The Interactive Temporal Microfoundations of Agglomeration Economies and Their Implications

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Abstract

Agglomeration is commonly defined as the spatial concentration of economic activity. While this approach has generated substantial insights, this paper argues instead that agglomeration economies are more convincingly microfounded in time. Actors are time-poor rather than distance-constrained, so demand for spatial proximity is derived from reducing the time required for productive interaction, alongside other time-cost frictions (e.g. cognitive difference). The paper introduces time density as a measure of agglomeration: the mass of potential interaction partners feasible within a given temporal budget – enabling plausible empirical separation of sorting and productivity effects and yielding new policy insights.

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1. Introduction

Perhaps the most enduring metaphor in spatial economics is Marshall (1890)'s observation that knowledge is 'in the air' (Ellison et al., 2010; Krugman et al., 1980; Glaeser, 1999).

The phrase captures a core intuition behind agglomeration, or 'benefits to density' (Duranton and Puga, 2020, p.4), that economic activity clusters because spatial proximity facilitates scale economies (Krugman, 1991). These scale economies are grouped into benefits to specialisation – summarised as sharing, matching and learning (Duranton and Puga, 2004; Marshall, 1890; Arrow, 1962; Romer, 1986) – and diversity (Jacobs, 1961; Waldfogel, 1999).

While this intuition underpins much of agglomeration theory (Fujita and Thisse, 2002), there are alternative approaches. Recent work in the proximity literature has challenged the sufficiency of geographical proximity alone (Boschma and Frenken, 2010; Hassink et al., 2019), emphasising the role of 'cognitive, organizational, social, institutional' as competing explanations that structure human interaction (Boschma, 2005, p.61). This work broadens the concept of proximity, yet it remains less explicit about the economic mechanism through which these dimensions become operative and jointly shape agglomeration outcomes, making operationalisation of these perspectives intractable.

This paper builds on these insights by advancing a temporal microfoundation of interaction as the behavioural primitive of agglomeration (Becker, 1965). Viewing the demand for co-location as the derived demand for reducing the temporal costs and uncertainties associated with geographic distance – alongside other proximities that govern interactions – agglomeration becomes the spatial expression of time-based interaction constraints (Chiappori and Lewbel, 2015). Because activities differ in their coordination requirements and time sensitivity, these constraints bind unevenly across workers, firms, and industries, generating heterogeneous spatial patterns (Andersson et al., 2016).

To ground density in its behavioural microfoundations (Hägerstrand, 1970; Miller, 1999), the paper introduces the concept of *time density*, defined as the mass of potential interaction partners feasible within a given temporal budget. Time density captures interaction capacity directly and clarifies why spatial density may misrepresent agglomeration where temporal frictions are high (Geurs and Van Wee, 2004), better handling uncertainties and risks associated with face-to-face interaction (e.g. congestion, delays and knock-on scheduling costs) (Roy and Thill, 2004; Storper and Venables, 2004).

The paper makes three contributions. First, it reconceptualises agglomeration as the expansion of feasible interaction opportunities within temporal budget sets rather than as concentration within spatial containers. Second, it provides a unifying economic interpretation of proximity by showing how different forms of proximity operate through their effects on the opportunity cost of time. Third, it introduces time density as a behavioural measure of agglomeration that clarifies the relationship between spatial density, interaction capacity, and equilibrium spatial outcomes.

Section 2 situates the argument within the agglomeration, proximity, and accessibility literatures. Section 3 develops the temporal microfoundation of interaction and clarifies the behavioural constraint that governs interaction feasibility. Section 4 formalises these ideas and defines time density. Section 5 and Section 6 discuss implications for academia and policy respectively, and Section 7 concludes.

2. Literature Review

2.1. Spatial density and measurement

Agglomeration is most commonly conceptualised and measured through spatial density (Kominers, 2008; O'Donoghue and Gleave, 2004), being defined as the 'spatial concentration of economic activity in a limited area' (Nakamura and Paul, 2019, p.386). In both theoretical and empirical work, spatial density underpins observed relationships between agglomeration and wages (Fingleton and Longhi, 2013), innovation (Carlino and Kerr, 2014; Fang, 2020), or productivity (Andersson and Lööf, 2011).

Despite its empirical success, I argue that spatial density functions primarily as a reduced-form object (Hägerstrand, 1970). It records where economic activity concentrates, but does not directly represent the constraint governing interaction (González, 1997). Distance, density, and spatial weights offer quantifiable proxies for a broader set of frictions—including travel time (Frank et al., 2008; Small, 2012), congestion (Jayasooriya and Bandara, 2017), coordination costs and uncertainty (Cummings and Kiesler, 2007)—that agents experience in temporal rather than spatial units (Becker, 1993).

The persistence of spatial metrics partly reflects historical data constraints (Rietveld and Vickerman, 2003). Distance is easy to measure, stable over time, and performs reasonably well empirically, making it an attractive proxy for interaction costs (Krugman, 1991). However, with the growing availability of detailed mobility data, transport networks, and computational accessibility tools, the empirical justification for privileging distance over time has weakened (Chen et al., 2016; Kitchin and McArdle, 2016). Although there is increasing support for (Han et al., 2018, p.451)'s statement on the 'death of geography' given the opportunities presented by big data (Friedman, 2005; Bertsimas et al., 2019), what remains underdeveloped is not measurement capacity, but a conceptual framework that treats time as the primitive constraint from which spatial concentration is derived, despite wider development of theory regarding the importance of time in spatial interaction (Miller, 2005).

This paper advances this literature with respect to agglomeration economies, arguing that given the temporal nature of the constraints governing actors' interactions, aggregate economic activity should be measured over time rather than space.

2.2. Agglomeration theory and interaction mechanisms

A large literature in urban and regional economics explains the spatial concentration of economic activity through agglomeration economies (McCann and Van Oort, 2019; Glaeser, 2010). In the New Economic Geography tradition, agglomeration emerges from increasing returns, transport costs, and demand linkages, producing self-reinforcing spatial equilibria (Fujita and Thisse, 2002; **?**). Interaction costs are represented indirectly through iceberg transport costs, with space structuring equilibrium outcomes via pecuniary externalities (Krugman, 1991).

A complementary strand of work focuses on micro-level interaction mechanisms. Contributions emphasise learning, human capital spillovers, and face-to-face contact as sources of urban productivity (Glaeser et al., 1995; Glaeser, 1999; Storper and Venables, 2004). Similarly, the sharing–matching–learning framework provides explicit microfoundations for agglomeration economies, each relying on repeated interaction among agents (Duranton and Puga, 2004; Rosenthal and Strange, 2020). In recent years these arguments have helped to explain the persistence of economic clustering despite the rise of digital technologies (c.f. (Florida, 2005) and Friedman (2005)), with the preference for in person interactions persisting due to enduring advantages over efficiency, incentive coordination, socialisation/learning and motivation than digital alternatives (as summarised by Storper and Venables (2004)).

Across these approaches, spatial density is treated as the key empirical object, implicitly standing in for the feasibility and intensity of interaction (Wood and Parr, 2005). While interaction is central to these theories, the constraint governing interaction itself is rarely specified (Hägerstrand, 1970). Spatial proximity is treated as sufficient to enable interaction, with coordination costs, congestion, and uncertainty absorbed into distance or density parameters (Rosenthal and Strange, 2020).

This paper builds directly on these insights but departs from them by shifting attention from where interaction occurs to whether interaction is feasible given limited time budgets. In doing so, it makes explicit the constraint that underpins the interaction-based mechanisms identified in the agglomeration literature.

2.3. Transport, accessibility, and time-aware approaches

In contrast to density-based approaches, the transport and accessibility literature has long recognised that interaction costs are fundamentally time-based (Rietveld and Vickerman, 2003). Accessibility frameworks explicitly model travel time, transport networks, and individual constraints, often focusing on the opportunities reachable within given temporal budgets (Kwan, 1998). For example, Niedzielski and Eric Boschmann (2014, p.1156) use Denver metropolitan area distance and travel time data, arguing that inclusion of a temporal dimension allowed for greater exploration of nonlinearities in 'diverging commuting experiences' between groups. By putting experience and temporality as the focus of study, these models attempt to provide a richer account of how people move through space and how constraints differ across individuals, modes, and contexts (Koster et al., 2011).

However, accessibility research has largely developed separately from agglomeration theory (Melo et al., 2017; Song et al., 2012). Its primary concern is measuring access to predefined opportunities rather than explaining why economic activity clusters or how interaction generates productivity advantages (Hewko et al., 2002). Time appears as an attribute of movement through space, not as the scarce resource governing whether interaction is feasible at all (Karlsson and Gråsjö, 2013). This paper reverses that logic by asking how cities emerge from interaction under limited temporal budgets, treating accessibility as a derived outcome rather than a behavioural primitive.

2.4. Proximity, transaction costs, and multidimensional constraints

A further limitation of treating agglomeration purely in spatial terms is that it gives undue primacy to geographic proximity when other constraints may be equally important (Hassink et al., 2019). This concern is central to the innovation and proximity literature, which emphasises that interaction depends on multiple dimensions of proximity (Frenken and Boschma, 2007), including cognitive, organisational, institutional, and social proximity (Boschma, 2005). As innovation is increasingly seen as a driver of regional growth (Maguire et al., 2011), beyond traditional supply chain linkage benefits to agglomeration, these mechanisms and the constraints on productive learning are increasingly important to understand (Brown and Mason, 2017).

Differences in routines, legal frameworks, trust, and institutional competence can inhibit interaction even among geographically proximate agents (Boschma and Frenken, 2010). Contrasting the examples of fast-paced cultures of exchange in Silicon Valley (Saxenian, 1990), and Teece (1992)'s insights on slower to change expectations and behaviours of 'long-term reciprocity' of inter-firm relations in Japan illustrates the importance of context in shaping the motivations for, and potential returns to, co-location. Alternatively, shared organisational or institutional contexts can sustain interaction over distance (Florida, 2005; Saxenian, 2002).

I argue that while these literatures are valuable because they rightly broaden the set of relevant constraints on human interaction (Balland et al., 2015), they often lack a common metric through which different frictions can be compared, making operationalising of these constructs difficult (Ponds et al., 2007). For example, although Noonan et al. (2021) attempt to analyse these different dimensions of proximity, they lack an underlying framework to interpret their findings, making trade-offs difficult to evaluate. This paper argues that time provides such a unit of account. Geographic distance, organisational complexity, institutional barriers, and cognitive mismatch all operate through their effects on the time required to initiate, coordinate, and sustain productive interaction.

2.5. From spatial proximity to temporal feasibility

Taken together, these literatures converge on a common insight: agglomeration arises through interaction, but interaction is costly. What they lack is a unified behavioural constraint governing interaction feasibility (Wood and Parr, 2005). By grounding interaction in temporal budgets (Miller, 1999), this paper provides a microfoundation that reconciles spatial density, accessibility, and proximity-based accounts with the recognised temporal microeconomic foundations of human interaction in the wider economic literature (Becker, 1965).

The following sections develop this argument formally by introducing time as the binding constraint on interaction and defining interaction budget sets. This provides the basis for introducing time density as a behavioural measure of agglomeration.

3. Time as the Binding Constraint on Interaction

3.1. Interaction feasibility under temporal budgets

A central limitation of analysing agglomeration through spatial co-location alone is that such representations remain descriptive rather than behavioural. Spatial density records where economic activity has concentrated, but does not specify the constraint governing whether interaction occurs. While proximity is widely recognised as facilitating productive exchange—particularly through face-to-face interaction (Storper and Venables, 2004) and across multiple dimensions of organisational and social closeness (Monge and Kirste, 1980; Boschma, 2005)—these accounts do not specify the mechanism through which proximity operates.

The mechanism proposed here is temporal. Economic interaction requires time (Medlin, 2004). Individuals and firms face limited temporal budgets within which coordination, learning, and exchange must occur, competing with other productive and non-productive activities (Becker, 1965). Interaction is therefore feasible only insofar as the time required for travel, coordination, and engagement fits within these budgets. Where interaction is time intensive—because of long travel times, high coordination demands, or risks and uncertainties—these constraints restrict (Bimpou and Ferguson, 2020; González, 1997).

Existing approaches gesture toward this insight but stop short of specifying a behavioural constraint. Transaction-cost perspectives recognise non-geographic frictions, yet notions such as 'abstract n-dimensional...transaction space' remain analytically diffuse and lack a common metric for evaluating trade-offs (Wood and Parr, 2005, p.4-5). Accessibility-based approaches incorporate travel time, but remain organised around space and focus on measurement rather than on interaction formation (Kwan, 1998). As a result, distance, density, and accessibility continue to function as reduced-form proxies for interaction costs.

The framework developed here instead focuses on interaction feasibility rather than interaction choice, asking what possible productive interactions would be able to occur – given heterogenous proximities – in the working time that individuals have (Heckman, 2015).

Conditional on feasibility, agents select partners and interaction intensities based on expected returns and complementarities (Chiappori and Lewbel, 2015). Time density affects economic outcomes by expanding or contracting the feasible interaction set, even holding preferences and technologies fixed.

3.2. Incommensurability and time as a unit of account

A temporal framing resolves a central problem in proximity-based accounts: incommensurability. Different forms of proximity are analytically distinct and qualitatively heterogeneous (Balland et al., 2015), and when treated directly as spatial or categorical attributes they lack a common metric. Interpreting proximity through time recognises that all such frictions operate via their time requirements (Wolff and Makino, 2012).

Time therefore functions as a unit of account analogous to money: it does not collapse heterogeneity, but renders heterogeneous constraints economically comparable within a single budget – positioning spatial co-location as a consequence rather than a cause of interaction (Medlin, 2004). High cognitive proximity may substitute for geographic distance by reducing interpretation time (Frenken and Boschma, 2007), while organisational or institutional proximity may complement spatial closeness by lowering coordination or enforcement costs (Saxenian, 1990). Non-linearities and lock-in effects highlighted in the proximity literature can thus be handled without assuming monotonic spatial relationships (Boschma, 2005).

3.3. Uncertainty, risk, and interaction reliability

A further advantage of the temporal plane is that it allows uncertainty and risk to be incorporated explicitly (Gollier, 2001). Uncertainties in terms of the regulatory and political environment facing firms have a geographic dimension, as discussed in Krugman (1997)'s analysis of Ireland. Yet these uncertainties are also conditioned by other dimensions of geography. Most spatial representations describe interaction costs in levels—average distance or average travel time—but say little about variance (Niedzielski and Eric Boschmann, 2014). Yet unreliability can be decisive when temporal budgets bind tightly. Unpredictable delays, coordination failures, or institutional uncertainty raise the effective cost of interaction even when mean travel times are unchanged (Bimpou and Ferguson, 2020).

These risks are not confined to transport. Cultural, organisational, and institutional heterogeneity can prevent interaction altogether discontinuously with space (Guiso et al., 2016). This is highlighted by Zhu (2000)'s analysis of the clashing of norms on enterprise, growth and stability in China's spatially uneven move towards post-Confucianism. In some contexts, interactions do not gradually decay with distance but fail outright, varying in a step-change nature due to regulatory or institutional barriers (Teece, 1998). Gaining institutional and organisational competence takes time rather than space (Simon, 1998), and so foes changing institutional context and regulations to correspond (if even a possibility in a current cultural and political environment), reinforcing the point that interaction feasibility depends on factors beyond geography alone (Teece, 1992).

The next section operationalises these ideas by defining interaction budget sets and introducing time density as a measure of agglomeration – demonstrating that where interaction costs bind tightly, agents cluster to economise on time and reduce risk; where they bind less tightly, interaction can be sustained over larger spatial extents

4. Model

4.1. Interaction under temporal constraints

The behavioural primitive of the framework is *productive interaction under binding temporal constraints*. Individuals are rational and time constrained, and economic interaction is feasible only insofar as the time required for travel, coordination, interpretation, and engagement fits within limited temporal budgets (Chiappori and Lewbel, 2015; Monge and Kirste, 1980). Interaction may occur directly between individuals or be organised through firms, teams, or projects (Medlin, 2004).

Let $\bar{T}_i$ denote the time available to individual i for productive interaction within a given period (for example, a working day). This time budget reflects both physical limits and the opportunity cost of time, which may vary across individuals due to differences in wages, skills, or valuation of forgone earnings (Becker, 1965).

Consider an individual i located at $l(i)$ and a potential interaction opportunity indexed by j. An interaction opportunity may correspond to interaction with another individual, participation in a project or team, or engagement mediated by a firm. Let T_{ij} denote the total time required for individual i to engage in interaction j. An interaction is feasible if

$$T_{ij} \leq \bar{T}_i.$$

This condition defines an *interaction feasibility set* for individual i:

$$\mathcal{I}_i(\bar{T}_i) = \left\{ j \ : \ T_{ij} \leq \bar{T}_i \right\}.$$

The size of this set captures the range of interaction opportunities available to individual i within the binding temporal constraint. From this set of interaction opportunities (which can be thought of as all face-to-face and digital interactions), I define *time density* at location ℓ as the aggregate interaction capacity of individuals located there:

$$D_\ell = \sum_{i \in \ell} \sum_{j \in \mathcal{I}_i(\bar{T}_i)} 1.$$

Time density therefore measures the mass of feasible face-to-face interaction opportunities within a location, rather than realised interaction or output. Conditional on feasibility, individuals select interaction partners and intensities based on expected returns and complementarities.

4.2. Components of interaction time

The total time required for interaction T_{ij} comprises multiple components:

$$T_{ij} = \frac{d_{l(i)l(j)}}{v_{ij}} + \phi_{ij} + \rho_{ij},$$

where $d_{l(i)l(j)}$ denotes physical distance between locations (Krugman et al., 1980), v_{ij} captures effective transport speed (including infrastructure quality and mode choice) (Rietveld and Vickerman, 2003), ϕ_{ij} represents spatially mediated temporal frictions such as ticket costs, congestion, waiting time, and unreliability (Bimpou and Ferguson, 2020), i.e. the shadow commuting costs, and ρ_{ij} captures non-spatial interaction frictions.

The term ρ_{ij} subsumes coordination, communication, organisational, cognitive, and institutional frictions (Frenken and Boschma, 2007). Some of these vary with individual attributes (e.g. skills or experience), while others are shaped by organisational arrangements, sectoral practices, or institutional context. All such frictions enter the model through their effect on the time required for productive interaction.

The analysis focuses on spatially mediated components of interaction time, which are systematically structured by geography and infrastructure and can therefore be analysed using spatial data (Han et al., 2018). As I am analysing agglomeration, for now non-spatial frictions are treated as background constraints that vary across individuals, organisations, and contexts but are not modelled explicitly.

4.3. Tasks, sectors, and organisational structure

Interaction requirements vary across between and within sectors. Tasks differ in their demands for coordination, interpretation, and feedback, implying systematic variation in the time required for productive interaction (Ryberg, 2026). Tasks involving exploratory knowledge creation or complex problem-solving typically require frequent, high-bandwidth interaction, while routinised or codified tasks can be sustained with lower interaction intensity (Storper and Venables, 2004). Sectoral and occupational heterogeneity therefore reflects differences in the typical task composition and organisational practices associated with different activities as discussed in Faggio et al. (2020), as well as systematic differences in the opportunity cost of time faced by individuals performing those tasks.

Formally, $T_{ij}^{(s)}$ would denote the structurally different interaction time associated with tasks prevalent in sector s, allowing for disaggregated analysis. Sectoral differences in interaction feasibility arise from the joint operation of task-level coordination requirements and individual time constraints, rather than from either margin in isolation.

4.4. Uncertainty, co-location, and spillovers

Temporal uncertainty in geographic movement–such as delays, cancellations, and unreliable travel times–raises the effective cost of interaction even when mean distance is unchanged (Niedzielski and Eric Boschmann, 2014). These frictions are particularly salient when interaction chains are tightly coupled and individuals face high opportunity costs of time.

Under high temporal uncertainty, co-location may persist as a *risk-adjusted coordination strategy*, adopted ex ante to economise on time and reduce exposure to interaction uncertainty (Burton, 2024; Tseng et al., 2012). Spatial density thus reflects attempts to manage risk under binding temporal constraints rather than the guaranteed presence of spillovers (Wood and Parr, 2005). From this individually grounded perspective, localisation arises from temporal feasibility constraints rather than from an intrinsic spatial limit to knowledge diffusion. Agglomeration emerges where time-cost savings and risk reduction are sufficient to sustain repeated interaction (Brown and Mason, 2017).

5. Academic implications

5.1. Theory

Spillovers. Reframing agglomeration through temporal constraints has direct implications for how spillovers are understood (Glaeser, 1999). As Morgan (2007, p.501) argues, '[l]earning, of course, is worth little if there are no opportunities to implement what has been learned'. A temporal perspective foregrounds the actors and coordination requirements that condition whether learning translates into productive outcomes. Spillovers occur not simply because knowledge circulates, but because agents have sufficient time to interpret, adapt, and deploy what they learn within binding temporal budgets (Medlin, 2004). An biological analogy would be that the cross-pollination of plants, a spatial phenomenon, is driven by the temporally bounded bee. The temporal perspective allows these analyses to move beyond ethereal 'in the air' black box conceptions to analytically tractable microfoundations centred around the question of temporal cost minimisation on economically productive interactions.

Dialogue between literatures. This framework also connects literatures by providing a theoretically grounded common unit of account for assessing proximities and colocation (Chiappori and Lewbel, 2015). Evolutionary economic geography and economic sociology emphasise non-geographic constraints on interaction—cognitive, organisational, institutional, and social- and the dynamic nature of these costs (Boschma and Frenken, 2010; Balland et al., 2015). While these are not modelled explicitly here, they enter implicitly through their effects on the time required to initiate, coordinate, and sustain interaction (Ponds et al., 2007). For instance, the reduction in time costs associated with habit forming and systems efficiencies facilitated through repeated exchange and shared cultures as a consequence of geographic proximity is a key source of interaction efficiencies (Luhmann et al., 1979). Time therefore renders heterogeneous interaction barriers commensurable within a single behavioural constraint, clarifying why proximity facilitates spillovers in some contexts but not others (Noonan et al., 2021).

5.2. Measurement

Exogeneity and identification. A central measurement implication of the temporal framework concerns identification. From Roback (1982), individuals and firms sort on wages, rents, and amenities. This makes disentangling agglomeration effects from equilibrium location choices in spatial analysis difficult (Rosen, 1974). Under a temporal approach, while agents may sort on long-run spatial attributes or average infrastructure quality, productive interaction is structured through short-run temporal conditions that are subject to frequent and largely unpredictable variation (Niedzielski and Eric Boschmann, 2014). Travel times, congestion, service reliability, and coordination delays fluctuate at high frequency, shaping interaction feasibility in ways that even forward-looking agents cannot fully anticipate or internalise (Larcom et al., 2017).

Reconceptualising agglomeration in terms of time density therefore introduces new sources of plausible exogeneity. With the increasing availability of high-frequency mobility and transport data (Šveda and Madajová, 2023), these short-run temporal fluctuations can be observed directly and regressed on high frequency agglomeration outcomes such as job-switching and output per worker, providing identifying variation that was historically unavailable (Geurs and Van Wee, 2004). This source of variation is largely absent from spatial representations, where distance and density change slowly and are more easily sorted on. Even where infrastructure quality and average reliability (levels) is capitalised into rents or wages (Soltani et al., 2021), quotidian performance (residual variance) cannot be perfectly forecast, allowing temporal measures to capture interaction effects that are orthogonal to long-run location choice (Engle et al., 1983; Zhang et al., 2025).

Spatial weights and proximity. A second implication concerns the construction of spatial weights. If the relevant empirical question is whether interaction is feasible or productive, spatial proximity, treated through decay and/or iceberg costs, is insufficient (Fotheringham, 1981; Rietveld and Vickerman, 2003). Interaction potential depends on sectoral characteristics, skill composition, and coordination requirements, which shape the time required for economically meaningful exchange (Hassink et al., 2019). The time-density framework allows such heterogeneity to be incorporated in a disciplined way, by treating sectoral and occupational differences as shifts in interaction time requirements rather than as distinct or ad hoc mechanisms. In doing so, it preserves interpretability while improving empirical alignment with the underlying interaction process (Medlin, 2004; Storper and Venables, 2004).

6. Policy Implications

6.1. Digital Technologies, Remote Work, and Interaction Trade-offs

Viewing interaction through temporal budget constraints clarifies the role of digital communication technologies and work-from-home arrangements as manifestations of the same mechanism (Delventhal and Parkhomenko, 2024). Both primarily operate by reducing traversal time, collapsing the spatial component of interaction costs and expanding the set of agents with whom interaction is technically feasible (Bond-Smith and McCann, 2025). The relevant distinction is therefore not between digital versus physical interaction, or remote versus in-person work, but between which components of interaction time remain binding once spatial frictions are relaxed (Noonan et al., 2021).

This is because reductions in traversal time do not in themselves eliminate other components of interaction cost (Nagle et al., 2020). Coordination, interpretation, attention, monitoring, and trust-related activities continue to consume time (Storper and Venables, 2004), and may in some cases become more demanding under remote interaction – especially in nascent stages of business relationships (Geiger et al., 2021). I would suggest an interesting avenue for future research is the mapping of movements of high human capital researchers between firms over significant geographic distances, and the extent to which there is collaboration with an individuals old firm, and new firm, as an avenue to analyse these reduced temporal costs that would be associated with low coordination or trust between enterprises (Teece, 1992).

From this perspective, remote and hybrid work emerge as equilibrium responses to heterogeneous temporal interaction requirements rather than as substitutes for agglomeration (Glaeser, 1999). Interactions that can be sustained at low coordination cost decentralise readily, while those requiring repeated, high-bandwidth engagement remain spatially concentrated (Melo et al., 2017). Agglomeration persists where interaction remains time-intensive, and relaxes only where productive exchange can be sustained at lower time density (Andersson et al., 2016).

6.2. Congestion, Transport, and the Limits of Agglomeration

A temporal perspective provides a natural interpretation of congestion and transport infrastructure as mechanisms shaping interaction feasibility rather than spatial density. Congestion weakens agglomeration not by reducing the number of potential interaction partners, but by increasing the time required to engage with them (Levine and Garb, 2002). Moderate congestion reduces interaction efficiency without eliminating feasibility, while more severe congestion pushes marginal interactions beyond temporal budgets, contracting interaction capacity and generating diminishing returns to agglomeration (Henderson, 1974). The question is therefore not whether congestion is a positive or negative externality across space (Thissen and Van Oort, 2010), but rather whether the impact on collective temporal budgets is acceptable for policymakers as individual action on feasibility sets may not align with social optima (Ostrom, 1990).

Further, when agglomeration operates through time rather than distance, transport infrastructure becomes inherently agglomerative by reshaping temporal budget sets (Venables, 2007). Improvements in speed, reliability, or network integration expand feasible interaction sets even without population relocation (Frank et al., 2008). This insight aligns with recent work on functional economic areas (Moreno-Monroy et al., 2021), which recognises that administrative boundaries often fail to capture real patterns of economic interaction (Castells-Quintana et al., 2020; Dijkstra et al., 2019). A temporal perspective extends this logic by grounding functional areas in opportunity costs of interaction rather than spatial contiguity alone.

6.3. Spatial Inequality and Uneven Time Density

Finally, the framework foregrounds that spatial density may systematically misrepresent interaction capacity, providing new ways to understand the increasing spatial inequalities (Zsibók, 2017). Because interaction constraints are temporally founded but spatially realised, the framework introduced here allows for the coexistence of multiple forms of density within the same geographic space (Miller, 1999). Spatial locations need not be characterised by a single, uniform level of agglomeration; instead, they may host overlapping interaction regimes that differ in their temporal intensity and economic relevance (Fu, 2024). This perspective goes further than accessibility-based approaches to understanding agglomerations (Kwan, 1998). Instead, time density is relational and symmetric: it characterises the size of the interaction set itself – conditional on characteristics other than temporally enumerated spatial distance (Geurs and Van Wee, 2004).

From a temporal perspective, 'left-behind' places that experience relatively poor socioeconomic outcomes may not be sparse in population (McCann, 2020; Pike et al., 2024), but sparse in feasible interaction opportunities due to their socioeconomic 'distance' from surrounding productive enterprise – requiring significant upskilling to participate in economic arenas, with associated temporal costs (Monge and Kirste, 1980; Perrons, 2004). Spatial inequalities can therefore be reinterpreted as differences in interaction capacity shaped jointly by transport conditions and by the wider time demands of economic activity itself, broadening understandings of spatial manifestations of exclusion (Dijkstra et al., 2020).

7. Conclusion

This paper argues that agglomeration should not be understood simply as the 'spatial concentration of economic activity in a limited area' (Nakamura and Paul, 2019, p.386), but as the spatial expression of economic interaction under limited temporal budgets. Agglomeration emerges as a response to both the level and variance of risk-adjusted interaction feasibility. Framing interaction in terms of time density, with time as the denominator under economic activity, rather than spatial area, clarifies why physical proximity and accessibility alone are insufficient indicators of productive interaction (Teece, 1998), and why dense or well-connected places may nonetheless underperform when interaction remains costly or unreliable in time (Castells-Quintana et al., 2020). Spatial co-location persists not because space is intrinsically productive, but because it economises on time and uncertainty in sustaining complex economic interactions.

By making explicit the time constraints that are implicit in spatial modelling, the framework offers a more behaviourally grounded account of how individuals and firms experience distance, while providing a unified way to incorporate the cognitive, organisational, and institutional frictions emphasised in the proximity literature (Boschma, 2005).

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