EXPLORING THE IMPACT OF TIERED PRICING UNDER COMPETITIVE ISP MARKETS

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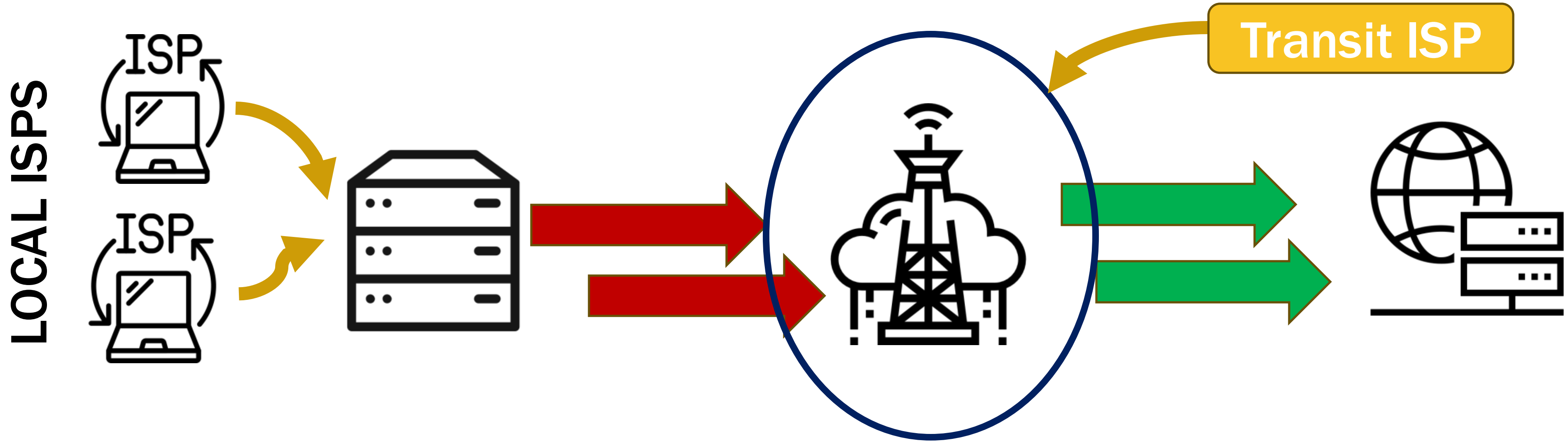
WHAT IS TRANSIT ISP

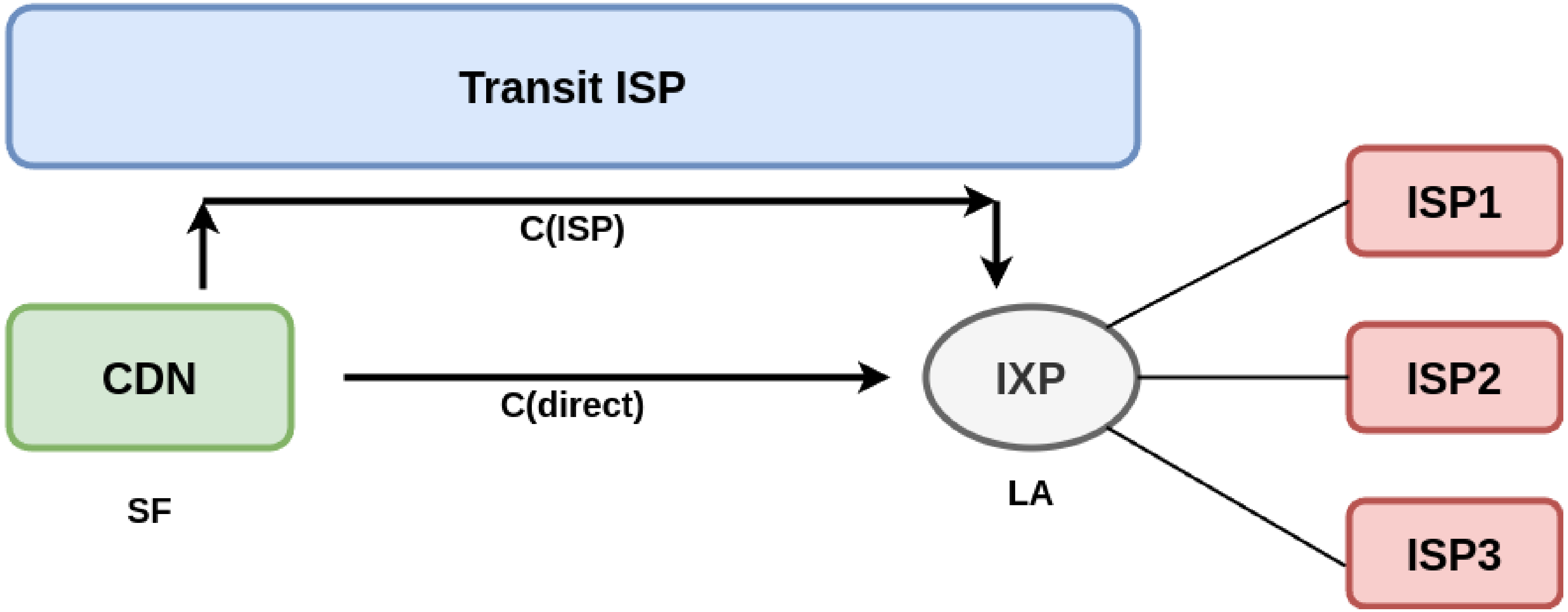
Transit ISP offers connectivity and bandwidth to smaller ISPs or businesses, allowing them to connect to the broader Internet.



- Transit ISPs act as intermediaries, routing traffic between local ISPs and major global networks.
- They offer access to large-scale backbone network

MOTIVATION

Set optimal pricing to attract the local ISPs to use the transit ISP



When C(ISP) > C(direct), then CDN will prefer to deploy their own connection to the IXP

RESEARCH QUESTION

What we are trying to find

How many tiers suffice for near-optimal profit in a single-ISP?

Can tiered pricing soften competition in a duopoly?

What are the welfare and economic implications?

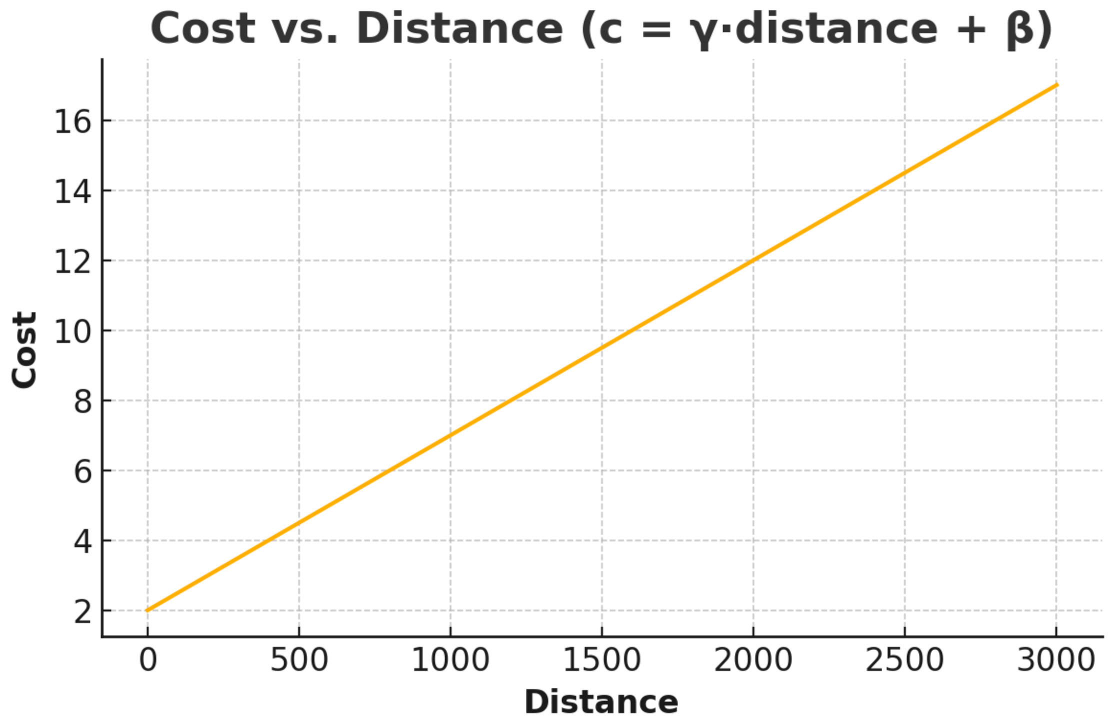
COST MODEL: FLAT PRICING

Set the cost modeling with flat pricing

$$c = \gamma * dist + \beta$$

Marginal Cost per Mile

Fixed Baseline Cost



- ✓ Linear backbone cost approximation
- ✓ Captures long-haul price escalation

DEMAND MODEL: FLAT PRICING

Traffic Demand and choice model

Constant-Elasticity Demand (CED)

$$Q(p) = \left(\frac{v}{p}\right)^{\alpha}$$

Valuation back-calculation

$$v = P_0 Q^{\frac{1}{\alpha}}$$

Per-flow willingness-to-pay

Elasticity used: $\alpha = 2.0$

CED is widely used for bandwidth pricing—keeps elasticity constant over price range.

With $\alpha = 2$, demand is very price-sensitive: small price hikes cause large traffic loss.

PRICE FUNCTION: FLAT PRICING

Traffic Demand and choice model

Constant-Elasticity Demand (CED)

$$\pi(P) = (P - C)Q(P)$$

$$p^* = \frac{\alpha}{\alpha - 1} * \mathrm{c}$$

CED Optimal Profit (Per Flow)

$$\pi^* = \frac{v^\alpha}{\alpha} \cdot \left(\frac{\alpha c}{\alpha - 1} - c\right) \cdot \left(\frac{1}{\frac{\alpha c}{\alpha - 1}}\right)^\alpha$$

Expression	Economic intuition
$\frac{v^\alpha}{\alpha}$	**Market scale:** Bigger valuation v ⇒ larger potential surplus
$\left(\frac{\alpha c}{\alpha - 1} - c\right)$	**Unit margin:** Optimal markup above cost
$\left(\frac{1}{\frac{\alpha c}{\alpha - 1}}\right)^\alpha$	**Elasticity shrink:** Demand contraction when price rises; steeper when α is high

TIER DEFINITION AND DERIVATION

Tier modeling and definition

TIER NO	TIER DEFINITION
Tier 0	Metro (< 500 mi)
Tier 1	Regional (500 - 2000 mi)
Tier 2	Intercontinental (> 2000 mi)

Baseline demand scale / markup knob

$$p_b = c_b + \frac{1}{\alpha s_0}$$

Average Weighted Cost

Constant elasticity parameter

Symbol	Role in the formula
c_b	“Floor” of the price
$\alpha (= 2.0)$	Inversely scales the markup
$s_0 (= 0.2)$	Controls the *fixed* markup that is added on top of cost

TIERED PRICING

Valuation and Cost for the tiered pricing scheme

Bundle Valuation

$$v_b = \max(v) + \frac{1}{\alpha}.\log\left(\sum_i e^{\alpha(v_i - \max(v))}\right)$$

Approximates the **aggregate valuation** of the bundle.

Bundle Cost

$$c_b = \frac{\sum_i c_i . w_i}{\sum_i w_i}$$

Weighted average of flow-level costs using demand-weighted exponential weights based on valuation.

DATASET: Description

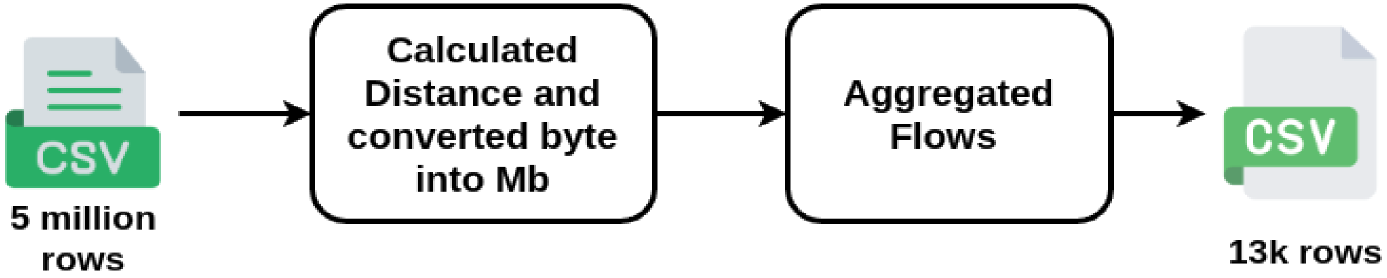
Dataset used to verify the pricing and valuation models

Appraise H2020 - Real labelled Net Flow dataset (For EU ISP)

Column Name	Description
IPV4_SRC_ADDR	IPv4 source address
IPV4_DST_ADDR	IPv4 destination address
IN_PKTS	Number of incoming packets
IN_BYTES	Number of incoming bytes
OUT_PKTS	Number of outgoing packets
OUT_BYTES	Number of outgoing bytes

DATASET: Preprocessing

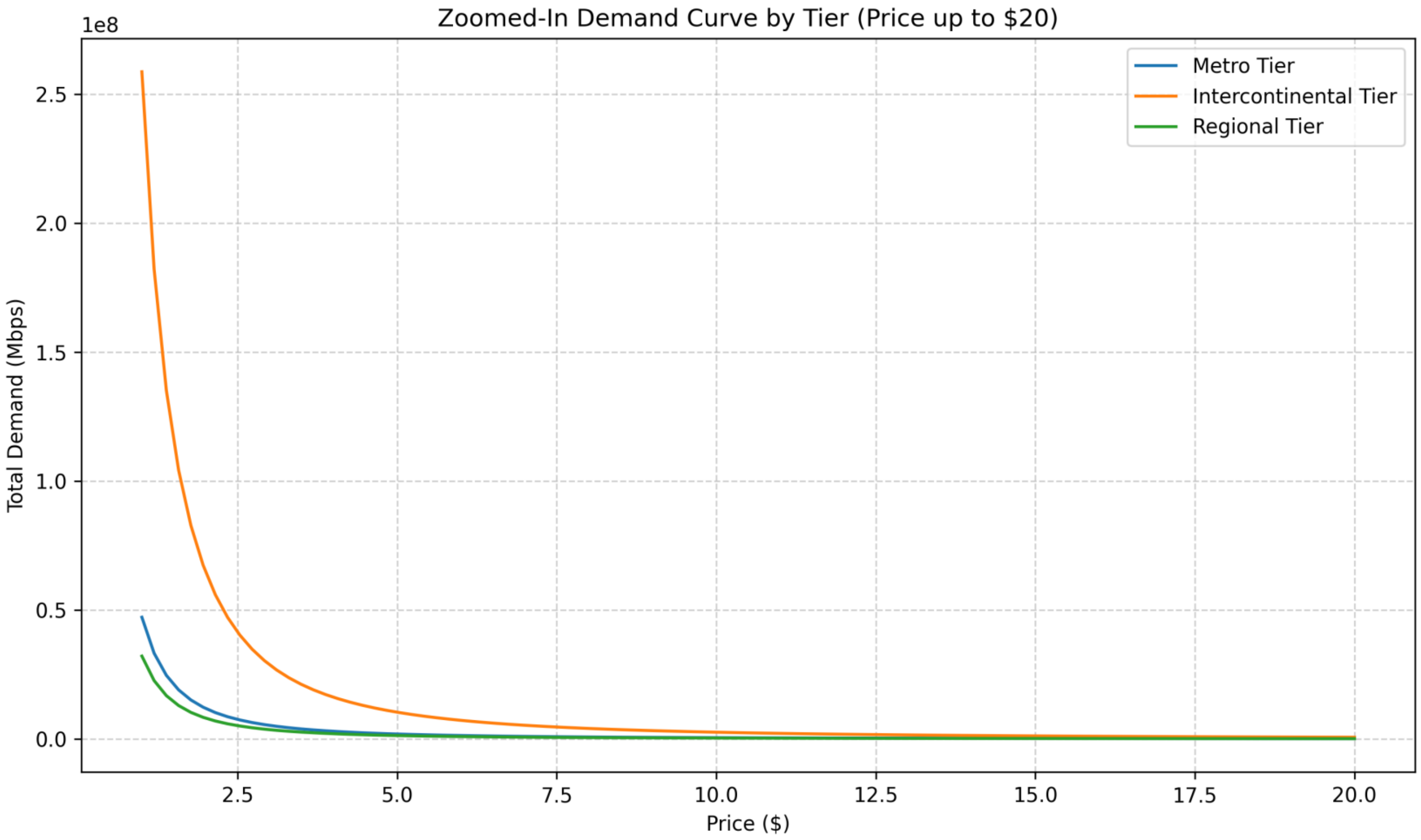
Preprocessing dataset to fit to the models



- ✓ Simulate or ingest NetFlow: (srcIP, dstIP, vol)
- ✓ GeoIP -> distances d_i

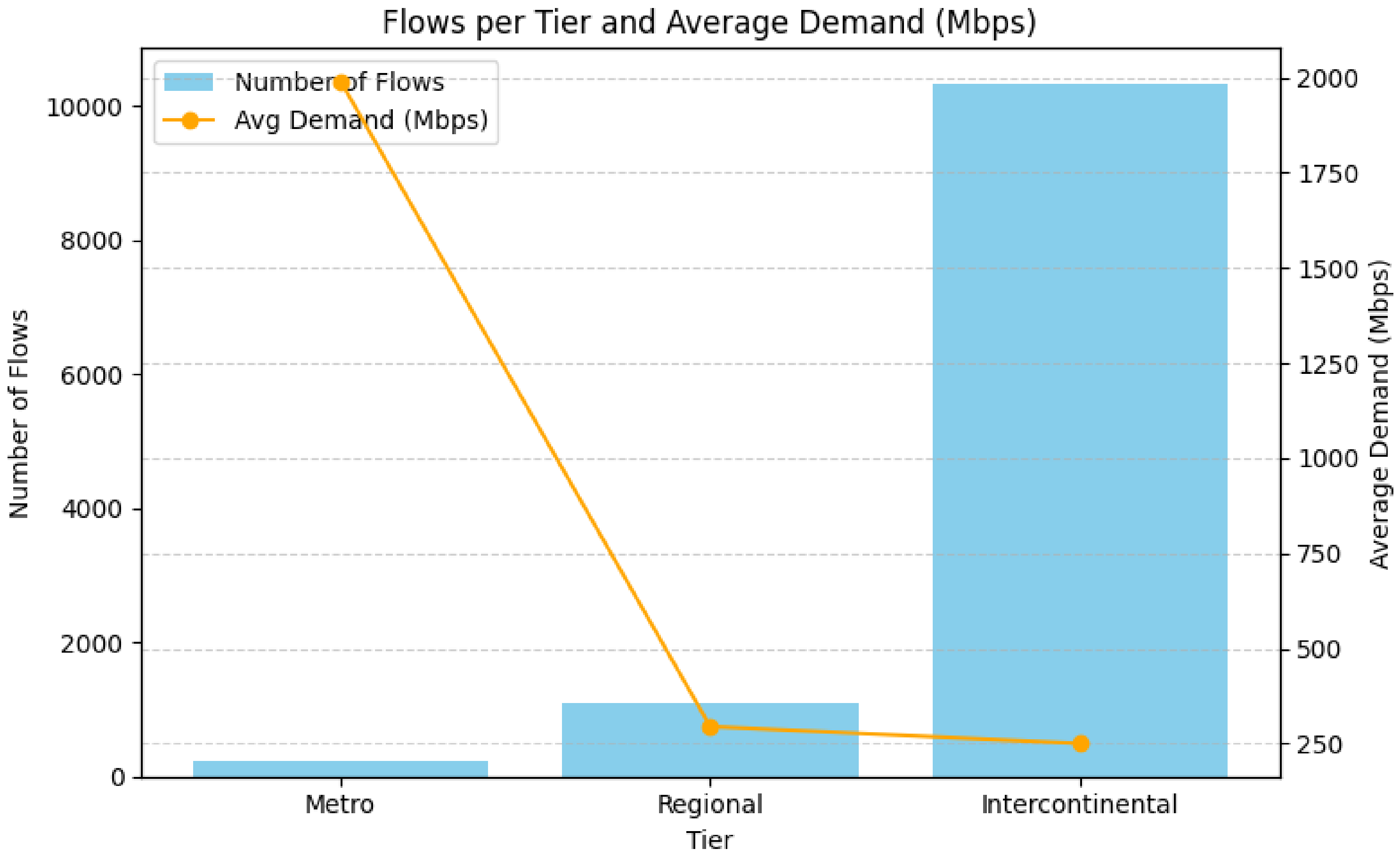
DATASET: Demand and Flow count

Plot of Price vs Demand



DATASET: Demand and Flow count

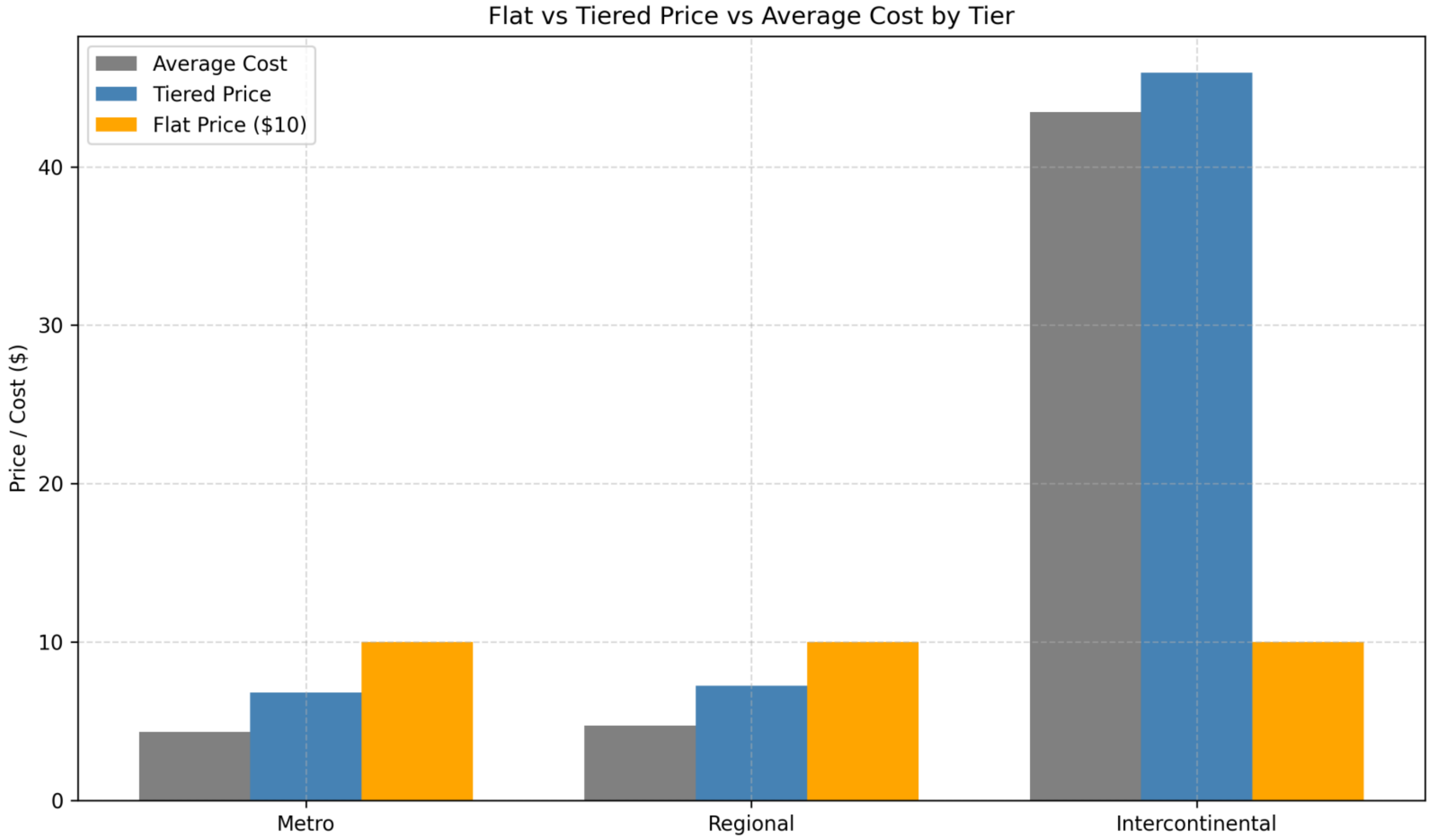
Demand and flow count insights from the dataset



Result: Pricing and Valuation Matrix

Tiered pricing and Flat pricing valuation matrix

Tier No	Price	Avg. Cost
Tier 0	6.81	4.31
Tier 1	7.23	4.73
Tier 2	45.95	43.45



Game Theory Setup

Competing pricing strategies: Flat vs. Tiered

Duopoly Payoff Matrix

	Flat	Tiered
Flat	-28.36, -28.36	-60.78, +1.67
Tiered	+1.67, -60.78	+16.93, +16.93

Players:

2 transit ISPs (A & B), identical cost structure

Strategy set:

Single - flat \$5/Mbps for every flow

Tiered - Metro \$7.8 | Regional \$12.1 | Inter \$90.4

Customer choice (logit share)

$$P_A = \frac{1}{1 + e^{\alpha(pA - pB)}}, \alpha = 2$$

Profit per ISP:

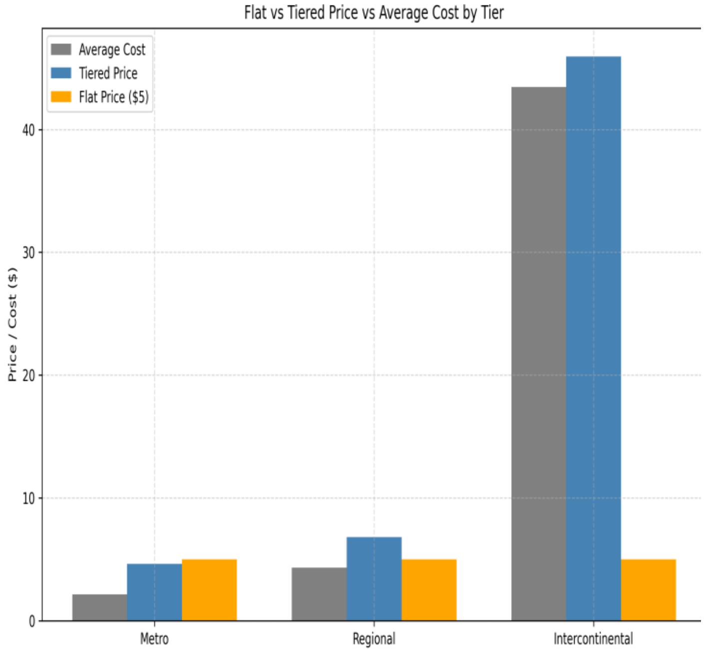
$$\pi = \sum_{flows} Q_i P_{ISP}(p - c_i)$$

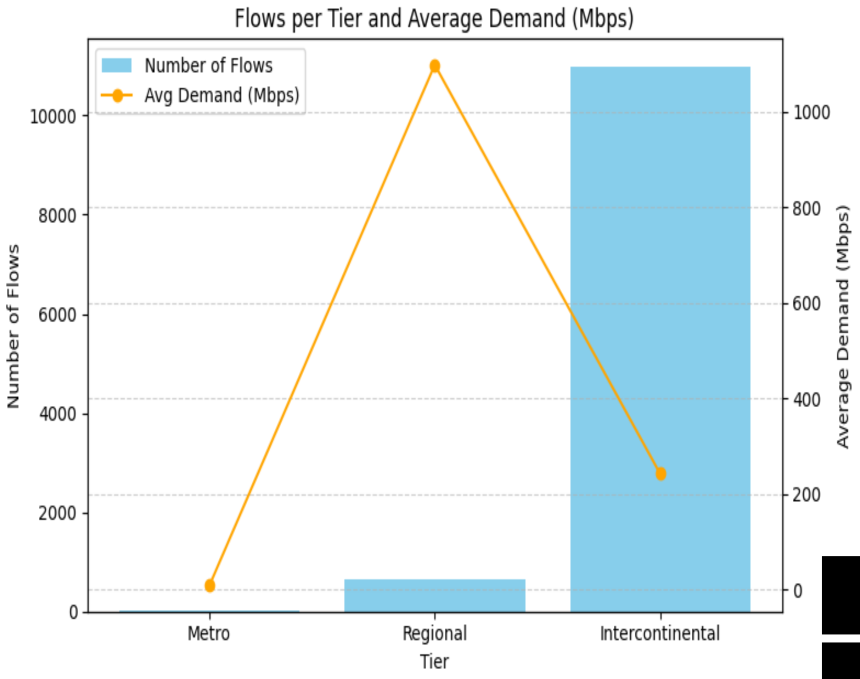
Outcome:

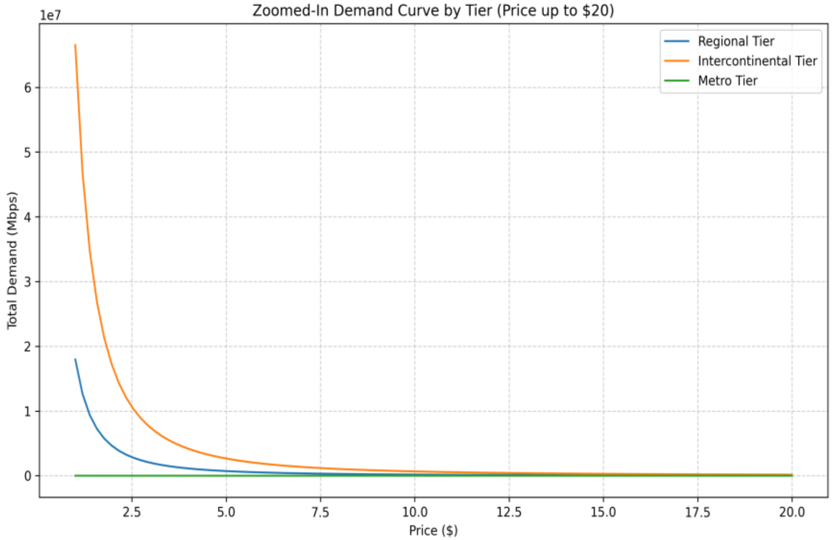
2 × 2 payoff matrix → find Nash equilibrium

More Results

Results obtaining by varying the parameters value







	Flat	Tiered
Flat	-78.7, -28.36	-15.73, +0.003 1
Tiered	+0.003, -15.73	+29.64, +29.6 4

Tiers: (< 100, < 500, < 1000),
Flat Price: $5, γ, β = 0.01, 2
$\alpha, s_0 = 2.0, 0.2$

Key Insights

Insights gained from the results and the game

- ✓ **Distance-based tiers beat flat pricing:**
  Tiered-Tiered equilibrium increased each ISP's profit by **+16.9 M $** compared with losses under Flat-Flat.
- ✓ **Flat price cross-subsidises long-haul traffic:**
  Intercontinental flows cost ≈ $88 but paid only $5; negative margins drove −28 M $ profit each when both ISPs stayed flat.
- ✓ **Elasticity amplifies the benefit of tiering:**
  With $\alpha = 2$, a 1 % price rise → 2 % demand drop; tiering lets ISPs raise price only where elasticity is low.
- ✓ **Small markup is enough:**
  A uniform +$2.50 ($1 / \alpha s_0$) on top of average cost yields positive margin in every tier while keeping metro price < $8.
- ✓ **Tier structure is stable under competition:**
  In the 2×2 payoff matrix, Tiered is a dominant strategy; Flat is never a best response.
- ✓ **Robustness checked:**
  Sweep of 36 parameter combinations (α, γ, β, P_0) always preserved Tiered-Tiered as Nash.

Conclusion

Limitations and Conclusions

Limitations

- ✓ Assumed identical QoS & peering terms – real-world asymmetries can shift customer share.
- ✓ Geographic bins are coarse (0–100 mi, 100–1000 mi, > 1000 mi); finer granularity or latency-based binning may improve pricing precision.
- ✓ Single-period, complete-information game – ignores dynamic reactions, capacity constraints, and multihoming.
- ✓ Demand model omits latency/packet-loss utility modifiers; only price drives choice.
- ✓ γ and β are stylised; true backbone costs vary by route congestion & vendor contracts.

Conclusion

Distance-based tiering aligns price with cost, removes cross-subsidy, and is the unique stable strategy for competing transit ISPs.

Thank You

Questions!