

# Effective Resistance Rewiring: A Simple Topological Correction for Over-Squashing

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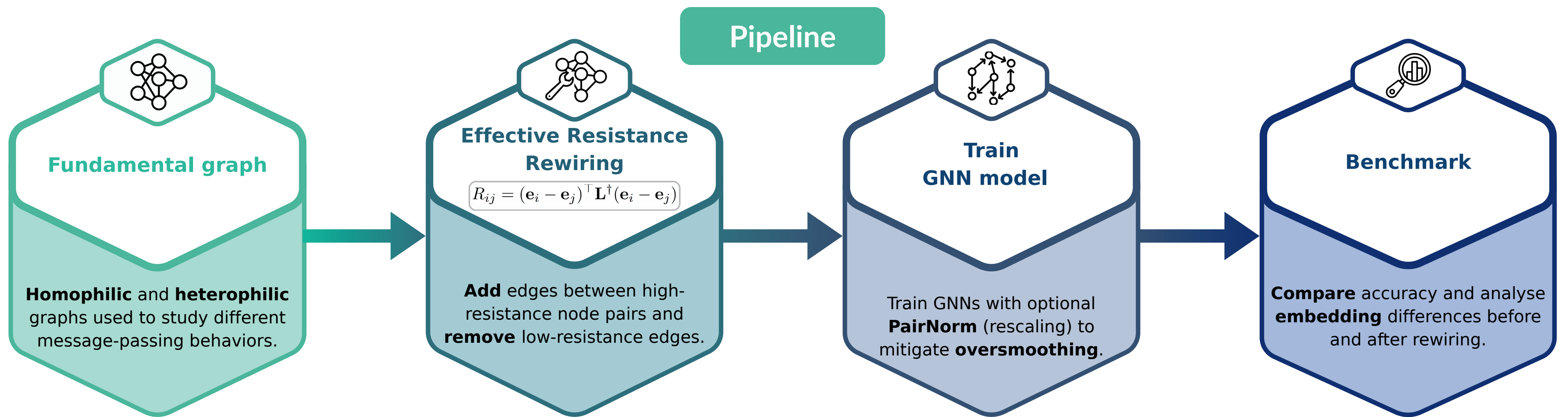
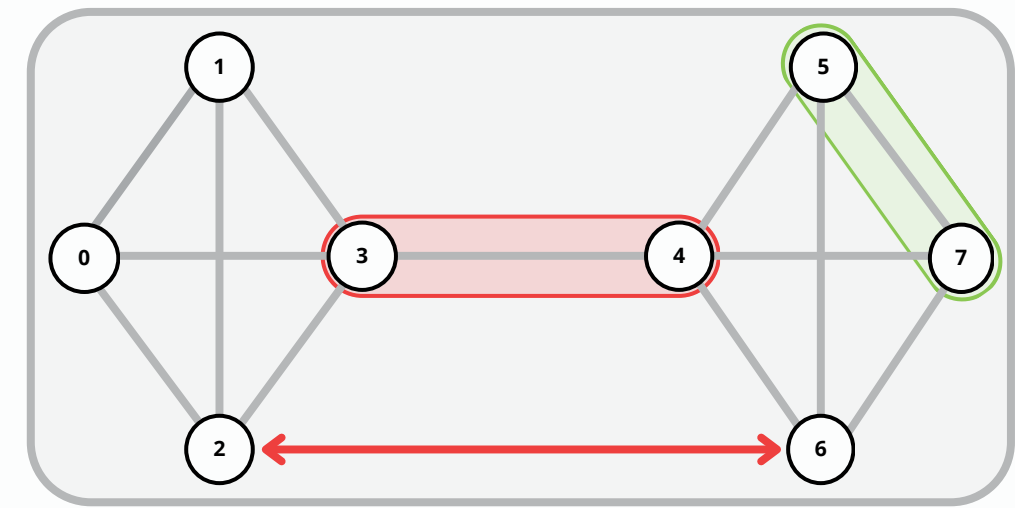
**TL;DR:** Effective-resistance rewiring alleviates over-squashing by correcting global connectivity bottlenecks with local modifications. A representation-level similarity analysis distinguishes genuine long-range communication gains from embedding geometry effects.

## Introduction

Message-passing GNNs struggle with long-range reasoning due to **over-squashing**, where information from many distant nodes is compressed through **structural bottlenecks**. Existing rewiring methods typically rely on local curvature, which may fail to capture global connectivity limitations.

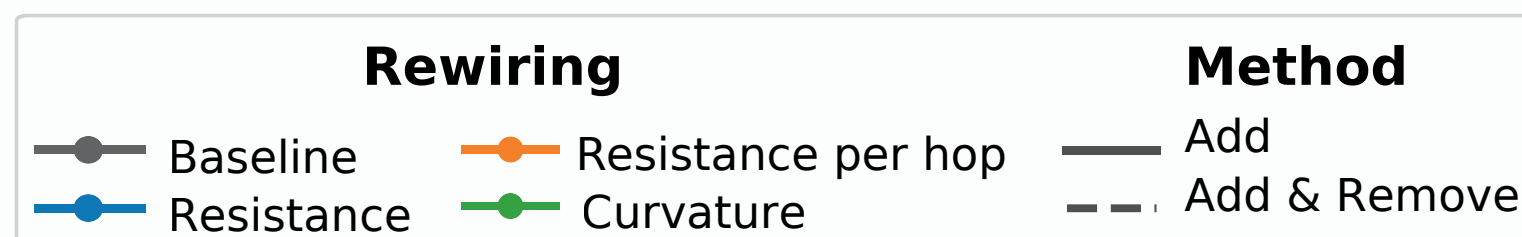
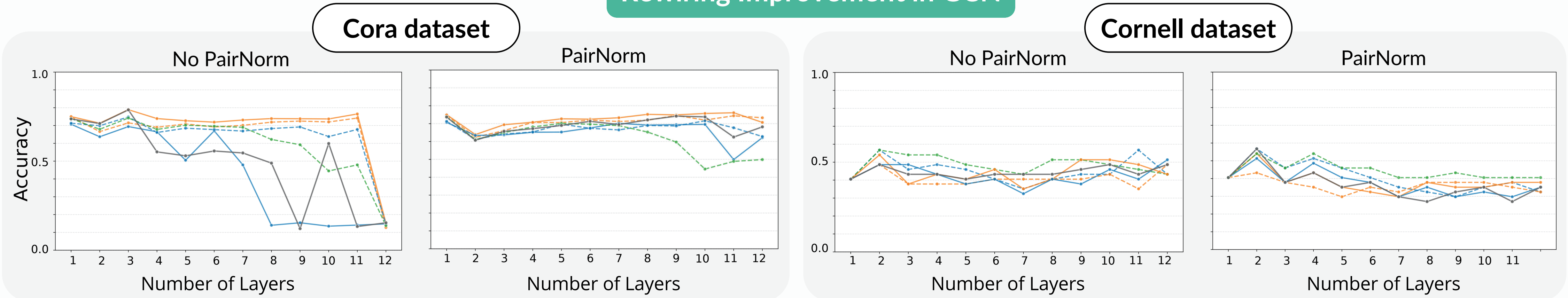
We propose **Effective Resistance Rewiring (ERR)**, a global topology correction that identifies poorly connected node pairs and adds edges to relieve bottlenecks while removing redundant connections under a fixed budget. This rewiring improves information flow with controlled smoothing.

We evaluate ERR on homophilic (Cora, CiteSeer) and heterophilic (Cornell, Texas) graphs, analyzing both accuracy vs. depth and representation similarity. This allows us to distinguish **long-range communication gains** from changes in embedding geometry.



## Results & Analysis

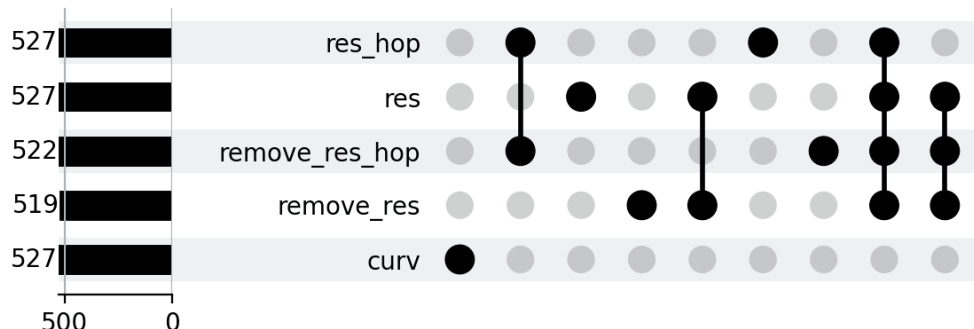
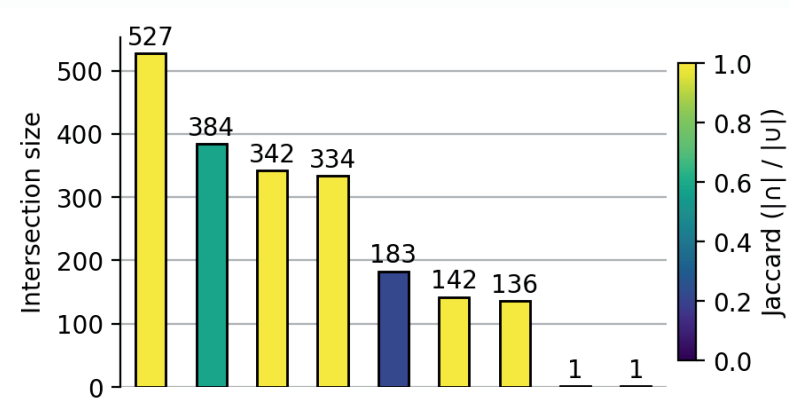
### Rewiring Improvement in GCN



### Added edges

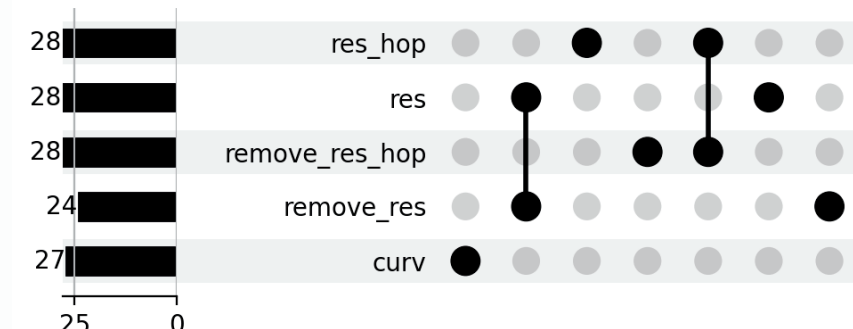
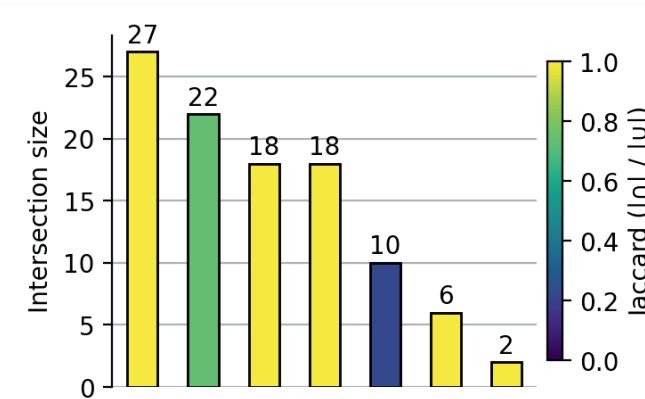
#### Cora dataset

Initial Number of Edges = 5278

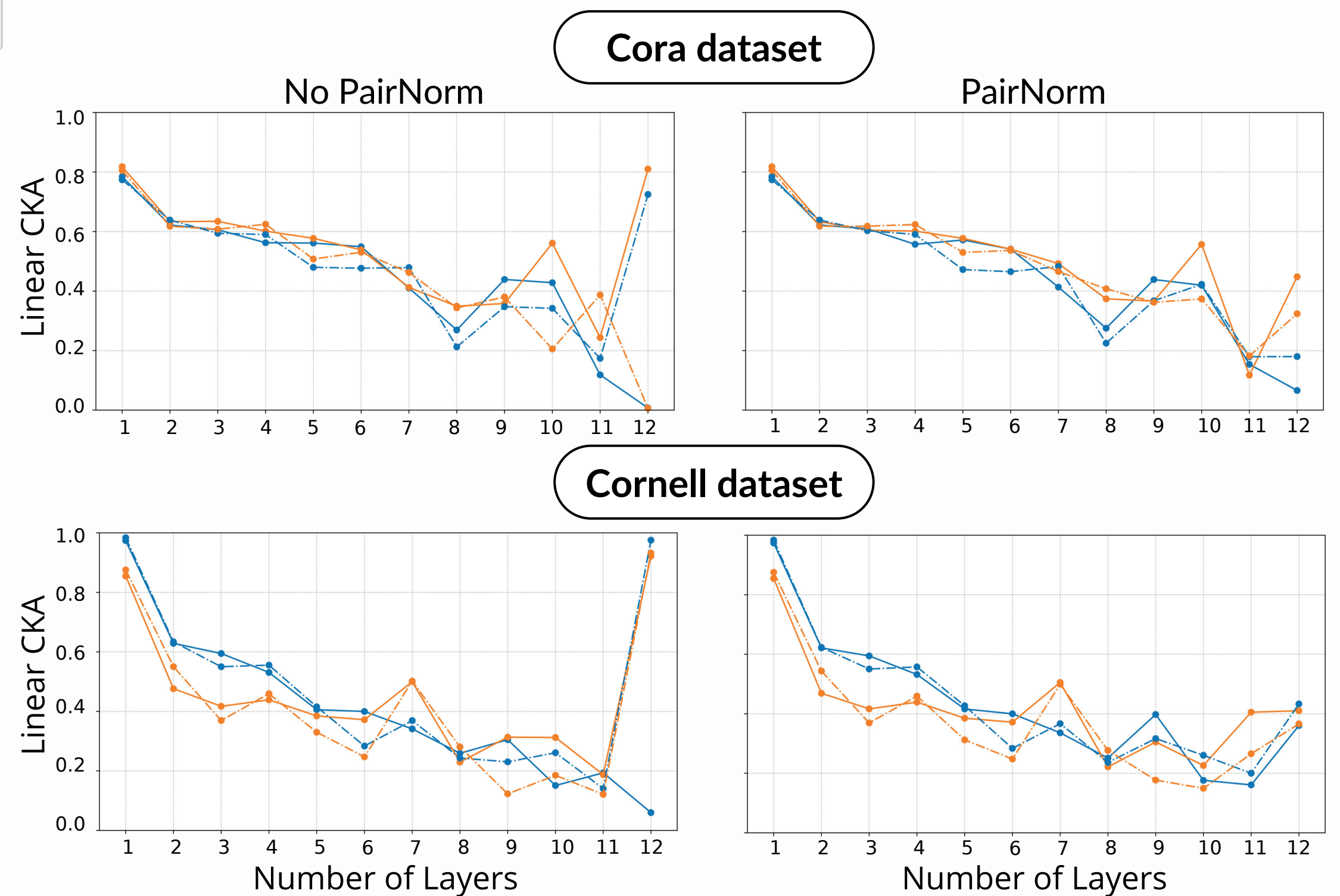


#### Cornell dataset

Initial Number of Edges = 280



### Embedding similarity against curvature



## Conclusions

- **Effective resistance identifies global bottlenecks** and enables targeted **rewiring** that improves long-range message passing.
- **Rewiring alleviates over-squashing**, particularly in heterophilic graphs and shallow to moderate depths.
- Increasing connectivity introduces a **trade-off** with oversmoothing, requiring normalization (e.g., PairNorm) for stable gains.
- Different rewiring strategies can achieve similar accuracy but **different representations**, highlighting the importance of representation-level analysis.