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Estimating cross-border connectivity and commuters using enhanced gravity models

Andrius Kučas, (Kucas.Andrius@gmail.com) UAB Demolit, Vilnius, Lithuania.

Matteo Berzi, (Matteo.Berzi@ec.europa.eu) European Commission, Joint Research Centre, Ispra, Italy.

Benedikt Herrmann, (Benedikt.Herrmann@ec.europa.eu) European Commission, Joint Research Centre, Ispra, Italy.

Abstract

This study presents a gravity-based methodological framework for estimating cross-border connectivity and potential commuter flows between regional labour markets. The proposed Gravity-Based Commuter Proxy Model provides a policy-relevant analytical approach for analysing functional labour interactions in situations where observed commuting statistics are incomplete or unavailable. The method supports evidence-based regional analysis by translating socioeconomic indicators into spatial interaction patterns that approximate labour mobility dynamics.

The framework conceptualises commuting as a response to structural imbalances between labour supply and employment opportunities across regions. Areas characterised by surplus working-age population generate outward commuting pressure, while regions offering stronger labour demand and higher economic attractiveness act as employment destinations. These relationships are operationalised through a spatial interaction model in which the intensity of commuting increases with economic opportunity and decreases with spatial separation.

The methodological workflow combines a conceptual labour-market model, a gravity-based interaction formulation, and a geospatial implementation environment. Labour surplus in origin regions and employment capacity in destination regions form the primary drivers of interaction, while wage conditions represent economic attractiveness and geographic distance introduces spatial friction. Estimated commuting flows are distributed proportionally among alternative destinations and subsequently balanced to maintain consistency between labour supply and demand constraints. Model outputs include regional indicators describing commuter departures, arrivals, and populations without accessible employment opportunities, alongside directional flow networks representing predicted commuting linkages.

The methodology is implemented using harmonised regional socioeconomic data and automated spatial processing procedures, producing spatially coherent commuting structures aligned with established principles of regional economics. Metropolitan regions emerge as primary labour attractors, suburban areas demonstrate balanced exchange dynamics, and rural regions predominantly function as labour-exporting territories. Cross-border commuting patterns concentrate along economically integrated neighbouring regions, reflecting wage differentials, proximity, and labour market complementarities.

The results demonstrate that cross-border commuting represents a structural component of regional labour market integration rather than a marginal phenomenon. The proposed framework offers a transparent, scalable, and transferable tool for analysing labour mobility in data-scarce environments and supports policymaking in regional development, transport planning, and cross-border cooperation by providing an interpretable representation of functional economic connectivity across territorial scales.

Keywords: Cross-border commuting, Gravity modelling, Spatial interaction, Labour mobility, Regional connectivity