How does the network structure of inter-industry labour flows within regions condition economic resilience and diversification over time?

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While all regional economies go through periods of crisis and decline, some prove to be more successful than others in coping with such challenging times. This impacts the long-term capacity for growth as the level of success in coping with one crisis conditions the ability of regions to deal with subsequent ones (*Simmie & Martin, 2010*). As a consequence the differential growth impact of a crisis slows down convergence and ultimately contributes to persistent spatial disparities. For instance the 2008 economic crisis put a stop to roughly a decade of regional economic convergence in the EU, driven predominantly by catching up of member states with less developed economies (*EC 2017*). For this reason the heterogeneous capacity to resist and recover from economic shocks is linked to persistent disparities in economic opportunities and welfare provisions for locals, while some regions already face increasing social tension in the wake of shrinking economic perspectives (*Rodríguez-Posé, 2018; Dijkstra et al., 2020*)

Knowing more about the capacity of regions to resist and recover from economic turmoil is high on the academic and policy agenda, especially in relation to the financial- and pandemic-induced crises of 2008 and 2020-21, and much effort has been devoted by the academic community to understand the economic resilience of regions. Briefly, while this concept builds on an interdisciplinary tradition (*Pendall et al., 2010*), recently the literature converges on an evolutionary approach, where resilience is seen as the capacity of regions to withstand economic shocks while also being able to develop new growth paths (*e.g.*

Boschma, 2015; Martin & Sunley, 2020; Bristow & Healy, 2020). Unsurprisingly, the structure of economic activities carried out in regions is one of the main determinants of resilience considered in the literature (*Martin & Sunley, 2020*).

First, regions with a more specialised economic portfolio may be more capable of exploiting their existing capabilities, while a more diverse structure of industries or technological knowledge may be better for mitigating the impact of an economic shock by spreading out the associated risks (*Doran & Fingleton, 2018; Boschma 2015, Martin & Sunley, 2020*). Second, advancements of the last decade made in evolutionary economic geography indicate that the related variety of economic activities, *i.e.* those with not too similar, but not too different productive knowledge (*Frenken et al., 2007*), is a key factor in the growth of regions, prominently in terms of employment (for an overview see *Content & Frenken, 2016*). Relatedness also steers how regions enter new growth paths, as new economic activities (industries, technologies and occupations among others) are more likely to enter a region if related activities are already present (for an overview see *Hidalgo 2021*). Finally, theoretical arguments were put forward that related variety may also be conducive of regional resilience, as it allows for regions to grow, while also retaining their ability to adapt to economic shocks through diversification (*Boschma, 2015; Martin & Sunley, 2020*). Empirical evidence, particularly for technological knowledge present in regions, gives support as related variety mitigates the negative effects of a crisis both in the case of regional employment (*Rocchetta & Mina, 2019; Rocchetta et al., 2021*) and knowledge production (*Balland et al., 2015*).

However, regional economies can be regarded as webs of specialized production units, largely dependent on the technologies, skills and tacit knowledge integrated in the process of value creation (*Boschma & Martin, 2010*). These locally available, nontradable productive capabilities function as building blocks that are combined to achieve a level of economic output, while the diversity and patterns of interactions between these capabilities explain differences in economic development and diversification (*Hidalgo et al., 2007*; *Hidalgo & Hausmann, 2009; Neffke et al., 2018*). What follows is that the local economic structure can be mapped into a network, where nodes represent economic activities (*e.g.* industries, occupations, products or technologies), and ties represent an overlap of underlying, often unobserved productive capability bases (*e.g. Hidalgo et al., 2007; Neffke et al., 2011; Kogler*

et al., 2017; Csáfordi et al., 2020). Hence, such networks can be considered to reflect potential solutions to particular coordination problems (*Shutters et al., 2018*).

Worker skills are a particularly important component of the local capability base. Skills of the labour force often reflect established patterns of regional industrial specialisation (*Walker & Storper, 1989*), and higher quality human capital and worker skills boost economic growth (*Ingram & Neumann, 2006; Ehrlich & Murphy, 2007*). However, human capital is, at least in part, contextual, as worker skills yield higher returns in workplaces with complementary co-workers (*Neffke 2019*), and workers can deploy their existing skills in a limited set of industries or occupations. Building on the latter, labour flows between pairs of industries or occupation inform us on the overlap of workforce skills needed for these activities (*Neffke et al., 2017*). These flows form skill-relatedness networks, that predict the economic diversification of regions (*Alabdulkareem et al., 2018; Neffke et al., 2018; Elekes et al., 2019; Hane-Weijman et al., 2020*). Importantly skill-relatedness networks represent, on the one hand, a degree of similarity between economic activities in terms of capabilities as skilled workforce. On the other hand, they represent feasible transitions for workers between skill-related industries and occupations. The latter aspect was found to be particularly important for the involuntary displacement of workers following major plant closures (*Andersson et al., 2018; Eriksson et al., 2018; Hane-Weijman et al., 2018*), and grand recessions (*Moro et al., 2021; Elekes et al. 2023*).

Yet, very few studies consider and put to the test how the explicit network structure of shared productive capabilities condition regional economic resilience. This is particularly important to understand as various economic shocks and structural pressures rarely hit every economic activity at the same time, and to the same degree. Indeed, *Boschma (2015)* for instance called for exploring how resilient regions are against the elimination of nodes and links from the network representation of their economic structure. Since capabilities' usefulness depends on how they can be combined with other capabilities (*Fink et al., 2017*), an elimination of some part of the local capability base likely hinders the systemic functioning of the region in delivering economic outcomes, such as output or employment. Hence, regional economic resilience can be interpreted as being able to retain function at the systemic level in the face of an economic shock (*Martin 2012*). This however depends on existing patterns of combining capabilities, as well as on the possibility for workers to carry over their skills to other industries and occupations. The few studies that took up on this task indeed found that

technology network structures influenced the resilience of regions in terms of patenting output in US (*Balland et al., 2015*) and regional employment in EU metropolitan regions (*Tóth et al., 2020*), while *Moro et al., (2021)* showed that the occupational skill-relatedness structure of US metropolitan regions influenced their resilience in terms of employment. Our own work in the context of local labour markets of Sweden indicate that the network structure of inter-industry labour flows within regions is a prominent predictor of how well they fare in terms of employment when facing a grand recession (*Elekes et al. 2023*). Notwithstanding these advancements, much more exploration is needed to give a complete account on this relationship across different economic activities and types of regions.

Hence, drawing on novel methods developed in network science, the aim of this paper is to provide empirical evidence on how the network robustness of the local industrial capability base evolves over time. Specifically, relying on a detailed individual-level panel dataset provided by Statistics Sweden, we construct skill-relatedness networks (building on the work of *Neffke et al. 2017*) based on above-expected labour flows between industries for 72 Swedish functional labour market regions over three decades. We then measure the robustness of these networks to the sequential elimination of their nodes (following *Elekes et al. 2023*), and the individual contribution of each industry to the labour flow network robustness of their region (following *Zitnik et al. 2019*). With these measurements we tackle three interrelated questions:

> *(1) How does labour flow network robustness in local labour markets changes over time?*
> *(2) Does the labour flow network structure around a specific industry-region predict its likelihood of experiencing lasting decline in economic performance?*
> *(3) Do observed (related) diversification patterns within local labour markets reinforce their overall labour flow network robustness?*

By exploring these questions this paper contributes first to the literature on regional economic resilience by considering the structure of the local economy as a determinant of resilience in a more detailed way, and by an improved measurement of this structure, rooted in network science. Second, it answers the call made in the literature on evolutionary economic geography by showing how robust the network representation of the shared local industrial

capability base is against the removal of some of its components. Overall the paper connects more tightly the literatures of evolutionary economic geography and network science.

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