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RESEARCH ARTICLE

# Economic geography meets Hotelling: the home-sweet-home effect

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**Abstract**
We introduce heterogeneous preferences for location in 2-region core-periphery models, thereby generating an additional dispersive force: the home-sweet-home effect. Different forms of heterogeneity in preferences for location induce different long-run spatial distributions of economic activity, depending on the short-run equilibrium model and the distribution of preferences for location that are considered. Our analysis highlights the importance of the convexity/concavity properties of utility from consumption and utility from location, as functions of the spatial distribution of economic activity.

**Keywords** New economic geography · Core-periphery model · Heterogeneous agents · Preferences for location

**JEL Classification** R10 · R12 · R23

## 1 Introduction

We propose a general framework for 2-region core-periphery models where agents are heterogeneous regarding their preferences towards living in one region or the other.

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Our aim is to investigate how agglomeration economies interact with heterogeneous preferences for location to determine agglomeration or dispersion of economic activity.

Each region (city, province, country) has its own tangible and intangible characteristics and amenities. Public schools and hospitals of better quality, lower crime rates, availability of parks, a cleaner environment, or a more pleasant landscape can be more or less valued by different individuals. The culture, history, language and lifestyle of a region can be attractive to some individuals but repulsive to others (Rodríguez-Pose and Ketterer 2012; Storper and Manville 2006; Albouy et al. 2013). This adds to the idea that "there is no place like home", which suggests that individuals are reluctant to leave their region of origin. For all these reasons, individuals are heterogeneous in their preferences for residential location (Greenwood 1985), and, therefore, potential migrants are differently attracted by the pecuniary advantage of living in the core vis-à-vis the periphery.

Idiosyncratic preferences towards places of residence constitute a significant dispersive force that is being gradually incorporated in New Economic Geography (NEG) to explain the observed uneven spatial distribution of economic activities beyond causes that are exclusively pecuniary such as real wage differences (Fujita and Mori 2005; Combes et al. 2008; Gaspar 2018). Steps in this direction are the works of Tabuchi and Thisse (2002), Murata (2003), Akamatsu et al. (2012), Ahlfeldt et al. (2015) and Redding (2016), who considered heterogeneous preferences borrowing from discrete choice theory (McFadden 1974).[1]

In discrete choice theory models of random utility, agents draw utility from a deterministic observable component (e.g., consumption from manufactured goods) and from a random unobservable component which represents their idiosyncratic tastes (e.g., preferences for residential location that stem from intangible amenities). The unobservable component is assumed to follow some probability distribution, typically Gumbel (Tabuchi and Thisse 2002; Murata 2003; Akamatsu et al. 2012), or Fréchet (Ahlfeldt et al. 2015; Redding 2016). Under the former, the probabilities for each alternative are given by the logit model.[2] Since it has a very simple closed-form, it is widely used for qualitative behavioural choice (Train 2009). In these models, inter-regional migration responds to the realization of a random variable (Tabuchi and Thisse 2002; Anderson et al. 1992).

We adopt the framework proposed by Hotelling (1929), which can be adapted to deal with preference heterogeneity across a wide array of domains.[3] Each agent's preferences are described by a parameter $x$ uniformly distributed along the unit interval $[0, 1]$. Regions correspond to points on opposite extremes of the unit interval, with the position of each agent on the line, $x \in [0, 1]$, indicating their relative preference for residing in one region or the other. The closer an agent is to a region, the greater

[1] Another important contribution is that of Mossay (2003), where individual preferences for residential location in a continuous circular space follow a random walk process.

[2] However, both the Gumbel and Fréchet distributions yield qualitative properties that can be generated by the conditional logit model (Behrens and Murata 2018).

[3] An alternative that has advantages for the characterization of dynamic stability of equilibria is the population games framework (Hofbauer and Sandholm 2007; Sandholm 2010), which has been recently used in urban economics by Osawa and Akamatsu (2020). See also Akamatsu et al. (2020).

is the utility penalty from residing in the other region. This idiosyncratic attachment to a region generates a dispersive force: the home-sweet-home effect.

We thus attempt to reconcile determinants of spatial agglomeration grounded on market factors with a Hotelling framework describing heterogeneity concerning non-market factors. While heterogeneity in agent preferences has been tackled in NEG, conclusions have been drawn under specific functional forms concerning the utility agents draw from consumption goods (market factors) and specific functional forms for agent heterogeneity (non-market factors). Instead, we consider a general framework which encompasses several set-ups as particular cases and allows the study of the consequences of agent heterogeneity in general. Our results highlight the importance of the convexity/concavity properties of the utility difference from consumption (as a function of the agglomeration level) and of the utility penalty from not residing in the preferred region (as a function of the position in the Hotelling line).

We assume that agents who live in the same region enjoy the same utility from consumption. However, each agent bears a utility penalty which depends on the extent to which they would prefer living in the other region. Therefore, those who have a lower preference for a region will get a lower overall utility if they reside in that region. In the long-run, each agent chooses the region that offers the highest overall utility. The long-run spatial distribution of agents is the result of two counteracting forces. On the one hand, gains from agglomeration due to increasing returns generate a higher utility from consumption in the more populated region. This promotes the well-known agglomeration of economic activities driven by pecuniary factors. On the other hand, the greater the number of agents in the more populated region is the more attached to the less populated region is the borderline migrant. This home-sweet-home effect is an obstacle to agglomeration. The overall utility difference between regions is the utility gain from consumption associated with residing in one region instead of the other, minus the home-sweet-home effect, i.e., the Hotelling utility penalty that the borderline agent suffers from residing in that region instead of the other. In the long-run, the latter is analogous to a congestion cost that increases with population.

We characterize the possible long-run spatial distribution of agents contingent on how the overall utility difference depends on the fraction of agents $h \in [0, 1]$ that live in a region. In our set-up, agents are myopic, i.e., they base their location choices on current utility differentials disregarding expected future utility. If the overall utility difference is strictly quasi-convex for $h \in [\frac{1}{2}, 1]$, then symmetric dispersion ($h = \frac{1}{2}$), agglomeration ($h = 1$), or both, are possible long-run equilibria. In the latter case, selection between the two possible spatial outcomes depends on the initial spatial distribution, that is, "history matters".[4] If the overall utility difference is strictly quasi-concave, then there exists a unique long-run equilibrium which may correspond to symmetric dispersion, agglomeration, or asymmetric dispersion $h \in (\frac{1}{2}, 1)$. The convexity of the overall utility difference function depends on the convexity of the utility difference from consumption and on the convexity of the utility penalty that stems from heterogeneity in preferences for residential location.

[4] This happens because agents are myopic. However, if agents are forward looking, as in Oyama (2009), a region that possesses some comparative advantage may disrupt the legacy of history that led to agglomeration in the other region, reversing the process of industrialisation towards the more advantageous region. In such a setting, path dependence plays no role under a framework of rational expectations (Gaspar 2020).

Our second aim is to illustrate which spatial distributions arise under three well-known models that differ from each other regarding the convexity/concavity of the utility difference from consumption goods derived from their respective short-run equilibria. These models, well established in the literature, are the models of Pflüger (2004), Ottaviano (2001) and Ottaviano et al. (2002). We focus on two functional forms for the utility penalty: the linear model and the logit model. In the linear model, the home-sweet-home effect is linearly increasing in local population. As a result, the convexity/concavity properties of the overall utility difference are the same as those of the utility difference from consumption, namely: concavity in the model of Pflüger (2004), convexity in the model of Ottaviano (2001), and linearity in the model of Ottaviano et al. (2002). The logit model entails an extreme convexity of the Hotelling utility penalty, which tends to infinity as $h$ approaches 0 or 1. For the agent who has the highest preference toward a region, the utility penalty from residing in the other region tends to infinity. Full agglomeration is thus precluded, because there are always agents who prefer to reside in the less populated region due to their idiosyncratic attachment towards it.

Finally, we study the impact of a variation in trade costs on the equilibrium level of agglomeration. We find that, independently of the functional form for the utility penalty, a decrease of trade costs favours agglomeration in the model of Pflüger (2004), but favours dispersion in the model of Ottaviano (2001). In the model of Ottaviano et al. (2002), the tendency for agglomeration is maximized at an intermediate level of trade costs.[5]

Our results show that agent heterogeneity can reverse standard predictions about the spatial distribution of economic activities. Different configurations of the home-sweet-home effect may contribute to explain why agent heterogeneity, which is bound to vary across different geographical scales in the real world, may change and even reverse some of the predictions envisaged by NEG models in the literature regarding the spatial distribution of economic activities. This fact is demonstrated by employing two simple functional forms for the home-sweet-home effect in three different well-known spatial economic models.

This article is organised as follows: Sects. 2 and 3 are devoted to the description of the model and to establishing conditions for existence and stability of long-run equilibria. Section 4 presents three well-known models that provide good illustrations of the effect of the utility difference on the stability of admissible configurations. The same three models are used in Sects. 5 and 6 where the outcome of two types of home-sweet-home effect is studied. In Sect. 7, the impact of trade costs on agglomeration is studied. Section 8 concludes. Most proofs are presented in the “Appendix”.

## 2 Model

There are two regions, $L$ and $R$, symmetric in all aspects except location and population (which is endogenous). Regions are located at opposite extremes of the interval [0, 1],

[5] Heterogeneity in preferences for location influence the number and the characteristics of long-run equilibria, but does not influence whether variations in trade costs favour agglomeration or dispersion.

and there is a unit mass of agents who are heterogeneous *à la* Hotelling (1929) in their preferences for region of residence. Agent types are uniformly distributed along $[0, 1]$, with agent of type $x \in [0, 1]$ suffering a utility penalty $\Delta t(x)$ for residing in region $L$ instead of region $R$, where $\Delta t : [0, 1] \to \mathbb{R}$ is differentiable and such that $\Delta t'(x) > 0, \forall x \in [0, 1]$.[6] We assume that $\Delta t(\frac{1}{2}) = 0$ and $\Delta t(x) = -\Delta t(1 - x)$ to reflect symmetry between regions.[7] Note that an agent of type $x = 0$ (resp. $x = 1$) has the strongest preference for residing in region $L$ (resp. $R$), and an agent of type $x = \frac{1}{2}$ is indifferent between the two regions.

As in all core-periphery models, the utility of residing in a region depends on its population, because the mass of residents influences wages, prices of consumption goods, and housing costs, among other variables. Let $h \in [0, 1]$ denote the mass of agents residing in $L$, and let $U : [0, 1] \to \mathbb{R}_+$ be a differentiable function describing the impact of local population on utility from consumption.[8] The overall utility difference for an agent of type $x \in [0, 1]$ from residing in region $L$ instead of $R$ is thus: $U(h) - U(1 - h) - \Delta t(x)$.

In a short-run equilibrium, the spatial distribution of agents across regions, and thus $h \in [0, 1]$, is fixed. Specific functional forms for $U(\cdot)$ are derived from short-run equilibria of well known core-periphery models in Sect. 4.

In a long-run equilibrium, each agent resides in the region that provides higher utility. Hence, the equilibrium distribution of agents must be such that agents with $x \in [0, h)$ are located in $L$ while agents with $x \in (h, 1]$ are located in $R$.[9] With this property, spatial distributions are completely described by $h \in [0, 1]$, and the overall utility difference between regions $L$ and $R$ for a borderline agent of type $x = h$ is given by:

$$\Delta V(h) = \Delta U(h) - \Delta t(h), \tag{1}$$

where $\Delta U(h) \equiv U(h) - U(1 - h)$ is the region-size effect, and $\Delta t(h)$ is the idiosyncratic preference effect, which we call the *home-sweet-home* effect. Note that, since $\Delta t$ is increasing, $\Delta t(h)$ is negative if $h < \frac{1}{2}$ and positive if $h > \frac{1}{2}$ (the borderline agent prefers to reside in the smaller region), and thus constitutes a dispersive force.

*Agglomeration* of all agents in a single region, $h^* \in \{0, 1\}$, is a long-run equilibrium if and only if $\Delta V(1) \geq 0$, or, equivalently, $\Delta V(0) \leq 0$. This condition means that if all agents are located in the same region, not even the agent with strongest preference for the other region would gain from migrating. The utility difference associated to residing in the core, $\Delta U(1)$, more than compensates the home-sweet-home effect, $\Delta t(1)$.

*Dispersion* of agents between the two regions, $h^* \in (0, 1)$, is a long-run equilibrium if and only if $\Delta V(h^*) = 0$. This condition means that the borderline agent (of type $x = h^*$) is indifferent between the two regions. Therefore, agents with $h < h^*$ do not gain from migrating to region $R$ and agents with $h > h^*$ do not gain from migrating

6 The assumption that agents are uniformly distributed is mild because $\Delta t(\cdot)$ can be non-linear.

7 For each agent (located at $x$) who suffers a utility penalty for residing in $L$ rather than $R$, there is another agent (located at $1 - x$) who suffers the same utility penalty for residing in $R$ rather than $L$.

8 In a more general model, this function could differ across regions. We restrict to symmetric regions.

9 Given any resident in $L$, all agents with stronger preference for $L$ also reside in $L$.

to region $L$. *Symmetric dispersion* ($h^* = \frac{1}{2}$) is always a long-run equilibrium because, since $\Delta V(h) = -\Delta V(1-h)$, $\forall h \in [0, 1]$, we have $\Delta V(\frac{1}{2}) = 0$.

A long-run equilibrium is *stable* if any small perturbation of the spatial distribution generates a utility difference which induces agents to return to their original location. Under a wide variety of migration dynamics, a sufficient condition for stability of agglomeration is $\Delta V(1) > 0$, or, equivalently, $\Delta V(0) < 0$.[10] If all agents strictly prefer to reside in the core, then (by continuity of $\Delta V(h)$ at $h = 1$), after a small perturbation of the spatial distribution, they continue to prefer to reside in the core. A sufficient condition for stability of dispersion is $\Delta V'(h^*) < 0$. After a small perturbation which increases (resp. decreases) $h$, the borderline agent strictly prefers to reside in region $R$ (resp. $L$), thereby restoring the original distribution. This happens when the relative utility gain from the increase of local population, $\Delta U'(h^*)$, is smaller than the increase of the home-sweet-home effect, $\Delta t'(h^*)$.

A long-run equilibrium with full agglomeration, $h^* = 1$ (resp. $h^* = 0$), is called *regular* iff $\Delta V(1) \neq 0$ (resp. $\Delta V(0) \neq 0$). A long-run equilibrium with dispersion, $h^* \in (0, 1)$, is called *regular* iff $\Delta V'(h^*) \neq 0$. For regular long-run equilibria, under a wide variety of migration dynamics, the previously mentioned sufficient conditions for stability are also necessary.[11]

## 3 Stable long-run equilibria

The convexity properties of the overall utility difference $\Delta V$ determine the number and type of stable long-run equilibria. We characterize existence, stability and uniqueness of long-run equilibria if $\Delta V$ is strictly quasi-convex or strictly quasi-concave. Recall that existence and stability of long-run equilibria only depend on the characteristics of $\Delta V$:

- *Agglomeration*, $h^* \in \{0, 1\}$, is a long-run equilibrium if and only if $\Delta V(1) \geq 0$. It is stable if $\Delta V(1) > 0$, which is equivalent to $\Delta U(1) > \Delta t(1)$.
- *Dispersion*, $h^* \in (0, 1)$, is a long-run equilibrium if and only if $\Delta V(h^*) = 0$, i.e., $\Delta U(h^*) = \Delta t(h^*)$. It is stable if $\Delta V'(h^*) < 0$, i.e., $\Delta U'(h^*) < \Delta t'(h^*)$.

**Proposition 1** *If $\Delta V$ is strictly quasi-convex for $h \in [\frac{1}{2}, 1]$, there is one or two stable long-run equilibria with $h^* \in [\frac{1}{2}, 1]$: agglomeration, symmetric dispersion, or both.*

***Proof*** There are four possible and mutually exclusive cases (see also Fig. 1):

- If $\Delta V'(\frac{1}{2}) \geq 0$, then $\Delta V(h) > 0$ for all $h \in (\frac{1}{2}, 1]$. Agglomeration and symmetric dispersion are long-run equilibria, but only agglomeration is stable.

[10] If $\Delta V(1) > 0$, then $h = 1$ is an evolutionary stable state and thus is locally stable under a wide variety of evolutionary dynamics (Sandholm 2010, ch. 8), such as the replicator dynamics, which is widely used in NEG (Fujita et al. 1999). See also Hofbauer and Sandholm (2007).

[11] It is more complicated to assess stability of long-run equilibria that are not regular, i.e., are *irregular*. An agglomeration equilibrium with $\Delta V(1) = 0$ is stable if there exists $\epsilon > 0$ such that $\Delta V(1-\delta) > 0$ for all $\delta \in (0, \epsilon)$. A dispersion equilibrium with $\Delta V'(h^*) = 0$ is stable if there exists $\epsilon > 0$ such that $\Delta V(h^* - \delta) > 0$ and $\Delta V(h^* + \delta) < 0$ for all $\delta \in (0, \epsilon)$. In models that are well-behaved, non-existence of irregular long-run equilibria is generic, i.e., holds in a full measure subset of a suitably defined parameter space.

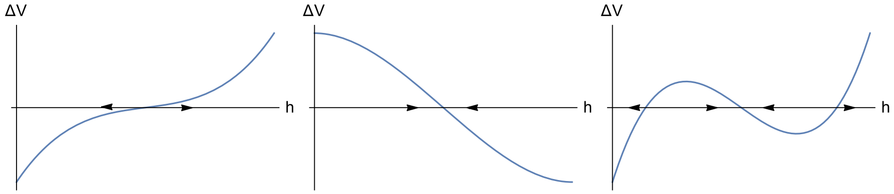


**Fig. 1** Stable equilibria when $\Delta V$ is strictly quasi-convex in $[\frac{1}{2}, 1]$: agglomeration (left); symmetric dispersion (middle); both (right)

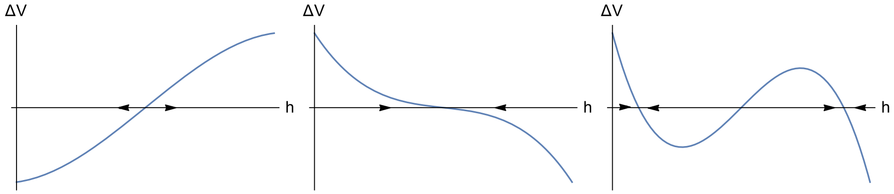


**Fig. 2** Stable equilibria when $\Delta V$ is strictly quasi-concave in $h \in [\frac{1}{2}, 1]$: agglomeration (left); symmetric dispersion (middle); asymmetric dispersion (right)

- If $\Delta V'(\frac{1}{2}) < 0$ and $\Delta V(1) < 0$, then $\Delta V(h) < 0$ for all $h \in (\frac{1}{2}, 1]$. Symmetric dispersion is the unique long-run equilibrium, and it is stable.
- If $\Delta V'(\frac{1}{2}) < 0$ and $\Delta V(1) = 0$, then $\Delta V(h) < 0$ for all $h \in (\frac{1}{2}, 1)$. Symmetric dispersion and agglomeration are long-run equilibria, but only symmetric dispersion is stable.
- If $\Delta V'(\frac{1}{2}) < 0$ and $\Delta V(1) > 0$, there exists a single $h^* \in (\frac{1}{2}, 1)$ s.t. $V(h^*) = 0$. Agglomeration and symmetric dispersion are stable long-run equilibria. Asymmetric dispersion with fraction $h^*$ of agents in the core is a long-run equilibrium, but is not stable. □

**Proposition 2** *If $\Delta V$ is strictly quasi-concave for $h \in [\frac{1}{2}, 1]$, there is a unique stable long-run equilibrium with $h^* \in [\frac{1}{2}, 1]$: agglomeration, symmetric dispersion, or asymmetric dispersion.*

***Proof*** There are three possible and mutually exclusive cases (see also Fig. 2):

- If $\Delta V'(\frac{1}{2}) \leq 0$, then $\Delta V(h) < 0$ for all $h \in (\frac{1}{2}, 1]$. Symmetric dispersion is the unique long-run equilibrium, and it is stable.
- If $\Delta V'(\frac{1}{2}) > 0$ and $\Delta V(1) \geq 0$, then $\Delta V(h) > 0$ for all $h \in (\frac{1}{2}, 1)$. Agglomeration is the unique stable long-run equilibrium. Symmetric dispersion is not stable.
- If $\Delta V'(\frac{1}{2}) > 0$ and $\Delta V(1) < 0$, there exists a single $h^* \in (\frac{1}{2}, 1]$ s.t. $V(h^*) = 0$. Asymmetric dispersion with fraction $h^*$ of agents in the core is the unique stable long-run equilibrium. Symmetric dispersion and agglomeration are not stable. □

In the next three sections, we use well-known core-periphery models and different forms of heterogeneity in preferences for location to derive properties of $\Delta V$, and apply Propositions 1 and 2 to characterize existence, stability and uniqueness of long-run equilibria.

## 4 Stable spatial equilibria for different NEG models

We now consider three well-known analytically solvable core-periphery models which lead to opposite convexity properties of the utility difference from consumption, $\Delta U$: the models of Pflüger (2004), Ottaviano (2001), and Ottaviano et al. (2002).[12]

### 4.1 Common ground

The economy comprises: two regions, $L$ and $R$; two sectors, manufactures and agriculture; and two types of agents, mobile and immobile.

The agricultural sector uses immobile labour to produce a perfectly tradable good under perfect competition and constant returns to scale (each agent produces one unit of the agricultural good). Choosing the agricultural good as numeraire, we set its price and the wage of immobile agents at unity in both regions.

In the manufacturing sector, many varieties of imperfectly tradable manufactured goods are produced under monopolistic competition and increasing returns to scale. Each firm produces a single variety using one unit of mobile labour (fixed cost) and, in addition, one unit of immobile labour per unit of output (variable cost). There is free entry in the manufacturing sector, thus firm profits are driven to zero (the nominal wage of mobile labour, $w_i$, totally absorbs operating profits).

There is a unit mass of mobile agents (who can migrate freely) and a mass $\lambda/2$ of immobile agents in each region, who choose their consumption with the objective of maximizing a common utility function. Agents in region $i$ maximize utility $u(C_i, A_i)$, where $C_i$ is the consumption level of a composite good of manufactures and $A_i$ is the consumption level of the agricultural good, subject to the budget constraint $P_i C_i + A_i = y_i$, where $P_i$ is the regional price index of the manufacturing goods composite, and $y_i$ is the nominal wage ($y_i = w_i$ for mobile agents and $y_i = 1$ for immobile agents).

Product market and labour market equilibrium yields unique short-run equilibrium wage, price and consumption levels as a function of the spatial distribution of agents, $h \in [0, 1]$. For each of the following models we use a different superscript for $\Delta U(h)$.

Without loss of generality, write the home-sweet-home effect as $\Delta t(x) = \theta f(x)$, where $\theta > 0$ is a scale parameter and $f(x)$ describes the shape of heterogeneity. The restrictions imposed on $\Delta t$ translate into $f(\frac{1}{2}) = 0$, $f(x) = -f(1-x)$ and $f'(x) > 0, \forall x \in [0, 1]$.

### 4.2 PF model

The PF model (Pflüger 2004) assumes quasi-linear logarithmic utility from consumption:

$$u_i^{PF} = \alpha \ln C_i + A_i, \tag{2}$$

[12] By analytically solvable, we mean that the utility $U(h)$ derived from the short-run equilibrium, which is model-specific, can be written as an explicit (rather than implicit) function of the spatial distribution $h$—unlike in the original core-periphery model of Krugman (1991).

where $\alpha > 0$; and a CES composite of manufactures:

$$C_i = \left[ \int_{s \in S} c_i(s)^{\frac{\sigma-1}{\sigma}} ds \right]^{\frac{\sigma}{\sigma-1}},$$

where $c_i(s)$ is consumption in region $i$ of variety $s$ of manufactures, and $\sigma > 1$ is the elasticity of substitution between varieties.

Trade across regions of manufactured varieties is subject to an iceberg cost: for each unit to arrive, it is necessary to ship $\tau \in (1, +\infty)$ units.

The short-run equilibrium utility difference is given by (Pflüger 2004, p. 569):

$$\begin{aligned} \Delta U^{PF}(h) = \frac{\alpha}{\sigma - 1} \Bigg( \left\{ \frac{(2h-1)(\sigma-1)(1-\phi)\left[(\lambda+2)\phi - \lambda\right]}{2\sigma\left[1 - h(1-\phi)\right]\left[(1-h)\phi + h\right]} \right\} \\ + \ln\left[ \frac{h(1-\phi)+\phi}{1-h(1-\phi)} \right] \Bigg), \end{aligned} \tag{3}$$

where $\phi = \tau^{1-\sigma}$ is the "freeness of trade" parameter.

**Assumption 1** *Freeness of trade is relatively low:*[13]

$$\phi < \frac{3\lambda(\sigma-1) - \sigma}{3\lambda(\sigma-1) + 7\sigma - 6}. \tag{4}$$

Gaspar et al. (2018), who extend the PF model to any finite number of equidistant regions, provide a critical value of the mass of immobile agents below which agglomeration is stable.[14] This critical value is greater than the lower bound on $\lambda$ imposed by Assumption 1, which means that stability of agglomeration is not precluded by Assumption 1 (and thus neither are stability of asymmetric or symmetric dispersion).

**Lemma 1** *Under Assumption 1, $\Delta U^{PF}$ is strictly concave in $h \in [\frac{1}{2}, 1]$.*

***Proof*** See "Appendix A". □

In the PF model, if freeness of trade is sufficiently low (or, equivalently, if the mass of immobile agents is sufficiently large), $\Delta U$ is strictly concave in $h \in [\frac{1}{2}, 1]$. Therefore, if $\Delta t$ is convex in $h \in [\frac{1}{2}, 1]$, then $\Delta V$ is also strictly concave in $h \in [\frac{1}{2}, 1]$. Hence, by Proposition 2, there is a unique stable equilibrium: agglomeration, symmetric dispersion, or asymmetric dispersion. The next result provides more detail.

**Proposition 3** *In the PF model under Assumption 1 with a convex home-sweet-home effect, there are thresholds $\theta_b$ (break point) and $\theta_s$ (sustain point), with $\theta_s < \theta_b$, such that:*[15]

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[13] It is equivalent to assume that the mass of immobile agents is relatively large: $\lambda > \frac{7\sigma\phi+\sigma-6\phi}{3(\sigma-1)(1-\phi)}$.

[14] See inequality (18) in Gaspar et al. (2018, p. 871).

[15] Note that if $\theta_s < 0$ then only two of the cases in Proposition 3 can be observed. If $\theta_b \leq 0$ then symmetric dispersion is the single stable equilibrium.

- *Agglomeration is the unique stable equilibrium if* $\theta \leq \theta_s$.
- *Asymmetric dispersion is the unique stable equilibria if* $\theta \in (\theta_s, \theta_b)$.
- *Symmetric dispersion is the unique stable equilibrium if* $\theta \geq \theta_b$.

***Proof*** See "Appendix A". □

The PF model with a convex home-sweet-home effect thus predicts a smooth transition from symmetric dispersion to increasingly asymmetric dispersion and, finally, agglomeration as the home-sweet-home effect becomes weaker.[16]

A strictly convex home-sweet-home effect ($\Delta t$) is relatively flat in the middle portion of [0, 1] and relatively steep near the boundaries of [0, 1]. This means that there is a large fraction of agents who are only mildly attached to their hometown, and a small fraction whose attachment is strong. By contrast, a strictly concave home-sweet-home effect ($\Delta t$) is relatively flat near the boundaries of [0, 1] and relatively steep in the middle portion of [0, 1]. In this case, a large fraction of agents is strongly attached to their hometown, and there is only a small fraction whose attachment is mild.[17]

While a strictly convex home-sweet-home effect is associated with a unimodal taste distribution (single peak at the centre), a strictly concave home-sweet-home effect is associated with a bimodal taste distribution (peaks at both ends). Standard taste distributions in random utility models are single-peaked, which suggests that a strictly convex home-sweet-home effect is perhaps more standard.[18] A natural situation where a bimodal taste distribution may arise is when we mix two populations with different unimodal taste distributions (e.g., agents whose hometown is $L$ and agents whose hometown is $R$). A strictly concave home-sweet-home effect is also connected with the existence of diminishing marginal cost of congestion, as in McGreer and McMillan (1993).

### 4.3 FE model

The only difference of the FE model (Ottaviano 2001) with respect to the PF model is that utility from consumption is:

$$u_i^{FE} = \mu \ln(C_i) + (1-\mu)\ln(A_i), \tag{5}$$

where $\mu \in (0, 1)$ is the share of income spent on manufactures.

The short-run equilibrium utility difference is given by (Ottaviano 2001, p. 57):

$$\Delta U^{FE}(h) = \ln\left[\frac{h\phi + (1-h)\psi}{(1-h)\phi + h\psi}\right] + \frac{\mu}{\sigma-1}\ln\left[\frac{(1-h)\phi + h}{h\phi + (1-h)}\right], \tag{6}$$

where $\psi = \frac{1}{2}\left[1 + \phi^2 - \frac{\mu}{\sigma}(1-\phi^2)\right]$.

[16] If the home-sweet-home effect, $\Delta t$, is not convex, the overall utility difference, $\Delta V$, is not necessarily strictly quasi-convex or strictly quasi-concave, and thus Propositions 1 and 2 may not apply.

[17] We thank an anonymous referee for suggesting this natural interpretation.

[18] Distributions with peaks at both ends are "type U" in the AJUS typology of Galtung (1967). An example is the arcsin distribution (a particular case of the beta distribution).

**Assumption 2** *The following condition holds:*[19]

$$\phi > \frac{\sigma - \mu}{\sigma + \mu}. \tag{7}$$

**Lemma 2** *Under Assumption 2, the utility difference* $\Delta U^{FE}$ *is strictly convex in* $h \in [\frac{1}{2}, 1]$.

***Proof*** See "Appendix A". □

In the FE model, if freeness of trade is sufficiently high, $\Delta U$ is strictly convex in $h \in [\frac{1}{2}, 1]$. Therefore, if $\Delta t$ is concave in $h \in [\frac{1}{2}, 1]$, then $\Delta V$ is also strictly convex in $h \in [\frac{1}{2}, 1]$. By Proposition 1, one or two equilibria may be stable: agglomeration, symmetric dispersion, or both.

**Proposition 4** *In the FE model under Assumption 2 with a concave home-sweet-home effect, there are thresholds* $\theta_b$ *(break point) and* $\theta_s$ *(sustain point), with* $\theta_b < \theta_s$*, such that:*[20]

- *Agglomeration is the unique stable equilibrium if* $\theta \leq \theta_b$.
- *Agglomeration and symmetric dispersion are the only stable equilibria if* $\theta \in (\theta_b, \theta_s)$.
- *Symmetric dispersion is the unique stable equilibrium if* $\theta \geq \theta_s$.

***Proof*** See "Appendix A". □

The FE model with a concave home-sweet-home effect predicts a catastrophic transition from symmetric dispersion to agglomeration as the home-sweet-home effect becomes weaker.[21]

### 4.4 OTT model

The OTT model (Ottaviano et al. 2002) has two important differences with respect to the PF and FE models. One is that preferences for manufactures are described by a quadratic aggregator instead of a CES aggregator. The other is that the cost of trading manufactured varieties, instead of being iceberg, is $\tau$ units of the numeraire good per unit shipped.

Utility from consumption is linear:

$$u_i^{OTT} = C_i + A_i, \tag{8}$$

[19] Note that Assumptions 1 and 2 apply to different models and thus are not cumulative. Assumption 1 restricts freeness of trade to be relatively low in the PF model. Assumption 2 restricts freeness of trade to be relatively high in the FE model. Note also that the two assumptions are not incompatible.

[20] Note that if $\theta_b < 0$ then only two of the cases in Proposition 4 can be observed. If $\theta_s \leq 0$ then symmetric dispersion is the unique stable equilibrium.

[21] If the home-sweet-home effect, $\Delta t$, is not concave, the overall utility difference, $\Delta V$, is not necessarily strictly quasi-convex or strictly quasi-concave, and thus Propositions 1 and 2 may not apply.

with quadratic sub-utility:

$$C_i = \alpha \int_{s \in S} c_i(s) ds - \frac{\beta - \gamma}{2} \int_{s \in S} c_i(s)^2 ds - \frac{\gamma}{2} \left[ \int_{s \in S} c_i(s) ds \right]^2 .$$

The short-run equilibrium utility difference is:

$$\Delta U^{OTT} = C\tau \left(\tau^* - \tau\right) \left(h - \frac{1}{2}\right), \tag{9}$$

where $C > 0$ and $\tau^* > 0$ are bundling parameters that depend neither on $h$ nor on $\tau$.[22]

**Lemma 3** *The utility difference $\Delta U^{OTT}$ is linear in $h \in \left[\frac{1}{2}, 1\right]$.*

In the OTT model, since $\Delta U$ is linear, $\Delta V$ has the opposite convexity of $\Delta t$. If $\Delta t$ is strictly convex in $h \in [\frac{1}{2}, 1]$, $\Delta V$ is strictly concave in $h \in [\frac{1}{2}, 1]$. Hence, by Proposition 2, there is a unique stable equilibrium: agglomeration, symmetric dispersion, or asymmetric dispersion.

**Proposition 5** *In the OTT model with a strictly convex home-sweet-home effect, there are thresholds $\theta_b$ (break point) and $\theta_s$ (sustain point), with $\theta_s < \theta_b$, such that:*[23]

- *Agglomeration is the unique stable equilibrium if $\theta \leq \theta_s$.*
- *Asymmetric dispersion is the unique stable equilibria if $\theta \in (\theta_s, \theta_b)$.*
- *Symmetric dispersion is the unique stable equilibrium if $\theta \geq \theta_b$.*

If $\Delta t$ is strictly concave in $h \in [\frac{1}{2}, 1]$, $\Delta V$ is strictly convex in $h \in [\frac{1}{2}, 1]$. By Proposition 1, one or two equilibria may be stable: agglomeration, symmetric dispersion, or both.

**Proposition 6** *In the OTT model with a strictly concave home-sweet-home effect, there are thresholds $\theta_b$ (break point) and $\theta_s$ (sustain point), with $\theta_b < \theta_s$, such that:*[24]

- *Agglomeration is the unique stable equilibrium if $\theta \leq \theta_b$.*
- *Agglomeration and symmetric dispersion are the only stable equilibria if $\theta \in (\theta_b, \theta_s)$.*
- *Symmetric dispersion is the unique stable equilibrium if $\theta \geq \theta_s$.*

The OTT model with a strictly convex home-sweet-home effect thus predicts a smooth transition from symmetric dispersion to increasingly asymmetric dispersion and, finally, agglomeration as the home-sweet-home effect becomes weaker. By contrast, with a strictly concave home-sweet-home effect, the OTT model predicts a catastrophic transition from symmetric dispersion to agglomeration as the home-sweet-home effect diminishes.

[22] See Ottaviano et al. (2002, p. 420) for more detail on the two expressions.

[23] Note that if $\theta_s < 0$ then stability of agglomeration is precluded. If $\theta_b \leq 0$ then symmetric dispersion is the unique stable equilibrium.

[24] Note that if $\theta_b < 0$ then symmetric dispersion is always stable. If $\theta_s \leq 0$ then symmetric dispersion is the unique stable equilibrium.

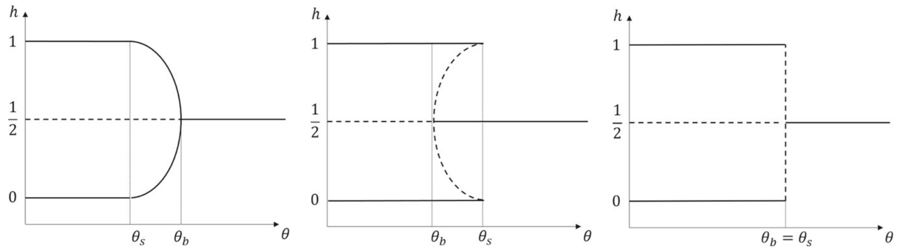


**Fig. 3** Bifurcation diagrams with linear home-sweet-home effect: PF model (left); FE model (middle); OTT model (right)

## 5 Linear home-sweet-home effect

We now address the specific case of a linear home-sweet-home effect: $\Delta t(x) = \theta(x - \frac{1}{2})$, where $\theta > 0$ is a scale parameter measuring the strength of heterogeneity (Hotelling 1929; Mansoorian and Myers 1993). In this case, the convexity properties of $\Delta U$ are inherited by $\Delta V$.

The discrete choice analog is the linear probability model (Caudill 1988; Heckman and Snyder 1997). The fraction of agents who choose to reside in region $L$ is:

$$h = \frac{1}{2} + \frac{\Delta U(h)}{\theta},$$

which means that the increase in $\Delta U$ necessary to attract an additional agent to region $L$ is independent of the level of agglomeration (constant and equal to $\theta$ in magnitude).

Of course, a linear home-sweet-home effect is simultaneously concave and convex. Hence, Propositions 3 and 4 characterize the number and type of stable spatial equilibria in the PF model under Assumption 1 and in the FE model under Assumption 2. In the OTT model, since $\Delta U$ is linear, $\Delta V$ is also linear. This leads to the degenerate case described next.

**Proposition 7** *In the OTT model with a linear home-sweet-home effect, there is a threshold value $\theta_{bs}$ (break and sustain point) such that:*

- *Agglomeration is the unique stable equilibrium if $\theta < \theta_{bs}$.*
- *There are no stable equilibria if $\theta = \theta_{bs}$.*
- *Symmetric dispersion is the unique stable equilibrium if $\theta > \theta_{bs}$.*

***Proof*** See "Appendix A". □

The OTT model with a linear home-sweet-home effect thus predicts a catastrophic transition from symmetric dispersion to agglomeration as the home-sweet-home effect becomes weaker. This conclusion is analogous to that concerning the FE model.

Figure 3 exhibits, qualitatively, the bifurcation diagrams of the PF, FE and OTT models with a linear home-sweet-home effect.

## 6 Logit home-sweet-home effect

One of the most widely used discrete choice models is the logit. It was used to describe heterogeneity in preferences for location by Tabuchi and Thisse (2002) and Murata (2003). According to the logit model, the fraction of agents who choose to reside in region $L$ is:

$$h = \frac{1}{1 + e^{-\frac{\Delta U(h)}{\theta}}}, \tag{10}$$

where $\theta > 0$ is a scale parameter which measures the strength of heterogeneity.

Manipulation of (10) yields:

$$U(h) - \theta \ln(h) = U(1-h) - \theta \ln(1-h).$$

which is our long-run equilibrium condition with $\Delta t(x) = \theta \ln(\frac{x}{1-x})$.

In this case, the home-sweet-home effect, $\Delta t(h) = \theta \ln(\frac{x}{1-x})$, is strictly convex for $h \in [\frac{1}{2}, 1]$. It is clear that, even for arbitrarily small $\theta$, the home-sweet-home effect is unbounded as $h \to 1$ and as $h \to 0$. Hence, it prevents full agglomeration (whenever $\Delta U$ is bounded, as in the PF, FE and OTT models).[25] This leads to the following results.

**Proposition 8** *In the PF model under Assumption 1 and in the OTT model, with a logit home-sweet-home effect, there is a threshold value $\theta_b$ (break point) such that:*[26]

- *Asymmetric dispersion is the unique stable equilibrium if $\theta < \theta_b$.*
- *Symmetric dispersion is the unique stable equilibrium if $\theta \geq \theta_b$.*

***Proof*** See “Appendix A”. □

With a logit home-sweet-home effect, both the PF model and the OTT model predict smooth transition from symmetric dispersion to increasingly asymmetric dispersion, tending to full agglomeration in the limit as the home-sweet-home effect becomes weaker. See Figure 4.

This is not the case with the FE model. Since $\Delta U^{FE}$ and $\Delta t$ are both convex, $\Delta V^{FE}$ is not necessarily either convex or concave. Equilibrium configurations can arise that are different from the ones encountered so far. In Fig. 4 (right), we illustrate, qualitatively, a case where symmetric dispersion and asymmetric dispersion are both stable.[27]

## 7 Impact of trade costs on agglomeration

It is frequently of interest to assess the impact of changes in parameters such as trade costs on the stability of symmetric dispersion, the stability of agglomeration, and on

[25] The fact that agglomeration is never a stable outcome under a logit home-sweet-home effect is not new (Tabuchi and Thisse 2002).

[26] The value of $\theta_b$ is model-dependent.

[27] A detailed analysis is presented in “Appendix B”, where $\theta_f$ is defined as the threshold value of $\theta$ below which asymmetric dispersion is stable.

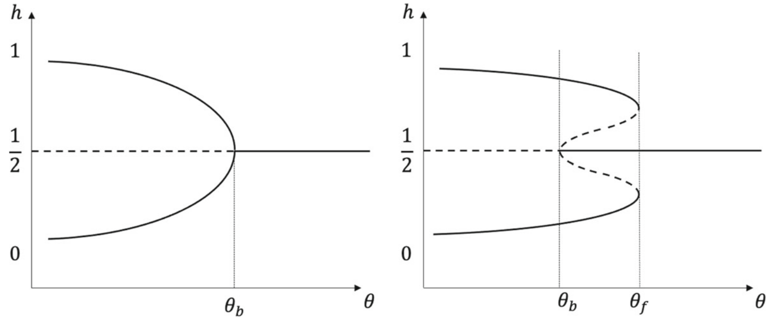


**Fig. 4** Bifurcation diagrams with logit home-sweet-home effect: PF and OTT models (left); FE model (left or right)

the level of agglomeration in the case of asymmetric dispersion. With this in mind, denote by $\Delta U(h; z)$ and $\Delta V(h; z)$ the consumption and overall utility differences, respectively, as functions of the spatial distribution of agents, $h$, and of a vector of parameters, $z \in Z$. In addition, let $E(z) \subseteq [\frac{1}{2}, 1]$ denote the set of stable equilibria for $z \in Z$.

A parameter shock from $z$ to $z'$ is said to favour agglomeration whenever the three following conditions are satisfied:[28]

- $\frac{1}{2} \notin E(z) \Rightarrow \frac{1}{2} \notin E(z')$ (symmetric dispersion may become unstable but not stable).
- $1 \in E(z) \Rightarrow 1 \in E(z')$ (full agglomeration may become stable but not unstable).
- $\max E(z) \in (\frac{1}{2}, 1) \Rightarrow \max E(z') > \max E(z)$, and $\min E(z) \in (\frac{1}{2}, 1) \Rightarrow \min E(z') > \min E(z)$ (asymmetric dispersion becomes more asymmetric).

Next, we provide a simple sufficient condition for a shock to favour agglomeration: that the overall utility difference increases.

**Proposition 9** *Suppose $\Delta V(h; z') > \Delta V(h; z)$, $\forall h \in (\frac{1}{2}, 1]$, and that all equilibria with $z$ and $z'$ are regular. A change of parameter values from $z$ to $z'$ favours agglomeration.*

***Proof*** See "Appendix C". □

A straightforward consequence is that an increase in $\theta$ favours dispersion—for any shape of heterogeneity in preferences for location, and any underlying short-run equilibrium model. As expected, the home-sweet-home effect favours dispersion.

Although we define the meaning of *favouring* agglomeration/dispersion in a way that applies to full agglomeration, symmetric dispersion and asymmetric dispersion, perhaps the most interesting case is when a stable long-run equilibrium featuring asymmetric dispersion becomes more or less asymmetric. As demonstrated in the previous sections, the existence of a stable long-run equilibrium featuring asymmetric dispersion in the FE and OTT models hinges on the existence and shape of the home-sweet-home effect. In any case, as we show below by applying Proposition 9,

[28] Similarly, a shock from $z$ to $z'$ is said to favour dispersion if the shock from $z'$ to $z$ favours agglomeration.

whether a variation in trade costs favours agglomeration or dispersion is independent of preferences for location, i.e., of the functional form of the home-sweet-home effect.

**Proposition 10** *A decrease in trade costs:*[29]

- *favours agglomeration in the PF model under Assumption 1 and* $\sigma \geq \frac{3}{2}$.
- *does not favour agglomeration in the FE model if* $\phi > \sqrt{\frac{\sigma-\mu}{\sigma+\mu}}$.
- *favours agglomeration (dispersion) in the OTT model if* $\tau(\tau^* - \tau)$ *increases (decreases).*

***Proof*** See "Appendix C". □

We conclude that a decrease of trade costs favours agglomeration in the model of Pflüger (2004) and favours dispersion in the model of Ottaviano (2001). In the model of Ottaviano et al. (2002), the tendency for agglomeration is maximized for intermediate values of the trade cost parameter (precisely, for $\tau = \frac{\tau^*}{2}$).

## 8 Concluding remarks

Individual preferences over locations with different cultural or historical amenities constitute an effective deterrent of inter-regional migration. This helps explaining why some people refuse to move to regions where they could otherwise improve their standard of living (as measured exclusively by pecuniary factors). Therefore, heterogeneity concerning preferences for residential location can be seen as a contributing factor for the reduced inter-regional mobility observed in some spatial contexts.

Agent heterogeneity toward residential location is usually modelled through probabilistic migration according to the discrete choice logit model. This assumption on the distribution of agent preferences implies that there are always agents who are unwilling to migrate. No matter how large the gains from agglomeration due to increasing returns and trade costs, some people will always prefer to live in a relatively poor region. In some geographical contexts, some people are in fact very attached to their location, which may help sustain the claim that full agglomeration in one single region is unlikely. This is even more so when regions have their very own and distinct sets of cultural and historical amenities. However, the importance of these amenities is likely to vary according to the geographical scale. For instance, cultural and historical differences are generally more important at a transnational scale than at the national scale. This makes individuals more reluctant to move to another country than to move to another region within their country.[30]

We built a core-periphery model that allows to arbitrarily specify how the utility from residing in a region varies across agents. Modelling the individual utility penalty of migrating to another location is important because it has implications on the spatial distribution of economic activities. We illustrate this point using a simple framework,

[29] In the FE and PF models the trade costs are measured by the freeness of trade parameter, $\phi$; in the OTT model, by the transport cost parameter $\tau$.

[30] While changes in the logit model account for different heterogeneity scales (Scarpa et al. 2008; Train 2009; Hess and Rose 2012), they do not capture the fact that agent preferences may vary qualitatively.

where the utility penalty is linear or logarithmic. Agents who are less attached to their most preferred region region face a lower utility penalty when they migrate to the other region. This increases the willingness to migrate as a response to regional differences in consumption. Given the pecuniary gains from agglomeration, this provides a relationship between the agents' reaction to non-market factors and income inequalities that is potentially empirically relevant. Specifically, we find that when regional size differences are small, the gains in consumption from relocating to the slightly larger region are not enough to offset the decrement in utility of even the agents who have a just marginally higher preference for the relatively smaller region. However, if initial spatial disparities are very high, then so is the prospective gain in consumption goods of those who consider relocating from the smaller to the larger region. This gain is large enough that it offsets the personal attachment of any agent toward the less populated region. In this case, the initial spatial distribution will determine if there is a tendency towards spatial convergence or divergence. In other words, history matters.

The variety of possible spatial outcomes conveyed by just two different specifications for agent preferences, while overlooking other well-known potential determinants of spatial inequality, highlights the importance of the qualitative distribution of individual tastes.

An increase in economic integration may foster (PF model) or discourage (FE model) agglomeration of industry, possibly depending on the level of integration (OTT model).[31] The direction of the impact of economic integration on the tendency for agglomeration does not depend, however, on the heterogeneity in preferences for location.

Hofbauer and Sandholm (2007) show that for a broad class of games, including potential games, the dynamics converge to a Nash equilibrium. In the context of NEG and for a static formulation, we describe the set of Nash equilibria taking into account the utility of the agents corrected by a utility penalty that accounts for their heterogeneity. Our game-theoretic setup can be seen as that of a potential game. In view of Hofbauer and Sandholm (2007), a dynamic version of our model exhibits convergence to one of the equilibria we characterise.[32]

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## Compliance with ethical standards

**Conflict of interest** None.

[31] It may also be interesting to consider other economic models with a non-monotonic relationship between economic integration and agglomeration, such as the model by Ghiglino and Nocco (2017), which features social interactions in the form of conspicuous consumption, and the modified footloose capital model by Takahashi et al. (2013). Noteworthy, in order to introduce heterogeneity in the latter model, one would have to replace inter-regionally mobile capital with inter-regionally mobile entrepreneurs.

[32] We thank an anonymous referee for bringing to our attention that our model can be framed as a potential game and thus results in the existing literature on potential population games apply.

## Appendix A: Mathematical proofs

***Proof of Lemma 1:*** Differentiating $\Delta U^{PF}(h)$ in (3) twice with respect to $h$ yields:

$$\Delta U^{PF''}(h) = \frac{(2h-1)\alpha(1-\phi)^3}{(\sigma-1)\sigma\,[1-h(1-\phi)]^3\,[h(1-\phi)+\phi]^3}\Phi,$$

where:

$$\begin{aligned}\Phi = &\lambda(\sigma-1)(\phi-1)\left[(h^2-h)(1-\phi)^2+\phi^2+\phi+1\right]\\ &+(h^2-h)(1-\phi)^2\,[\sigma(\phi-1)-2\phi]\\ &+\phi\left\{\sigma\,[\phi(2\phi+3)+3]-2\left(\phi^2+\phi+1\right)\right\}.\end{aligned}$$

It is readily observable that the first term in the product of $\Delta U^{PF''}(h)$ is positive if and only if $h > \frac{1}{2}$. Therefore, $\Delta U^{PF''}(h) < 0$ for $h > \frac{1}{2}$ if and only if $\Phi < 0$. In terms of $\lambda$, this becomes:

$$\lambda > \frac{h\,(1-h)\,(1-\phi)^2\,[\sigma(1-\phi)+2\phi]-\phi\left\{2\left(\phi^2+\phi+1\right)-\sigma\,[\phi(2\phi+3)+3]\right\}}{(\sigma-1)(1-\phi)\left[(h^2-h)(1-\phi)^2+\phi^2+\phi+1\right]}. \tag{11}$$

It is straightforward to show that the RHS of (11) is decreasing in $h$, which means that setting $h = \frac{1}{2}$ provides us the following sufficient condition:

$$\lambda > \frac{7\sigma\phi+\sigma-6\phi}{3(\sigma-1)(1-\phi)}, \tag{12}$$

equivalent to Assumption 1. We thus have $\Phi < 0$, which implies that $\Delta U^{PF''}(h) < 0$ for $h > \frac{1}{2}$. □

***Proof of Lemma 2:*** Differentiating $\Delta U^{FE}(h)$ in (6) with respect to $h$, we get:

$$\begin{aligned}\Delta U^{FE''}(h) = (2h-1)&\left\{\frac{\mu(1-\phi)^3(\phi+1)}{(\sigma-1)\,[1-h(1-\phi)]^2\,[h(1-\phi)+\phi]^2}\right.\\ &\left.+\frac{(\phi-\psi)^3(\phi+\psi)}{[h(\phi-\psi)+\psi]^2\,[h(\psi-\phi)+\phi]^2}\right\}.\end{aligned} \tag{13}$$

The first term inside the curved brackets is positive. The sign of the second term depends on that of $\phi-\psi$, which is:

$$\frac{(1-\phi)\,[\phi(\mu+\sigma)+\mu-\sigma]}{2\sigma} > 0$$

for $\phi \in \left(\frac{\sigma-\mu}{\sigma+\mu}, 1\right)$, which corresponds to Assumption 2. This implies that (13) is positive, concluding the proof. □

***Proof of Proposition 3:*** Since $\Delta V$ is strictly concave for $h \in [\frac{1}{2}, 1]$, Proposition 2 applies. There is a unique stable long-run equilibrium with $h \in [\frac{1}{2}, 1]$: symmetric dispersion if $\Delta V'(\frac{1}{2}) \leq 0$; agglomeration if $\Delta V(1) \geq 0$; asymmetric dispersion if $\Delta V'(\frac{1}{2}) > 0$ and $\Delta V(1) < 0$. See the proof of Proposition 2.

Considering the utility difference in (3) and a convex home-sweet-home effect $\Delta t(x) = \theta f(x)$, with $f'(\frac{1}{2}) > 0$, the overall utility difference is:

$$\Delta V^{PF} = \frac{\alpha}{\sigma - 1}\left(\left\{\frac{(2h-1)(\sigma-1)(1-\phi)\left[(\lambda+2)\phi-\lambda\right]}{2\sigma\left[1-h(1-\phi)\right]\left[(1-h)\phi+h\right]}\right\} + \ln\left[\frac{h(1-\phi)+\phi}{1-h(1-\phi)}\right]\right) - \theta f(h).$$

Agglomeration $h^* = 1$ is stable if $\Delta V(1) \geq 0$, i.e., if:

$$\theta \leq \theta_s \equiv \frac{\alpha(1-\phi)\left[2\phi - \lambda(1-\phi)\right]}{2\sigma\phi f(1)} - \frac{\alpha \ln \phi}{(\sigma-1) f(1)}.$$

Symmetric dispersion $h^* = \frac{1}{2}$ is stable if $\Delta V'(\frac{1}{2}) \leq 0$, that is, if:

$$\theta \geq \theta_b \equiv \frac{4\alpha(1-\phi)\left[\sigma(1+3\phi) - \lambda(\sigma-1)(1-\phi) - 2\phi\right]}{3(\sigma-1)\sigma(1+\phi)^2 f'(\frac{1}{2})}.$$

□

***Proof of Proposition 4:*** Since $\Delta V$ is strictly convex for $h \in [\frac{1}{2}, 1]$, Proposition 1 applies. There is one or two stable long-run equilibria with $h \in [\frac{1}{2}, 1]$: only agglomeration if $\Delta V'(\frac{1}{2}) \geq 0$, which implies $\Delta V(1) > 0$; only symmetric dispersion if $\Delta V'(\frac{1}{2}) < 0$ and $\Delta V(1) \leq 0$; both agglomeration and symmetric dispersion if $\Delta V'(\frac{1}{2}) < 0$ and $\Delta V(1) > 0$. See the proof of Proposition 1.

Considering the utility difference in (3) and a concave home-sweet-home effect $\Delta t(x) = \theta f(x)$, with $f'(\frac{1}{2}) > 0$, the overall utility difference is:

$$\Delta V^{FE} = \ln\left[\frac{h\phi + (1-h)\psi}{(1-h)\phi + h\psi}\right] + \frac{\mu}{\sigma-1}\ln\left[\frac{(1-h)\phi + h}{h\phi + (1-h)}\right] - \theta f(h).$$

Agglomeration $h^* = 1$ is stable if $\Delta V(1) > 0$, that is, if:

$$\theta < \theta_s \equiv \frac{1}{f(1)}\ln\left[\frac{2\sigma\phi}{\phi^2(\mu+\sigma) - \mu + \sigma}\right] - \frac{\mu \ln \phi}{(\sigma-1) f(1)}.$$

Symmetric dispersion $h^* = \frac{1}{2}$ is stable if $\Delta V'(\frac{1}{2}) < 0$, that is, if:

$$\theta > \theta_b \equiv \frac{2(1-\phi)\left[\mu^2(1-\phi) - \mu(2\sigma-1)(\phi+1) + (\sigma-1)\sigma(1-\phi)\right]}{(\sigma-1)(\phi+1)\left[\phi(\mu+\sigma) - \mu + \sigma\right] f'(\frac{1}{2})}.$$

□

***Proof of Proposition 5:*** When $\Delta t$ is strictly convex, $\Delta V$ is strictly concave. Hence, by Proposition 2, there is a unique stable equilibrium: agglomeration, symmetric dispersion, or asymmetric dispersion.

From (9), the overall utility difference is:

$$\Delta V^{OTT} = C\tau\left(\tau^* - \tau\right)\left(h - \frac{1}{2}\right) - \theta f(h).$$

Agglomeration $h^* = 1$ is the unique stable equilibrium if $\Delta V(1) \geq 0$, that is, if:

$$\theta \leq \theta_s \equiv \frac{C\tau\left(\tau^* - \tau\right)}{2f(1)}.$$

Symmetric dispersion is the unique stable equilibrium if $\Delta V'(\frac{1}{2}) \leq 0$, that is, if:

$$\theta \geq \theta_b \equiv \frac{C\tau\left(\tau^* - \tau\right)}{f'(\frac{1}{2})}.$$

Strict convexity of $\Delta t$ implies that $f(1) > f'(\frac{1}{2})\frac{1}{2}$. Therefore, $\theta_s < \theta_b$. □

***Proof of Proposition 6:*** When $\Delta t$ is strictly concave, $\Delta V$ is strictly convex. Hence, by Proposition 1, one or two equilibria may be stable: agglomeration, symmetric dispersion, or both.

The expressions for $\theta_s$ and $\theta_b$ are those obtained in the proof of Proposition 5. Agglomeration $h^* = 1$ is a stable equilibrium if $\theta < \theta_s$. Symmetric dispersion is a stable equilibrium if $\theta > \theta_b$.

Strict concavity of $\Delta t$ implies that $f(1) < f'(\frac{1}{2})\frac{1}{2}$. Therefore, $\theta_b < \theta_s$. □

***Proof of Proposition 7:*** Consider the utility difference in (9) and a linear home-sweet-home effect. Then the overall utility difference is given by:

$$\Delta V^{OTT} = \left[C\tau\left(\tau^* - \tau\right) - \theta\right]\left(h - \frac{1}{2}\right).$$

Agglomeration $h^* = 1$ is stable if:

$$\theta < \theta_{bs} \equiv C\tau\left(\tau^* - \tau\right),$$

while symmetric dispersion $h^* = \frac{1}{2}$ is stable if $\theta > \theta_{bs}$.

If $\theta = \theta_{bs}$, every state is an equilibrium and therefore none is stable. □

***Proof of Proposition 8:*** For the PF model under Assumption 1 (by Lemma 1) and for the OTT model (by Lemma 3), $\Delta U$ is concave in $h \in [\frac{1}{2}, 1]$. Hence, since $\Delta t$, is strictly convex in $h \in [\frac{1}{2}, 1]$, $\Delta V$ is strictly concave in $h \in [\frac{1}{2}, 1]$. By Proposition 2, there is a unique stable equilibrium. If $\Delta V'(\frac{1}{2}) \leq 0$, then $\Delta V(h) < 0$ for all $h \in (\frac{1}{2}, 1]$.

Symmetric dispersion is the unique long-run equilibrium and it is stable. If $\Delta V'(\frac{1}{2}) > 0$, since $\Delta V(1) < 0$, asymmetric dispersion is the unique stable equilibrium.

We now compute the threshold value of $\theta$ below which $\Delta V'(\frac{1}{2}) > 0$ for the PF and the OTT models, with $\Delta t(h) = \theta \ln\left(\frac{h}{1-h}\right)$.

In the PF model, the utility difference is given by (4), and the overall utility difference is given by:

$$\Delta V(h) = \frac{\alpha}{\sigma - 1}\left\{\frac{(2h-1)(1-\phi)(\sigma-1)\left[(\lambda+2)\phi - \lambda\right]}{2\sigma\left[1-h(1-\phi)\right]\left[(1-h)\phi + h\right]} + \ln\left[\frac{h(1-\phi)+\phi}{1-h(1-\phi)}\right]\right\} - \theta \ln\left(\frac{h}{1-h}\right).$$

Symmetric dispersion $h^* = \frac{1}{2}$ is stable if $\Delta V'(\frac{1}{2}) \leq 0$, i.e., if:

$$\theta \geq \theta_b^{PF} \equiv \frac{\alpha(1-\phi)\left[\lambda(\sigma-1)(\phi-1) + 3\sigma\phi + \sigma - 2\phi\right]}{(\sigma-1)\sigma(1+\phi)^2}.$$

In the OTT model, the utility difference is given by (9), and thus $\Delta V'(\frac{1}{2}) \leq 0$ if and only if:

$$\theta \geq \theta_b^{OTT} \equiv \frac{1}{4} C\tau\left(\tau^* - \tau\right).$$

□

## Appendix B: FE model with logit home-sweet-home effect

We can use some of the calculations in the proof of Proposition 4 by noting that

$$\Delta V_{logit}^{FE} = \Delta U^{FE} - \theta \ln\left(\frac{h}{1-h}\right) \text{ whereas } \Delta V_{linear}^{FE} = \Delta U^{FE} - \theta(2h-1).$$

*Existence and multiplicity of equilibria*

Notice that under the logit home-sweet-home effect, we have:

$$\frac{d\Delta V^{FE}}{dh}(h) = \frac{ah^4 + bh^3 + ch^2 + dh + e}{D},$$

where the numerator is a 4th-degree polynomial whose coefficients depend on $\mu$, $\phi$, and $\sigma$; and

$$D = h(1-h)(\sigma-1)\left[1-h(1-\phi)\right]\left[h(1-\phi)+\phi\right] \times \left\{\sigma\left[1+\phi^2 - h(1-\phi)^2\right] - \mu(1-h)(1-\phi^2)\right\}$$

$$\times \; \{h(1-\phi)\,[\sigma(1-\phi)-\mu(1+\phi)]+2\sigma\phi\}\,,$$

which is strictly positive for $h \in (0, 1)$.

Hence, the sign of the derivative for $h \in (0, 1)$ is the sign of the numerator – which has at most four real zeros. This means that $\Delta V^{FE}$ has at most four zeros besides $h = \frac{1}{2}$. Due to symmetry, there are at most two asymmetric equilibria for $h \in (\frac{1}{2}, 1)$. In Fig. 5, we plot $\Delta V$ for parameter values such that there are five equilibria (three of which are stable).

*Bifurcation at symmetric dispersion*

Symmetric dispersion, $h^* = \frac{1}{2}$, is stable if:

$$\theta > \theta_b \equiv \frac{(1-\phi)\left[\mu^2(\phi-1)+\mu(2\sigma-1)(\phi+1)+(\sigma-1)\sigma(\phi-1)\right]}{(\sigma-1)(\phi+1)\,[\phi(\sigma+\mu)+\sigma-\mu]}, \tag{14}$$

where $\theta_b$ is the break-point, or the degree of consumer heterogeneity above which symmetric dispersion is stable. To ensure that the break point is positive, we assume that the following "no black-hole" condition is satisfied:

$$\phi > \frac{(\sigma-\mu)(\sigma-\mu-1)}{(\sigma+\mu)(\sigma+\mu-1)}. \tag{15}$$

This, in turn, requires that the no black-hole condition from Fujita et al. (1999), $\sigma > 1+\mu$, holds. Otherwise, the condition $\theta > \theta_b$ is trivially satisfied and symmetric dispersion is always stable.

At the break point, $\theta = \theta_b$, we have

$$\frac{\partial^2 \Delta V^{FE}}{\partial h^2}\left(\tfrac{1}{2};\theta_b\right)=0,\; \frac{\partial \Delta V^{FE}}{\partial \theta}\left(\tfrac{1}{2};\theta_b\right)=0,\; \frac{\partial^2 V^{FE}}{\partial h \partial \theta}\left(\tfrac{1}{2};\theta_b\right)=-4<0,$$

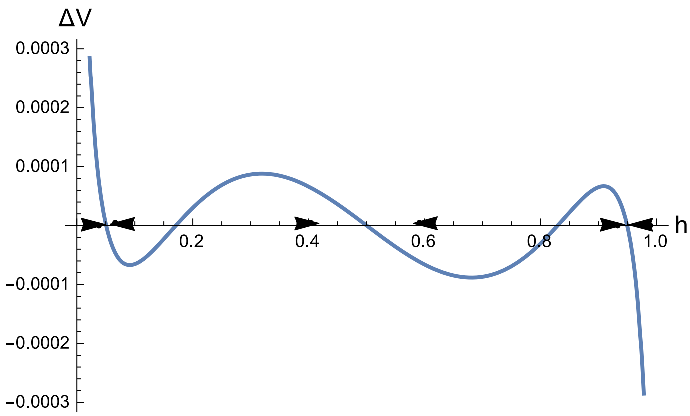


**Fig. 5** Existence of five interior equilibria, three of which are stable, in the FE model with logit home-sweet-home effect

and:

$$\frac{\partial^3 \Delta V^{FE}}{\partial h^3}\left(\tfrac{1}{2};\theta_b\right) = -\frac{128(1-\phi)\phi\Psi}{(\sigma-1)(\phi+1)^3\left[\phi(\sigma+\mu)-\mu+\sigma)^3\right]},$$

where:

$$\begin{aligned}\Psi(\phi) = &\phi^3(\sigma+\mu)^2\left[\mu^2+\mu\sigma+2(\sigma-1)\sigma\right]\\ &+\phi^2(\sigma-\mu)(\sigma+\mu)\left[3\mu^2+3\mu\sigma-2(\sigma-1)\sigma\right]\\ &+\phi(\mu-\sigma)(\sigma+\mu)\left[3\mu^2-3\mu\sigma-2(\sigma-1)\sigma\right]\\ &-(\mu-\sigma)^2\left[\mu^2-\mu\sigma+2(\sigma-1)\sigma\right].\end{aligned}$$

The sign of the third derivative of $\Delta V^{FE}$ is opposite to the sign of $\Psi$. Notice that $\Psi(0) < 0$ and $\Psi(1) > 0$ and $\Psi'(\phi) > 0$. This means that $\Psi$ has exactly one zero $\phi_c \equiv \phi \in (0, 1)$ and that $\Psi(\phi) > 0$ if $\phi > \phi_c$. Therefore, we have $\frac{\partial^3 \Delta V^{FE}}{\partial h^3}\left(\frac{1}{2};\theta_b\right) > 0$ if $\phi < \phi_c$. According to Guckenheimer and Holmes (2002, p. 150), the FE model with logit home-sweet-home effect undergoes a pitchfork bifurcation at symmetric dispersion if $\phi \neq \phi_c$. If $\phi < \phi_c$, the bifurcating branch is unstable and exists for $\theta > \theta_b$. The asymmetric equilibria arising through this bifurcation are unstable. If $\phi > \phi_c$ then a branch of stable asymmetric equilibria arises for $\theta < \theta_b$ – we do not pursue this case any further. When $\phi < \phi_c$ the primary branch may undergo another (secondary) bifurcation which we study next.

*Bifurcation for asymmetric equilibria*

Let $\phi < \phi_c$ and consider the half-branch of unstable asymmetric equilibria that exists for $h^* \in (\frac{1}{2}, 1)$. Then $h^*$ changes stability at some value $\theta_f > 0$ such that $\frac{d\Delta V^{FE}}{dh}\left(h^*;\theta_f\right) = 0$. This threshold value $\theta_f$ is given by:

$$\begin{aligned}\theta_f = &(1-h^*)h^*\\ &\times\left(\frac{(1-\phi)(\phi+1)\left[\phi^2(\mu+\sigma)^2-(\sigma-\mu)^2\right]}{\left[(1-h^*)\phi^2(\mu+\sigma)+(h^*-1)(\mu-\sigma)-2h^*\sigma\phi\right]\{h^*(\phi-1)\left[\phi(\mu+\sigma)+\mu-\sigma\right]+2\sigma\phi\}}\right.\\ &\left.+\frac{\mu-\mu\phi^2}{(\sigma-1)\left[h^*(\phi-1)+1\right]\left[h^*(1-\phi)+\phi\right]}\right) > 0.\end{aligned}$$

It can be shown that the sign of $\frac{\partial^2 \Delta V}{\partial h^2}^{FE}(h)$ depends on the sign of its numerator, which is a fifth degree polynomial, $P(h)$, and is zero at $h = \frac{1}{2}$. This means that the derivative has at most two positive roots for $h \in \left(\frac{1}{2}, 1\right)$. Cumbersome yet standard calculations permit to show that, for $(\phi, \sigma, \mu) = (0.5, 4, 0.3)$, we have $P(h) > 0,\ \forall h \in \left(\frac{1}{2}, 1\right)$.

Therefore, there exists an open subset of parameter values $(\phi, \sigma, \mu)$ such that, for any equilibrium $h^* \in \left(\frac{1}{2}, 1\right)$, we have:

$$\frac{\partial^2 \Delta V^{FE}}{\partial h^2}\left(h^*;\theta_f\right) = 0.$$

Finally, notice that:

$$\frac{\partial \Delta V^{FE}}{\partial \theta}\left(h^*;\theta_f\right) = \ln\left(\frac{1-h}{h}\right),$$

which is negative for any $h^* \in \left(\frac{1}{2}, 1\right)$. Thus, according to Guckenheimer and Holmes (2002, p. 148), there exists a set of values in $(\phi, \sigma, \mu)$ space such that an asymmetric equilibrium $h^* \in \left(\frac{1}{2}, 1\right)$ undergoes a saddle-node bifurcation at the limit point $\theta_f$. Since the primary branch from symmetric dispersion is unstable, we can conclude that a curve of asymmetric equilibria exists tangent to the line $\theta = \theta_f$, lying to its left, such that the more asymmetric equilibria (higher $h$) are stable.

## Appendix C: Comparative statics

***Proof of Proposition 9:*** Let us show each of the three points in the definition of favouring agglomeration:

- $\frac{\partial}{\partial h}\Delta V(\frac{1}{2}; z') = \lim_{\epsilon\to 0}\frac{\Delta V(\frac{1}{2}+\epsilon; z')}{\epsilon} \geq \lim_{\epsilon\to 0}\frac{\Delta V(\frac{1}{2}+\epsilon; z)}{\epsilon} = \frac{\partial}{\partial h}\Delta V(\frac{1}{2}; z)$.
- $\Delta V(1; z') > \Delta V(1; z) > 0$.
- Let $\overline{h} \equiv \max E(z)$. Note that $\Delta V(\overline{h}; z') > \Delta V(\overline{h}; z) = 0$. If $\Delta V(1; z') > 0$, $\max E(z') = 1$. If $\Delta V(1; z') < 0$, existence of a stable equilibrium with $h^* \in (\overline{h}, 1)$ follows from the intermediate value theorem and from non-existence of irregular equilibria.
  Let $\underline{h} \equiv \min E(z)$. Note that $\Delta V(h; z') > \Delta V(h; z) \geq 0$, for all $h \in (\frac{1}{2}, \underline{h}]$, thus there are no equilibria with $h^* \in (\frac{1}{2}, \underline{h}]$. At least one stable equilibrium exists because we assume there are no irregular equilibria. Therefore, $\min E(z') > \underline{h}$.

□

***Proof of Proposition 10:*** The proof is straightforward consequence of Proposition 9, together with:

- Lemma 4 below for the PF model, showing that $\Delta U^{PF}$ increases in $\phi$.
- Lemma 5 below for the FE model, showing that $\Delta U^{FE}$ decreases in $\phi$.
- The observation that, for all $h \in (\frac{1}{2}, 1]$, $\Delta U^{OTT}(h)$ is linearly increasing in $\tau$ $(\tau^* - \tau)$.

□

**Lemma 4** *Under Assumption 1 and if $\sigma \geq \frac{3}{2}$, we have $\frac{\partial \Delta U^{PF}}{\partial \phi} > 0$ for all $h \in (\frac{1}{2}, 1]$.*

***Proof*** Recall (3):

$$\Delta U^{PF}(h) = \frac{\alpha}{\sigma-1}\left(\left\{\frac{(2h-1)(\sigma-1)(1-\phi)\left[(\lambda+2)\phi-\lambda\right]}{2\sigma\left[1-h(1-\phi)\right]\left[(1-h)\phi+h\right]}\right\} + \ln\left[\frac{h(1-\phi)+\phi}{1-h(1-\phi)}\right]\right).$$

Differentiating $\Delta U^{PF}$ with respect to $\phi$, we get:

$$\frac{\partial \Delta U^{PF}}{\partial \phi} = \frac{\alpha(2h-1)\left[2h(h-1)(1-\phi)^2-(\lambda+2)(\sigma-1)\phi^2+\lambda(\sigma-1)-2\sigma\phi\right]}{2\sigma(\sigma-1)\left[1-h(1-\phi)\right]^2\left[h(1-\phi)h+\phi\right]^2},$$

which is strictly positive for $h \in (\frac{1}{2}, 1]$ if:

$$2h^2(1-\phi)^2 - 2h(1-\phi)^2 - (\lambda+2)(\sigma-1)\phi^2 + \lambda(\sigma-1) - 2\sigma\phi > 0. \quad (16)$$

The LHS of (16) is increasing in $\lambda$. Replacing the lower bound for $\lambda$ imposed by Assumption 1:

$$\frac{1}{3}\left[-6h(1-h)(1-\phi)^2 + \sigma(1+\phi)^2 - 6\phi\right],$$

which is positive for

$$\sigma > 6\frac{h(1-h)(1-\phi)^2 + \phi}{(1+\phi)^2}. \quad (17)$$

The RHS is strictly increasing in $\phi$ and equal to $\frac{3}{2}$ at $\phi = 1$.

**Lemma 5** *If $\phi > \sqrt{\frac{\sigma-\mu}{\sigma+\mu}}$, we have $\frac{\partial \Delta U^{FE}}{\partial \phi} < 0$, for all $h \in (\frac{1}{2}, 1]$.*

***Proof*** Differentiating $\Delta U^{FE}$ with respect to $\phi$, we get $\frac{\partial \Delta U^{FE}}{\partial \phi} = (2h-1)(a_1 + a_2)$, where:

$$a_1 = \frac{\mu}{(\sigma-1)[h(1-\phi)-1][h(1-\phi)+\phi]}$$

$$a_2 = \frac{2\sigma\left[\phi^2(\mu+\sigma) - \sigma + \mu\right]}{\left[-(1-h)(\sigma-\mu) - (1-h)\phi^2(\sigma+\mu) - 2h\sigma\phi\right]\{2\sigma\phi - h(1-\phi)[\phi(\mu+\sigma)+\mu-\sigma]\}}.$$

Since $(2h-1)$ is positive and $a_1$ is negative, it is sufficient to show that $a_2 \le 0$.

The first factor in the denominator of $a_2$ is negative. Looking at the second factor in the denominator of $a_2$:

$$2\sigma\phi - h(1-\phi)[\phi(\mu+\sigma)+\mu-\sigma] \ge 0 \Leftrightarrow \sigma \ge \frac{h\mu(1-\phi^2)}{2\phi + h(1-\phi)^2}.$$

Since $h(1-\phi^2) < 2\phi + h(1-\phi)^2$, this factor is always positive.

Finally, we look at the numerator and find that it is positive

$$\phi^2(\mu+\sigma) + \mu - \sigma > 0 \Leftrightarrow \phi^2 > \frac{\sigma-\mu}{\sigma+\mu}.$$

Hence, $a_2$ is negative.

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