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
  - Amount to $\simeq$ 30% of international trade costs $\Leftrightarrow$ A 21% markup over production costs

$\Rightarrow$ 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)
    - With p the import price, $\widetilde{p}$ the export price, q the quantity traded and $\tau > 1$ the trade cost

$$pq = \tau \widetilde{p} q$$

- Yet... A debated question
- Would not trade costs rather exhibit an additive structure ?
  - Why would it be more costly to transport from Milan to Paris, a pair of Italian shoes at price €300 than a pair of Italian shoes at price €50?
  - Pricing shipping often includes an additive component
    - ⋆ UPS: A $125 fee charged for a 2 pound package from Oslo to NYC (Irrarazabal et al., 2014)
  - Some trade policy instruments as well (quota license price)

- The structure (additive vs iceberg) of transport costs, not anecdotal
  - Additive trade costs play an important role in shaping the pattern of trade flows (Alchian & Allen, 1964)
  - Strong normative implications, notably w.r.t. the welfare gains of trade liberalization (Sorensen, 2014)
  - The additive structure of trade costs is supported by recent empirical evidence (Irrarazabal et al. 2014, Hummels & Skiba, 2004)

$\Rightarrow$ 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 in 3 questions (and 3 answers)

An empirical decomposition of the structure of transport costs

(1) **What is the size of the iceberg and the additive costs?**

$\Rightarrow$ Provide a quantitative measure of both, using US imports data

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

(2) **What do we lose by skipping the additive part of transport costs?**

$\Rightarrow$ We lose much: With the additive term included,

- The estimated iceberg component is reduced by a factor of 2
- A significantly better "goodness-of-fit"

(3) **How have international transport costs evolved over time?**

⇒ The importance of excluding composition effects

- *Pure* transport costs have fallen since 1985 (not 1974), by $\simeq$ 40%

⇒ The importance of including the additive component

- Not much difference between air and sea transport, $\neq$ Hummels (2007) and Behar & Venables (2010)
- Marked difference in the evolution of additive and multiplicative costs in Air

Plan of the talk

- Data Sources
- Empirical Methodology
- Results
- 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
  - The export (fas) price, $\widetilde{p}$: the price for one kg of merchandise at the country export point
  - 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: Based on 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

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 the levels of both the ad-valorem and the additive trade costs ($\neq$ Irrarazabal et al., 2015)

Empirical specification (1)

The equation at the root of the estimation

- 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:

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

$\Rightarrow$ For each year over 1974-2013 (at the $k =$ 3-digit classification level)

  - The equation is also 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 $\frac{p_{ik}}{\widetilde{p}_{ik}} - 1 > 0$, the error term should be always positive and multiplicative

$\Rightarrow$ The equation of interest 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

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

- A non-linear equation (due to the additive costs)

⇒ Estimation using non-linear squares

  - 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 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

Empirical specification (3)

How to characterize the importance of additive costs relatively to iceberg?

- Estimate Equation (2) constraining $t = 0$

$\Rightarrow$ Estimate *two* equations, for each year over 1974-2013, by transport mode (air/ocean)

- With additive costs included:

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

$\Rightarrow$ By year and transport mode, $\simeq$ 800 fixed effects to estimate

- With only ad-valorem costs:

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

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

Result 1: Estimating transport costs over time

For both the ad-valorem and the additive components

- Average values over 1974-2013, in percent of the export price ▸ More

# digit	3 digits		4 digits	
Mode	Vessel	Air	Vessel	Air
With only Ad-Valorem 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 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 ($\widehat{t}^{add}/\widetilde{p}$)				
Mean	**2.9**	**1.8**	2.8	1.9
Median	1.9	0.7	1.7	0.8
Data				
Mean	5.3	5.0	5.6	3.9
Median	4.3	2.0	4.4	1.9
# obs.	29279	28207	29317	27680
# origin country	188	191	188	189
# products	230	211	666	567

Result 1: Comments

- Transport costs are sizeable
  - Add $\simeq$ a 5% margin over the export price
  - Lower than the 21% markup taken from AVW, but
    - AVW decompose the 21% markup in 9% of time costs and 11% in pure freight costs
    - Their 11% markup: A "rough" estimate, based on Hummels (2001) with 1994 data

  $\Rightarrow$ Our work: A more precise and exhaustive estimation of international transport costs
- Opening the black box of transport costs
  - Iceberg cost: 2.5% and 3.2% of the export price in Air & Vessel resp.
  - Additive cost: 1.8% and 2.9% of the export price

$\Rightarrow$ Valuable insights for related papers more theoretically-oriented, in need for calibration

Result 2: Additive transport costs do matter

- International transport costs: A sizeable additive component
  - Omitting the additive term substantially biases the iceberg component upwards (Table 1)
    - The ad-valorem cost is reduced by a factor of 2 when additive transport costs are included in the estimation
    - From 5.8% to 3.2% in ocean shipping (mean value over the period)
    - From 5.1% to 2.5% in Air transport
  - A sizeable share of the additive component in total transport costs
    - 48.2% in average for ocean, 42.3% for air
    - A result that holds throughout the period See Figure 1

- A better quality of fit with the additive component included
  - Compare the goodness-of-fit of Model (2) (with additive TC) vs Model (4) (without additive TC)
  - 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 Akaike Information Criterion (the lower AIC, the better the fit)
    - The log-likelihood ratio test (H_0: both models are equivalent)

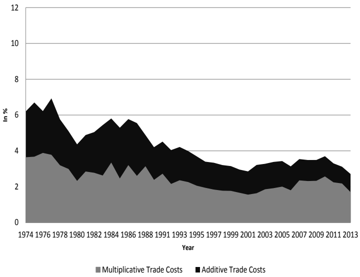
$\Rightarrow$ A systematically better goodness of fit when including the additive component

  - See the results
  - Even when taking into account the additional degrees of freedom

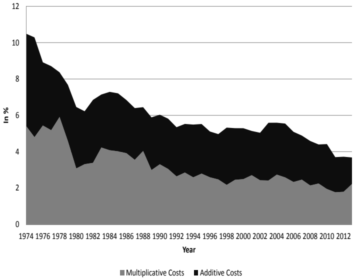
Result 3: Characterizing the trends of transport costs

- Study the shares of both ad-valorem and additive components in total transport costs Go back to Result 2 Go back to Main findings

(a) Air



(b) Vessel



- Lower overall transport costs in Air than in Vessel
- Downward trend for both modes since 1974 Robustness of this result
  - ⋆ A 50% decrease in Air, a 60% decrease in Vessel

Time trends in transport costs & composition effects

- 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*

$\Rightarrow$ What we do, in accordance with Hummels (2007)

Excluding the composition effects

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

$$\ln(\widehat{\tau}_{ikt}) \quad = \quad \delta + \underbrace{\sum_{i \neq \text{AFG}} \alpha_i . \mathbb{1}_i}_{\ln(\widetilde{\tau}_i)} + \underbrace{\sum_{k \neq 011} \beta_k . \mathbb{1}_k}_{\ln(\widetilde{\tau}_k)} + \underbrace{\sum_{t \neq 1974} \gamma_t . \mathbb{1}_t}_{\text{Time trend}} + \epsilon_{ikt} \qquad (5)$$

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

- For the additive component:

$$\ln(\widehat{t}_{ijt}) \quad = \quad \ln\left(\delta + \underbrace{\sum_{i \neq \text{ARG}} \alpha_i . \mathbb{1}_i}_{\widetilde{t}_i} + \underbrace{\sum_{k \neq 011} \beta_k . \mathbb{1}_k}_{\widetilde{t}_k}\right) + \underbrace{\sum_{t \neq 1974} \gamma_t . \mathbb{1}_t}_{\text{Time trend}} + \epsilon_{ijt} \qquad (6)$$

- Underlying rationale
  - 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 ▸ More details

⇔ Isolate the change in the time dimension

  - From the ad-valorem component estimation (Equation (5)), build the variable Γ_t ($\forall\ t > 1974$):

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

    * with $\bar{\tau}_{1974} = \exp(\delta + \sum_i \alpha_i + \sum_k \beta_k)$ the mean TC in 1974

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

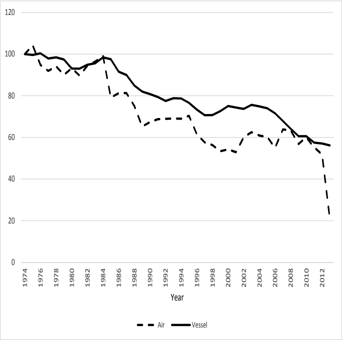
$$\Gamma_t^{add} = 100\exp(\gamma_t)$$

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

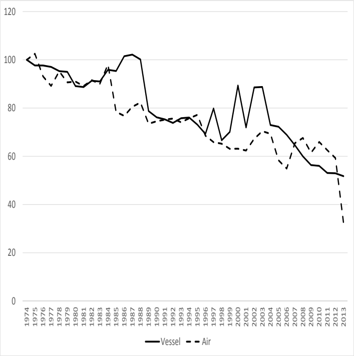
Time trends in transport costs *per se*

- Total transport costs (composition effects excluded) over time

(a) Iceberg alone



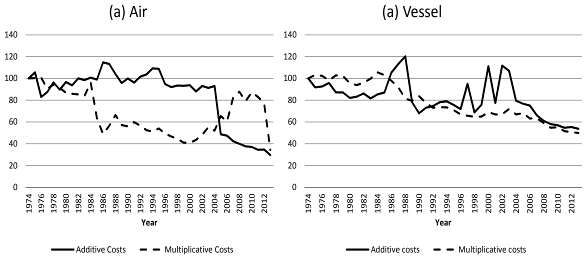
(b) With additive



Two main findings

- The importance of excluding composition effects
  - The reduction of the *pure* transport costs: Starts in 1985 (not in 1974)
  - The reduction between 1974 and 1984 (▸ Figure 1) is attributable to change in the composition of trade patterns
  - Overall (pure) transport costs have declined by $\simeq$ 40% since 1985
- The importance of the additive component of transport costs (again)
  - When only iceberg costs are modeled (Panel (a)): A stronger decrease in Air transport over the 1985-2005 period
  - In accordance with Hummels (2007), Behar & Venables (2011)
  - But... No substantial difference when additive costs are included (Panel (b))

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
  - Trend reversal around 2005: Any suggestion?

Conclusion: Main findings

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
  - Based on the US imports flows from 1974 to 2013
  - 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 they are 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 : What to do next?

Three main possible extensions

- On the empirical side:
  - (1) Compare the trends in transports costs *between* air and vessel (excluding composition effects)
  - (2) 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:
  - (3) 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)

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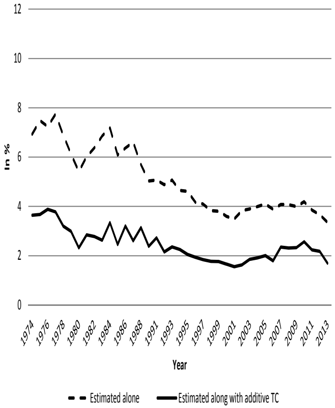
Figure: Ad-valorem Costs (Yearly mean value, 3 digits)

(a) Air



(b) Vessel

More on Result 2: 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.

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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.

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Goodness of fit: Comments

- **Result 2**: 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-fas ratio, vs 31% in Air
  - But their explanatory power seems to have decreased over time
    - For vessel: 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

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Excluding the composition effects: More details

- **For the ad-valorem cost**, rewriting Equation (5) :

$$\widehat{\tau}_{ikt} = \exp\left(\delta + \sum_{i \neq \text{AFG}} \alpha_i.\mathbb{1}_i + \sum_{k \neq 011} \beta_k.\mathbb{1}_k\right).\exp\left(\sum_{t \neq 1974} \gamma_t.\mathbb{1}_t\right).\exp\left(\epsilon_{ikt}\right)$$

  - From which we deduce after estimation: $\widehat{\tau}_{ik74} = \exp(\delta + \alpha_i + \beta_k)$
  - And, for any year $t > 1974$: $\widehat{\tau}_{ikt} = \exp(\delta + \alpha_i + \beta_k) \times \exp(\gamma_t)$
  - Which implies:

$$\widehat{\tau}_{ikt} = \widehat{\tau}_{ik74} \times \exp(\gamma_t)$$

- With $\tau > 1$, rewrite things to get the percentage change between years 1974 and t:

$$\Gamma_{ikt} = 100.\frac{\widehat{\tau}_{ikt} - 1}{\widehat{\tau}_{ik74} - 1} = 100.\frac{\widehat{\tau}_{ik74}\exp(\gamma_t) - 1}{\widehat{\tau}_{ik74} - 1}$$

  - With Γ_{ikt} an index of transport costs in t (relative to 1974)
  - Only depend on the cost observed in 1974 and the time trend
  - But, specific to a product-origin country pair

- Choose to pick as reference the mean value of the cost in 1974
  - Build the index Γ_t such that:

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

  - With $\bar{\tau}_{1974} = \exp(\delta + \sum_i \alpha_i + \sum_k \beta_k)$ the mean TC in 1974

- **For the additive component**, after estimating Equation (6):

$$\begin{aligned} \widehat{t}_{ik74} &= \delta + \alpha_i + \beta_k \\ \widehat{t}_{ikt} &= (\delta + \alpha_i + \beta_k) . \exp(\gamma_t), \qquad \forall t > 1974 \end{aligned}$$

  - From which we deduce:

$$\widehat{t}_{ikt} = \widehat{t}_{ik74} \times \exp(\gamma_t)$$

  - With $t > 0$, obtain the percentage change from 1974 through:

$$\Gamma_{ikt}^{add} = 100 \frac{\widehat{t}_{ikt}}{\widehat{t}_{ik74}} = 100 \exp(\gamma_t)$$

  - Independent of the i, k dimension, such that we can rewrite:

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

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