time, import more goods that are cheaper to transport, and/or from countries with which it is cheaper to trade

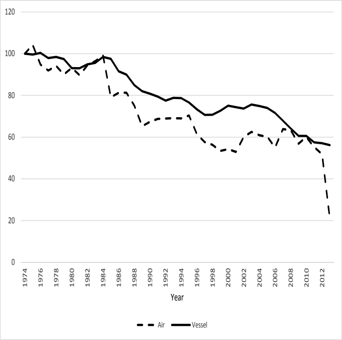
$\Rightarrow$ Necessary to eliminate the composition effects of trade flows, to isolate the evolution of transport costs *per se*

  - What we do, in accordance with Hummels (2007) ▸ More on the method

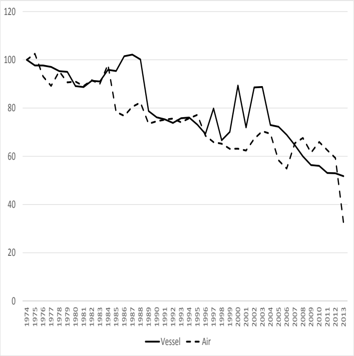
Time trends in transport costs *per se*

- Total transport costs (composition effects excluded) over time

(a) Iceberg alone



(b) With additive



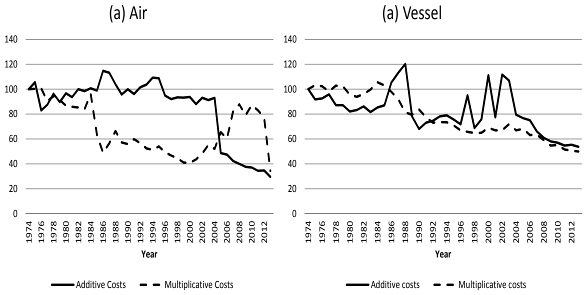
Comments

Result 3: About the time trends in transport costs

- The reduction of the *pure* transport costs : Starts in 1985
  - For both transport modes
  - The reduction between 1974 and 1984 (Figure 1), attributable to change in the composition of trade patterns
- Overall (pure) transport costs have declined by $\simeq$ 40% since 1985
- Comparing air and ocean shipping
  - When only iceberg costs are modeled (Panel (a)): A stronger decrease in air over the 1985-2005 period
  - A result in accordance with Hummels (2007), Behar and Venables (2011)
  - No more substantial difference when additive costs are included (Panel (b))

$\Rightarrow$ The importance of taking into account the additive component of trade costs

Decomposing (*pure*) transport costs over time



- For Vessel: Similar downward trend for both τ and t
- For Air: Much more contrasted trends
  - Substantial decrease in the ad-valorem costs over 1985-2005, but roughly constant additive costs
  - $\Rightarrow$ An explanation to the difference between Panels (a) and (b) above

$\Rightarrow$ The importance of modeling additive costs

Conclusion

Our paper: Empirical evidence about the role of the additive component in international transport costs

- Provide a quantitative evaluation of both the additive and the ad-valorem components
  - Additive cost: amount to 2.8% of the export price in ocean shipping, 1.8% in air transport
  - Iceberg cost: 3.2% and 2.5% for air and ocean respectively
- The importance of taking into account additive transport costs
  - Additive costs are far from negligible quantitatively
  - A better fit of the model when taken into account
- Characterize the evolution of transport costs over time
  - Importance of the composition effects
  - Biased picture of the time trends of transport costs in air when omitting the additive dimension

Conclusion

Two main possible extensions

- On the empirical side: Go deeper in the structural determinants of transport costs
  - Identify the respective roles of handling costs, insurance and freight costs at the root of the import-export prices gap
- On the theoretical side: Use our results to explore the role of additive costs
  - In shaping international trade flows (trade theory)
  - In affecting the international transmission of business cycles (business cycle theory)

More on our database

- Implications (and limitations)
  - Only cover international transport costs
  - Among transport costs, quantitative freight costs (not those related to the time value of goods)
- A rich database to exploit
  - US imports, large time period: Broad view of international trade flows
  - A reliable database, already used by Hummels (2007), but on a larger period of time
  - Have both the import and the export prices: Estimate both the levels of the ad-valorem and the additive trade costs ($\neq$ Irrarazabal et al., 2015)

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More on the estimation method

- The non-linear least squares method
  - At the basis of the method: Approximate the model by a linear one and refine the parameters by successive iterations
  - The criterion for convergence: That the sum of the squares of the residuals does not not decrease **increase?** from one iteration to the next.
- Eliminate potential influence of outliers: Exclude the 5 percent of the upper and lower tails of the distribution

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Decomposing transport costs: Summary

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Mean value over 1974-2013				
# digit	3 digits		4 digits (*)	
Mode	Vessel	Air (**)	Vessel	Air
With only Ad-Valorem Trade Costs				
Mean	1.058	1.051	1.060	1.049
Median	1.051	1.042	1.052	1.037
Std	0.032	0.042	0.036	0.045
Min. value	1.003	1.001	1.003	1.000
Max. value	1.304	1.685	1.408	2.051
With Additive & Ad-Valorem Trade Costs				
Ad-valorem term				
Mean	1.032	1.025	1.033	1.024
Median	1.028	1.018	1.028	1.016
Std	0.023	0.023	0.025	0.026
Min. value	1.001	1.000	1.000	1.000
Max. value	1.227	1.474	1.264	1.537
Additive term				
Mean	0.029	0.018	0.028	0.019
Median	0.019	0.007	0.017	0.008
Std	0.041	0.034	0.039	0.034
Min. value	0.000	0.000	0.000	0.000
Max. value	2.941	13.303	3.197	11.440
# obs.	29279	28207	29317	27680
# origin country	188	191	188	189
# products	230	211	666	567

Notes: Statistics are obtained weighting each observation by its value. The additive term is expressed in fraction of fab price. (*): Four 4-digit estimation: 0n selected years. (**): 1989 omitted in 3 digit estimation for air.

Ad-valorem costs over time

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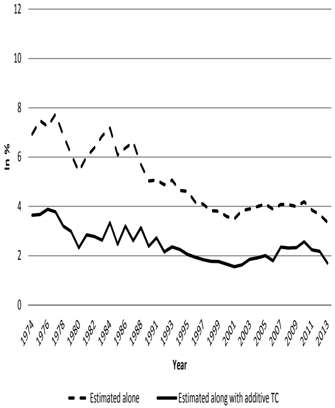
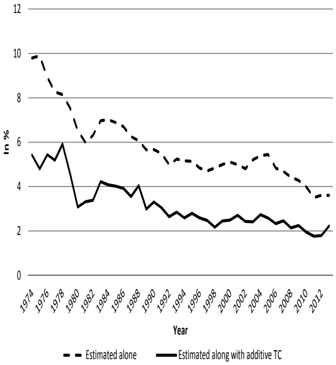
Figure: Ad-valorem Costs (Yearly mean value, 3 digits)

(a) Air



(b) Vessel



Excluding the composition effects of transport costs changes

- For the ad-valorem component, we estimate the following equation:

$$
\begin{aligned}
\widehat{\tau}_{ikt} &= \delta \times \exp\left(\sum_{i \neq AFG} \alpha_i . \mathbb{1}_i\right) . \exp\left(\sum_{k \neq 011} \beta_k . \mathbb{1}_k\right) . \exp\left(\sum_{t \neq 1974} \gamma_t . \mathbb{1}_t\right) . \exp\left(\epsilon_{ikt}\right) \\
\Leftrightarrow \ln(\tau_{ikt}) &= \delta + \sum_{i \neq AFG} \alpha_i . \mathbb{1}_i + \sum_{k \neq 011} \beta_k . \mathbb{1}_k + \sum_{t \neq 1974} \gamma_t . \mathbb{1}_t + \epsilon_{ikt} \qquad (5)
\end{aligned}
$$

  - With $\widehat{\tau}_{ikt} = \widehat{\tau}_{ikt}^{ice}, \widehat{\tau}_{ikt}^{adv}$ previously obtained

- For the additive component:

$$
\begin{aligned}
\widehat{t}_{ikt} &= \left(\prod_{i \neq ARG} \alpha_i . \mathbb{1}_i + \prod_{k} \beta_k . \mathbb{1}_k\right) . \exp\left(\sum_{t \neq 1974} \gamma_t . \mathbb{1}_t\right) . \exp\left(\epsilon_{ikt}\right) \\
\Leftrightarrow \ln(t_{ijt}) &= \ln\left(\prod_{i \neq ARG} \alpha_i . \mathbb{1}_i + \prod_{k} \beta_k . \mathbb{1}_k\right) + \sum_{t \neq 1974} \gamma_t . \mathbb{1}_t + \epsilon_{ijt} \qquad (6)
\end{aligned}
$$

- More on the estimation method
  - Equations (5) and (6): Preserve our specification of the ad-valorem and the additive costs (Equation (1))
  - Equation (5) estimated using OLS,
  - Equation (6) using non-linear least squares (by transport mode)
- Exclude the composition effects of transport costs changes $\Leftrightarrow$ Isolate the change in the time dimension
  - From the ad-valorem component estimation (Equation (5)), build the variable Γ_t ($\forall\ t \geq 1974$):

$$\Gamma_t = 100. \frac{\bar{\tau}_{1974}.\exp(\gamma_t) - 1}{\bar{\tau}_{1974} - 1}$$

  - For the additive cost, we build the variable ($\forall\ t \geq 1974$)

$$\Gamma_t^{add} = 100 \exp(\gamma_t)$$

- The Γ_t^{add} and Γ_t series: Interpretation in percentage changes with an initial value of 100 for $t = 1974$

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