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Product diversity, taste heterogeneity, and geographic distribution of economic activities: market vs. non-market interactions ☆

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Abstract

There are two independent strands of literature on the geographic distribution of economic activities. One is the new economic geography that emphasizes product diversity, and the other is probabilistic migration that stresses taste heterogeneity in residential location. This article incorporates these two characteristics into a single framework, and analyzes how they affect the number and stability of equilibrium geographic structures. It shows that the home market effect due to market-mediated product diversity creates an agglomeration force, whereas idiosyncratic taste differences due to non-market interactions serve as a probabilistic immobile factor and induce a dispersion force. The tension between these opposite forces, together with the decline in transportation costs, yields different patterns of agglomeration and the associated changes in interregional wage differentials.
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1. Introduction

The interregional differences in economic activities arise from myriad market and non-market interactions. This view dates back at least to Hicks [14]. In "The Theory of Wages" Hicks proposed that the persistence of regional differences in wages is due to "differences in the cost of living" and "indirect attractions of living in certain localities."[1] Thirty years later, Sjaastad [35] divided the costs and returns of migration into "money" and "non-money" factors. The money costs are literally pecuniary ones, whereas the non-money costs are subdivided in two: "opportunity costs" related to the distance of migration and the level of unemployment in the destination, and "psychic costs" that prevent people from leaving familiar surroundings, family, and friends.[2] On the other hand, he defined the money returns of migration as an increment to a migrant's real earnings stream, whereas he related the non-money returns of migration to factors such as climate, smog, and congestion.[3] Furthermore, Jane Jacobs [15,16] emphasized both social and economic factors as determinants of the rise and fall of cities. In part one of [15] she focused on how neighborhood environments, such as sidewalk safety, useful and enjoyable contacts, and parks (i.e., non-market interactions) affect the residential configuration, and in part two, on the condition for urban diversity (i.e., market interactions).[4] Jacobs' subsequent work [16] can be considered as further elaboration of the latter perspective. In those days, the dichotomy between market and non-market interactions was dominant, and these two types of interactions were treated in a unified framework.

Since then, the effects of each type of interactions on the geographic distribution of economic activities have been independently explored in each strand of literature with solid theoretical frameworks. One is the so-called new economic geography (such as Krugman [18] and Fujita et al. [5]) that utilized the Dixit–Stiglitz model of monopolistic competition (Dixit and Stiglitz [4]). It emphasized the importance of product diversity, transportation costs, and immobile factors such as peasants and land that are jointly associated with pecuniary externalities for creating agglomeration and dispersion forces. It focused solely on interactions within markets where the prices transmit all information on the economy. In addition, it assumed that both peasants and workers have identical preferences for

[1] The "quality of life" literature, such as Rosen [32] and Roback [31], suggests that the interregional wage differentials are affected not only by land prices but also by amenities.

[2] Makower et al. [21–23] found that a longer distance of migration and a relatively higher unemployment rate in the destination reduce a migration rate. Mincer [26] made a distinction between personal and family migration decisions, and confirmed that family ties and a labor market attachment of women tend to deter migration.

[3] Glaeser et al. [10] used regional dummies and stated that "weather and other regional characteristics have played an important role in migration and hence the growth of cities" (p. 129). Moreover, Glaeser et al. [9] found that population growth of cities has a positive relationship with amenities such as temperate climate, dryness, and proximity to the coast.

[4] Glaeser et al. [8] tested the relationship between urban diversity and employment growth in cities and concluded that urban diversity and local competition encourage employment growth. Note, however, that their definition of "diversity" includes non-market factors such as knowledge spillovers among different industries.

commodities, and that all manufacturing firms have an identical technology, so that the effect of heterogeneity on the geographic distribution of economic activities is neglected.[5]

The other strand of literature deals in probabilistic migration (see Miyao [27], and Miyao and Shapiro [28]). It attempted to generalize the pioneering works of non-market interactions by Schelling [33,34]. It related transition probabilities between regions to the choice probabilities derived in the discrete choice theory (McFadden [25], and Anderson et al. [3]). It stressed the importance of local technological externalities and taste heterogeneity in residential location that jointly create agglomeration and dispersion forces. It relied solely on non-market interactions where the price mechanism is absent.[6]

Based on these independent analytical developments, this article attempts to reincorporate both market and non-market interactions into a single framework, as had been traditionally done by Hicks, Jacobs, and Sjaastad. Specifically, we examine the relative role of product diversity as an agglomeration force, and taste heterogeneity as a dispersion force in the geographic distribution of economic activities. We consider a two-region and a single primary factor (mobile worker) economy where differentiated goods are produced with an increasing returns technology under monopolistic competition. All workers not only have identical preferences over the commodities provided by markets, but also have idiosyncratic tastes in residential locations that reflect non-market interactions. Given these settings, the basic mechanism of the model is described as follows: a larger population in one region creates a greater variety of products, which tends to reduce the price index in that region in the presence of transportation costs. In addition, the nominal wage rate is higher in a more populous region due to the home market effect.[7] Thus, the utility from differentiated goods, or the utility from market interactions, tends to be higher in a more populous region, which attracts even more people to that region. However, taste heterogeneity arising from non-market interactions serves as a "probabilistic immobile factor" and thus weakens the self-reinforcing agglomeration force. The equilibrium geographic distribution of economic activities is determined by the relative strength of the two opposite forces, which are, in turn, affected by the level of transportation costs.

The advantages of our modeling strategy are two-fold. First, the present model can yield a dispersion force without conventional deterministic immobile factors such as peasants and land, since taste heterogeneity serves as a "probabilistic immobile factor." This can rule out the less plausible prediction in much of the existing new economic geography literature: the nominal wage rate in a *larger* region is, in general, *lower or equal to* that in a *smaller* region.[8] According to Krugman [18, p. 491], this unsatisfactory result is due to gains from

[5] There is one notable exception. Mori and Turrini [29] investigated the role of *skill* heterogeneity in the geographic distribution of economic activities. Instead, we focus on *taste* heterogeneity that has been stressed in the probabilistic migration literature, as will be shown.

[6] Although our attention is limited mainly to the geographic distribution of economic activities and the associated interregional wage differentials, there is a resurgence of interest on broader classes of non-market and social interactions. Glaeser [7], Glaeser and Scheinkman [11,12], and Manski [24] made comprehensive surveys including empirical analysis.

[7] We follow the usage of the term "home market effect" by Krugman [18], that is, "other things being equal, the wage rate will tend to be higher in the larger market" (p. 491).

[8] One can easily check by numerical methods that the nominal wage rate is *lower* in a *larger* region under the parameter values for Fig. 1 by Krugman [18].

lack of competition for the local peasant market ("extent of competition") overwhelming gains from proximity to the larger market ("home market effect"). Since we abstract from conventional immobile factors, the former effect vanishes, so that we can obtain a more plausible result that the nominal wage rate is always *higher* in a *larger* region.

Secondly, as transportation costs decline, different patterns of agglomeration can emerge, which are typically classified as:

(a) dispersion for all transportation costs in the case of large taste heterogeneity;
(b) from dispersion to agglomeration and to redispersion in the case of intermediate taste heterogeneity; and
(c) from agglomeration to dispersion in the case of small taste heterogeneity.

These patterns of agglomeration are associated with the changes in the interregional wage differentials. In particular, in case (b) we can obtain a bell-shaped (inverted U-shaped) relationship between economic development and income inequality, as was indicated by Kuznets [20] and Alonso [1].

The rest of the article is organized as follows. Section 2 describes a two-region model. It shows how product diversity generates an agglomeration force through the home market effect. It also shows how taste heterogeneity serves as a probabilistic immobile factor and induces a dispersion force. Section 3 characterizes the number and stability of equilibrium geographic structures by three parameters: the degree of taste for product diversity, the degree of taste heterogeneity, and transportation costs. Section 4 compares the equilibrium outcomes with the social optimum properly defined. Section 5 revisits the classical literature on the determinants of the interregional wage differentials, which are, in turn, related to the main results of this article. Section 6 concludes.

2. A two-region model

2.1. Product diversity as an agglomeration force

The economy is endowed with one unit of mobile workers who are distributed as

$$\lambda_1 + \lambda_2 = 1,$$

where λ_r is the number of workers in region r. These workers have identical preferences over differentiated goods. Their preferences are described by a CES utility function, which is widely used in the new economic geography literature:[9]

[9] Tabuchi and Thisse [38] have introduced taste heterogeneity into the quadratic utility model by Ottaviano et al. [30]. Since, unlike the present article, it does not eliminate the conventional immobile factors and also includes the exogenous interregional amenity differentials, it can produce richer implications for the real world. In contrast, this article, by using the simplest model in the determination of the geographic distribution of economic activities, aims to clarify the fundamental roles of three parameters: product diversity, taste heterogeneity, and transportation costs. Both models should be viewed as complementary.

$$U_r = \left[\int_0^{N_1} c_{r1}(i)^{\frac{\sigma-1}{\sigma}}\,\mathrm{d}i + \int_0^{N_2} c_{r2}(i)^{\frac{\sigma-1}{\sigma}}\,\mathrm{d}i\right]^{\frac{\sigma}{\sigma-1}},$$

where N_s is the number of varieties produced in region s, $c_{rs}(i)$ is region r's consumption of variety i produced in region s, and $\sigma > 1$ is the elasticity of substitution between any pair of differentiated goods. If we assume symmetry across these products and across the regions, then the utility function is reduced to $N^{1/(\sigma-1)}(Nc)$, where $N = N_1 + N_2$ is the total number of firms. This implies that with the total consumption Nc held constant, the utility level is higher if one can consume more varieties. This is due to the term $N^{1/(\sigma-1)}$ and thus we define $1/(\sigma-1)$ as a parameter of taste for diversity, which represents the degree of the gains from diversification.

Next, we introduce the structure of transportation costs between regions. Let $q_{rs}(i)$ denote the c.i.f. price in region r of variety i produced in region s. In addition, let $q_s(i)$ denote the price in region s of variety i produced in region s. Transportation costs T_{rs} have an iceberg form. If differentiated goods produced in region s are shipped into region r, then $q_{rs}(i) = q_s(i)T_{rs}$, where $T_{rs} = T > 1$ for $r \neq s$ and $T_{rs} = 1$ for $r = s$. Given the structure of transportation costs, utility maximization yields the demand function

$$c_{rs}(i) = \left[q_s(i)T_{rs}\right]^{-\sigma} Q_r^{\sigma-1} w_r,$$

where w_r is the wage rate and

$$Q_r = \left[\int_0^{N_1} \left[q_1(i)T_{r1}\right]^{1-\sigma}\,\mathrm{d}i + \int_0^{N_2} \left[q_2(i)T_{r2}\right]^{1-\sigma}\,\mathrm{d}i\right]^{1/(1-\sigma)}$$

is the price index of differentiated goods in region r.

Each of differentiated goods is produced by an increasing returns technology under monopolistic competition. To produce x_r requires labor input $l_r = f + vx_r$, where f and v are the fixed and marginal labor inputs, respectively. Given this technology and the demand function, profit maximization of each firm yields the familiar markup pricing rule $q_r(i) = (\sigma/(\sigma-1))vw_r$. Free entry assures that no firm earns strictly positive profit. The zero-profit condition implies the equilibrium output level $x_r^* = f(\sigma-1)/v$, and the labor input of each firm $l_r^* = f\sigma$. The number of firms in region r is $N_r = \lambda_r/f\sigma$. Therefore, the total number of firms is $N = N_1 + N_2 = 1/f\sigma$. To simplify notation, we make some normalizations as done by Fujita et al. [5, p. 54]. We set $v = (\sigma-1)/\sigma$, so that the local price of each variety produced in one region is equal to the nominal wage rate in that region. We also assume that $f\sigma = 1$, which sets the number of firms equal to the number of workers in each region.

Given the taste for diversity and the production technology, we can analyze the structure of interregional trade. Following Krugman [17], the balance of payments in region 1, measured in wage units of region 2, is given by

$$\begin{aligned} &B(\lambda, \omega; T, \sigma) \\ &\quad = \lambda(1-\lambda)\left[\frac{\omega^{1-\sigma}T^{1-\sigma}}{\lambda\omega^{1-\sigma}T^{1-\sigma} + (1-\lambda)} - \frac{\omega^{\sigma}T^{1-\sigma}}{\lambda + (1-\lambda)\omega^{\sigma-1}T^{1-\sigma}}\right], \end{aligned} \qquad (1)$$

where we set $\lambda = \lambda_1$ and $\omega = w_1/w_2$. We consider the case where the balance of payments is in equilibrium, that is, $B(\lambda, \omega; T, \sigma) = 0$. This, in turn, is equivalent to the condition for market clearing of differentiated goods. From (1), we know that the candidates of the equilibrium geographic structure are given by $\lambda = 0$, $\lambda = 1$, and

$$\lambda(\omega) = \frac{1}{\frac{\omega T^{1-\sigma} - \omega^{1-\sigma}}{T^{1-\sigma} - \omega^{\sigma}} + 1}. \tag{2}$$

As we shall see later, the extreme structures ($\lambda = 0, 1$) violate other equilibrium conditions in the presence of taste heterogeneity. Therefore, we limit our attention to the interior solutions that satisfy (2) in the subsequent arguments.

The rest of this subsection is devoted to showing how the geographic distribution of economic activities affects interregional differences in the nominal wage rate and the utility from differentiated goods. However, such analyses entail some difficulties since ω is not a function of λ (although λ is a function of ω, as shown in (2)). To achieve our goal, we first examine the condition where the number of mobile workers in region 1, λ, is strictly increasing in the relative nominal wage ω, which leads to the existence of an inverse function.

Lemma 1. $\lambda(\omega)$ *is strictly increasing if and only if* $\omega \in (\underline{\omega}, \overline{\omega})$, *where*

$$\underline{\omega} = \left[\frac{(2\sigma-1)T^{\sigma-1} - T^{1-\sigma}}{2(\sigma-1)} - \sqrt{\left[\frac{(2\sigma-1)T^{\sigma-1} - T^{1-\sigma}}{2(\sigma-1)} \right]^2 - 1} \right]^{1/\sigma},$$

$$\overline{\omega} = \left[\frac{(2\sigma-1)T^{\sigma-1} - T^{1-\sigma}}{2(\sigma-1)} + \sqrt{\left[\frac{(2\sigma-1)T^{\sigma-1} - T^{1-\sigma}}{2(\sigma-1)} \right]^2 - 1} \right]^{1/\sigma}.$$

Proof. By differentiating $\lambda(w)$ in (2) and setting $\lambda'(\omega) > 0$, we know that $\lambda(\omega)$ is strictly increasing if and only if

$$\omega^{\sigma} + \omega^{-\sigma} < \frac{(2\sigma-1)T^{\sigma-1} - T^{1-\sigma}}{\sigma-1} = 2T^{\sigma-1} + \frac{T^{\sigma-1} - T^{1-\sigma}}{\sigma-1}. \tag{3}$$

The inequality can be regarded as a quadratic form with respect to $\Omega \equiv \omega^{\sigma}$, that is, $\Omega^2 - 2C\Omega + 1 < 0$, where $C > 1$ is half of the right-hand side (RHS) in (3). Solving the quadratic inequality, we obtain

$$\underline{\Omega} \equiv C - \sqrt{C^2 - 1} < \Omega < \overline{\Omega} \equiv C + \sqrt{C^2 - 1}.$$

Noting the definitions of Ω and C, the claim is obtained. □

Thus, we can find the lower and upper bounds of ω, between which $\lambda(\omega)$ is strictly increasing. On the other hand, by definition $\lambda(\omega)$ must lie in $[0, 1]$. Therefore, we must examine whether the definition of $\lambda(\omega)$ is consistent with the lower and upper bounds of ω. The result is summarized as follows.

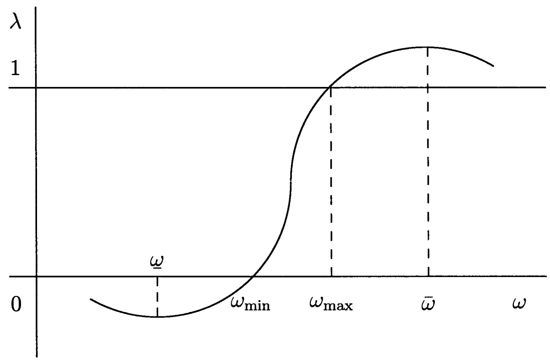

Fig. 1. Home market effect.

Lemma 2. *Suppose that $\omega_{\min}$ and $\omega_{\max}$ are implicitly defined as $\lambda(\omega_{\min}) \equiv 0$ and $\lambda(\omega_{\max}) \equiv 1$, respectively. Then, the relationships $\underline{\omega} < \omega_{\min} = T^{\frac{1-\sigma}{\sigma}}$ and $\overline{\omega} > \omega_{\max} = T^{\frac{\sigma-1}{\sigma}}$ hold.*

Proof. By setting $\lambda = 0$ (respectively $\lambda = 1$) in square brackets in Eq. (1) and by setting the balance of payments equal to zero, $\omega_{\min} = T^{\frac{1-\sigma}{\sigma}}$ (respectively $\omega_{\max} = T^{\frac{\sigma-1}{\sigma}}$) is obtained. Next, we show that $\omega_{\min}^{\sigma} > \underline{\omega}^{\sigma}$. Taking the difference between the left-hand side (LHS) and the RHS yields $\sqrt{C^2 - 1} - (C - T^{1-\sigma})$. Since both $\sqrt{C^2 - 1}$ and $(C - T^{1-\sigma})$ are positive, we can compare the relative magnitude by taking the difference of the two squares, which yields $(CT^{1-\sigma} - 1) + T^{1-\sigma}(C - T^{1-\sigma}) > 0$ (note that Eq. (3) and the definition of C imply $CT^{1-\sigma} - 1 > 0$). Thus, the former claim is obtained. Similarly, we have $\overline{\omega}^{\sigma} - \omega_{\max}^{\sigma} = (C - T^{\sigma-1}) + \sqrt{C^2 - 1} > 0$, which implies $\omega_{\max} < \overline{\omega}$. □

Therefore, $\lambda(\omega)$ is strictly increasing for all relevant values of ω such that $\lambda(\omega) \in [0, 1]$, which assures the existence of an inverse function $\omega(\lambda)$. In addition, $\omega(1/2) = 1$. Thus, we obtain the home market effect.

Proposition 1. *The nominal wage rate is higher in a larger market, that is, $\omega'(\lambda) > 0$ for all $\lambda \in [0, 1]$, and $\omega(1/2) = 1$.*

This result can be related to the first proposition in Krugman [17, p. 954], which states that a country with a larger population has a higher nominal wage. Our result is summarized in Fig. 1, where $\underline{\omega} < \omega_{\min} < \omega_{\max} < \overline{\omega}$ and λ is increasing in the relevant domain $[\omega_{\min}, \omega_{\max}]$. The intuition of Proposition 1 is as follows: in the interior equilibrium, where each region has a positive number of firms, each firm in a larger market has the advantage in transportation costs. Since each firm must be indifferent between the two regions in equilibrium, production cost, which is the nominal wage rate, must be higher in a larger market in order to offset the advantage in transportation costs.

On the other hand, the difference of the indirect utility from differentiated goods between regions 1 and 2 is determined as

$$\begin{aligned}\Delta\widetilde{U}(\lambda) &= \widetilde{U}_1(\lambda) - \widetilde{U}_2(\lambda)\\ &= \left[\lambda + (1-\lambda)\omega(\lambda)^{\sigma-1}T^{1-\sigma}\right]^{\frac{1}{\sigma-1}}\\ &\quad - \left[\lambda\omega(\lambda)^{1-\sigma}T^{1-\sigma} + (1-\lambda)\right]^{\frac{1}{\sigma-1}},\end{aligned} \tag{4}$$

where $\widetilde{U}_r(\lambda)$ is the indirect utility associated with differentiated goods derived from market interactions. Now, in the next proposition we relate the number of workers in region 1, λ, to the indirect utility difference $\Delta\widetilde{U}(\lambda)$.

Proposition 2. *The indirect utility from differentiated goods is higher in a larger market.*

Proof. By differentiating the indirect utility difference (4), we obtain

$$\begin{aligned}\frac{\mathrm{d}\Delta\widetilde{U}(\lambda)}{\mathrm{d}\lambda} &= \frac{A(\lambda)^{\frac{1}{\sigma-1}-1}}{\sigma-1}\Bigg[1 - \omega(\lambda)^{\sigma-1}T^{1-\sigma}\\ &\qquad + (1-\lambda)(\sigma-1)\omega(\lambda)^{\sigma-1}T^{1-\sigma}\frac{\omega'(\lambda)}{\omega(\lambda)}\Bigg]\\ &\quad + \frac{B(\lambda)^{\frac{1}{\sigma-1}-1}}{\sigma-1}\Bigg[1 - \omega(\lambda)^{1-\sigma}T^{1-\sigma}\\ &\qquad + \lambda(\sigma-1)\omega(\lambda)^{1-\sigma}T^{1-\sigma}\frac{\omega'(\lambda)}{\omega(\lambda)}\Bigg],\end{aligned} \tag{5}$$

where

$$A(\lambda) \equiv \lambda + (1-\lambda)\omega(\lambda)^{\sigma-1}T^{1-\sigma}, \quad \text{and} \quad B(\lambda) \equiv \lambda\omega(\lambda)^{1-\sigma}T^{1-\sigma} + 1 - \lambda.$$

The result $\omega'(\lambda) > 0$ in Proposition 1 implies that if $1 > \omega^{\sigma-1}T^{1-\sigma}$ and if $1 > \omega^{1-\sigma}T^{1-\sigma}$, then $\mathrm{d}\Delta\widetilde{U}(\lambda)/\mathrm{d}\lambda > 0$. These inequalities hold since $T^{-1} < \omega_{\min} < \omega < \omega_{\max} < T$. In addition, we know $\Delta\widetilde{U}(\lambda)|_{\lambda=1/2} = 0$, which completes the proof. □

The result in Proposition 2 is due to the home market effect in Proposition 1 and the price index effect. The latter implies that, in the presence of transportation costs, the price index of differentiated goods tends to be lower in a larger market since more varieties of differentiated goods can be purchased without incurring transportation costs in such a larger market. Therefore, it turns out that *higher concentration of mobile workers in one region yields both higher nominal wage and higher indirect utility from differentiated goods in that region. Thus, product diversity generates an agglomeration force.*

2.2. Taste heterogeneity as a dispersion force

The results in the previous subsection imply that workers concentrate in a single region if they decide their residential locations by taking only product diversity into account. However, in reality, each worker also considers idiosyncratic taste for residential location, as mentioned in the Introduction. Therefore, an overall utility for individual k must incorporate both market and non-market factors, that is,

$$V_r^k(\lambda) = \widetilde{U}_r(\lambda) + \xi_r^k,$$

where $\widetilde{U}_r(\lambda)$ is the indirect utility associated with differentiated goods common to the residents in region r. On the other hand, ξ_r^k is a random variable representing idiosyncratic taste differences in residential location.[10] We assume that ξ_r^k are i.i.d. across individuals and regions according to the double exponential distribution with zero mean and variance equal to $\pi^2\beta^2/6$,

$$F(x) = \Pr(\xi_r^k \leqslant x) = \exp\left[-\exp\left(-\frac{x}{\beta} - \gamma\right)\right], \tag{6}$$

where γ is Euler's constant (≈ 0.5772), β is a positive constant and is referred to as the degree of taste heterogeneity. Since β has a positive relationship with variance, the larger the value of β the more heterogeneous the attachment of workers to each location tends to be. Given the geographic distribution λ and the distribution function (6), the individual k's choice probability of each region is expressed as a logit form (see McFadden [25], and Anderson et al. [3]):

$$P_1(\lambda) = \Pr\left(V_1^k(\lambda) > V_2^k(\lambda)\right) = \frac{\exp(\widetilde{U}_1(\lambda)/\beta)}{\exp(\widetilde{U}_1(\lambda)/\beta) + \exp(\widetilde{U}_2(\lambda)/\beta)}, \tag{7}$$

$$P_2(\lambda) = \Pr\left(V_2^k(\lambda) > V_1^k(\lambda)\right) = \frac{\exp(\widetilde{U}_2(\lambda)/\beta)}{\exp(\widetilde{U}_1(\lambda)/\beta) + \exp(\widetilde{U}_2(\lambda)/\beta)}. \tag{8}$$

The two extreme cases help us to understand the relative importance of agglomeration and dispersion forces. If $\beta \to 0$, then people decide their location only by the indirect utility associated with differentiated goods (that is, they choose a region with a higher indirect utility from differentiated goods with probability one), which corresponds to the case without heterogeneity. On the other hand, if $\beta \to \infty$, then they choose their location with equal probability. In this case, taste for residential location can be considered as extremely heterogeneous, so that the local availabilities of differentiated goods do not affect any decision on location. Thus, *taste heterogeneity generates a dispersion force.*

3. The number and stability of equilibria

This section analyzes how the two opposite forces, product diversity as an agglomeration force analyzed in Section 2.1 and taste heterogeneity as a dispersion force analyzed in Section 2.2, determine the number and stability of equilibria. As done by Miyao [27] and Miyao and Shapiro [28], equilibrium is defined as the geographic distribution of economic activities λ, such that the choice probability for each location is equal to the number of individuals who actually choose that location. Since, in general, the former does not coincide

[10] Anas [2, Chapter 2] made meaningful interpretations of the random variable relevant to the urban context: they include interhousehold and intrahousehold variations in utility as well as the possible change between the *ex ante* and *ex post* utility.

with the latter, we must specify some kind of dynamic adjustment. If we assume that time is represented as a continuous variable t and that the adjustment is made gradually through time, we have

$$\begin{aligned}\frac{\mathrm{d}\lambda(t)}{\mathrm{d}t} &= P_1\bigl(\lambda(t)\bigr) - \lambda(t) = \frac{\exp(\Delta\widetilde{U}(\lambda(t))/\beta)}{\exp(\Delta\widetilde{U}(\lambda(t))/\beta)+1} - \lambda(t) \\ &\equiv G\bigl(\lambda(t)\bigr).\end{aligned} \tag{9}$$

Noting that, in equilibrium, the number of workers in each region must be a constant, or $G(\lambda) = 0$, the number and stability of equilibria can be characterized by the following proposition.

Proposition 3. *In the two-region model, there exists a locally stable equilibrium with $\lambda = 1/2$ if and only if*

$$\frac{(2\sigma-1)(1-T^{1-\sigma})}{\beta(\sigma-1)[(2\sigma-1)+T^{1-\sigma}]} \leqslant \left[\frac{1+T^{1-\sigma}}{2}\right]^{\frac{1}{1-\sigma}}. \tag{10}$$

In contrast, when (10) *is violated, the economy has at least three equilibria, one of which is $\lambda = 1/2$ and locally unstable. The others, at least two of which are locally stable, are asymmetric with a positive population in both regions. In addition, in the case of nontradable goods ($T \to \infty$), the condition* (10) *is reduced to* $(1/\beta)(1/(\sigma-1)) \leqslant 2^{1/(\sigma-1)}$, *that is, taste heterogeneity β and taste for diversity* $1/(\sigma-1)$, *together with the number of locations* $(= 2)$, *are the determinants of the number and local stability of equilibria.*

Proof. First, in equilibrium $G(\lambda) = 0$ must hold. Also, we know $G(0) > 0$ and $G(1) < 0$. Since $G(\bullet)$ is continuous in λ, there exists an interior equilibrium $\lambda \in (0, 1)$. In addition, noting that $\omega(1/2) = 1$, we obtain $G(1/2) = 0$ regardless of the parameter values. The number and local stability of equilibria are determined by the sign of $G'(1/2)$. If $G'(1/2) \leqslant 0$, then the symmetric equilibrium with $\lambda = 1/2$ is locally stable. Otherwise, the number of equilibria is at least three, one of which is $\lambda = 1/2$ and is locally unstable. The others correspond to asymmetric geographic structures, at least two of which are locally stable, since there exists $\epsilon > 0$ such that $G((1/2) - \epsilon) < 0$ and $G((1/2) + \epsilon) > 0$ (in addition to the facts, $G(0) > 0$ and $G(1) < 0$, and the continuity of $G(\lambda)$). By differentiating (9) and evaluating at $\lambda = 1/2$ hold, we have

$$G'(1/2) = \frac{1}{4\beta}\frac{\mathrm{d}\Delta\widetilde{U}(\lambda)}{\mathrm{d}\lambda}\bigg|_{\lambda=1/2} - 1. \tag{11}$$

Using the definitions of $A(\lambda)$ and $B(\lambda)$ as in the proof of Proposition 2, we obtain:

$$\begin{aligned}G'(1/2) = \frac{1}{4\beta(\sigma-1)}\Biggl[&\frac{A'(\lambda)}{A(\lambda)}\bigg|_{\lambda=1/2}\widetilde{U}_1(\lambda)\big|_{\lambda=1/2} \\ &- \frac{B'(\lambda)}{B(\lambda)}\bigg|_{\lambda=1/2}\widetilde{U}_2(\lambda)\big|_{\lambda=1/2}\Biggr] - 1.\end{aligned}$$

Since $A(\lambda)|_{\lambda=1/2} = B(\lambda)|_{\lambda=1/2}$ and $A'(\lambda)|_{\lambda=1/2} = -B'(\lambda)|_{\lambda=1/2}$ hold, we have:

$$G'(1/2) = \frac{1}{4\beta(\sigma-1)} \frac{A'(\lambda)}{A(\lambda)}\bigg|_{\lambda=1/2} \left[\widetilde{U}_1(\lambda)\big|_{\lambda=1/2} + \widetilde{U}_2(\lambda)\big|_{\lambda=1/2}\right] - 1. \tag{12}$$

Finally, noting that $\omega'(1/2) = 4(1-T^{1-\sigma})/[(2\sigma-1)+T^{1-\sigma}]$, we obtain:

$$G'(1/2) = \frac{1}{4\beta(\sigma-1)} \times \underbrace{\frac{2(2\sigma-1)(1-T^{1-\sigma})}{(2\sigma-1)+T^{1-\sigma}}}_{\text{relative rate of change of } A(\lambda)} \times \underbrace{2\left[\frac{1+T^{1-\sigma}}{2}\right]^{\frac{1}{\sigma-1}}}_{\text{absolute utility level}} -1, \tag{13}$$

which completes the proof. □

As the proof of Proposition 3 indicates, the relative strength between an agglomeration force due to changes in the indirect utility difference $\mathrm{d}\Delta\widetilde{U}(\lambda)/\mathrm{d}\lambda|_{\lambda=1/2}$ and a dispersion force due to taste heterogeneity β is important for characterizing the number and local stability of equilibria (see Eq. (11)). The changes in the indirect utility difference $\mathrm{d}\Delta\widetilde{U}(\lambda)/\mathrm{d}\lambda|_{\lambda=1/2}$, in turn, can be decomposed into two parts (see Eqs. (12) and (13)):

(i) *the relative rate of change* $A'(\lambda)/A(\lambda)|_{\lambda=1/2}$; *and*
(ii) *the absolute level of the indirect utility from differentiated goods in each region* $\widetilde{U}_r(\lambda)|_{\lambda=1/2}$.

Next, we consider how the decline in transportation costs affects the number and local stability of equilibria. As transportation costs decline, the relative rate of change $A'(\lambda)/A(\lambda)|_{\lambda=1/2}$ decreases (and thus $B'(\lambda)/B(\lambda)|_{\lambda=1/2} = -A'(\lambda)/A(\lambda)|_{\lambda=1/2}$ increases). Thus, the decline in transportation costs, by reducing the larger region's advantage in transportation costs, stabilizes the symmetric equilibrium. The LHS in (10) represents the mechanism that weakens the agglomeration force together with the degree of taste heterogeneity. On the other hand, the decline in transportation costs strengthens the agglomeration force by magnifying the larger region's advantage through the rise in the absolute level of the indirect utility from differentiated goods in each region. The RHS in (10) reflects (the inverse of) the absolute indirect utility level evaluated at $\lambda = 1/2$. Therefore, both the LHS and RHS in (10) turn out to be increasing in T.

By noting these relationships, we learn that as transportation costs decline, the present model can theoretically yield five patterns of agglomeration depending on the relative size between taste heterogeneity β and taste for diversity $1/(\sigma-1)$ (more specifically, between $(1/\beta)(1/(\sigma-1))$ and $2^{1/(\sigma-1)}$). We can numerically confirm that three of them do exist in reality. These are summarized as follows.

Corollary 1. *As transportation costs decline, different patterns of agglomeration emerge in the two-region model, which are typically classified as*:

(a) *dispersion regardless of transportation costs for large taste heterogeneity*;

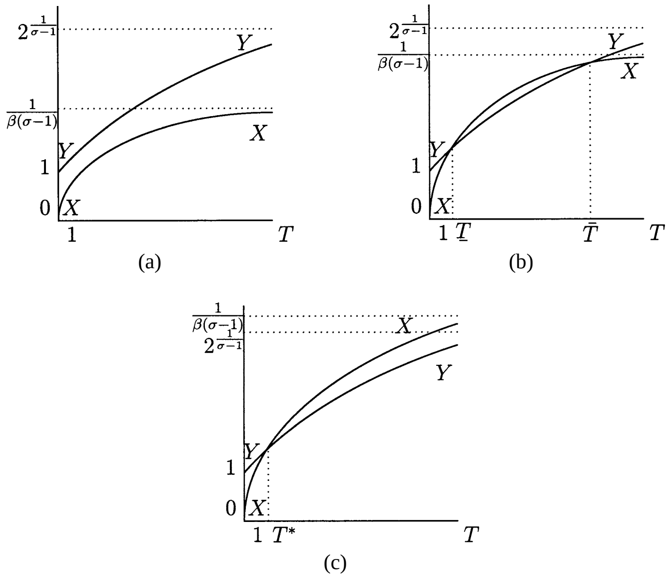

Fig. 2. Patterns of agglomeration: (a) large taste heterogeneity, (b) intermediate taste heterogeneity, (c) small taste heterogeneity.

(b) *from dispersion to agglomeration and to redispersion for intermediate taste heterogeneity*; *and*
(c) *from agglomeration to dispersion for small taste heterogeneity.*[11]

Pattern (a) is depicted in Fig. 2(a), where the LHS and RHS in (10) are denoted by XX and YY, respectively. Since $\lim_{T\to 1}$ LHS $= 0$ and $\lim_{T\to 1}$ RHS $= 1$, the symmetric geographic structure is obtained for sufficiently low T. In addition, if β is sufficiently large, then $(1/\beta)(1/(\sigma-1)) < 2^{1/(\sigma-1)}$ holds, which implies dispersion for sufficiently high T. Finally, since the RHS in (10) does not include β, we can show that for sufficiently large β the symmetric geographic structure is never broken for all $T > 1$.

Pattern (b) is more likely to emerge when the degree of taste heterogeneity is intermediate. Figure 2(b) shows the case where the inequality $(1/\beta)(1/(\sigma-1)) < 2^{1/(\sigma-1)}$ is not violated and XX and YY intersect twice at $\overline{T}$ and $\underline{T}$. Thus, the economy changes its geographic structure from dispersion to agglomeration (at $\overline{T}$) and to redispersion (at $\underline{T}$) as transportation costs decline. In the case of $\sigma = 1.25$ and $\beta = 0.475$, these critical values are $\overline{T} = 15.3$ and $\underline{T} = 10.8$.

[11] Although we have not been able to construct any example yet, the following two patterns of agglomeration are theoretically possible: pattern (b'), D (Dispersion) $\to$ A (Agglomeration) $\to$ D $\to$ A $\to \cdots \to$ D (this implies that XX and YY in Fig. 2(b) might intersect more than twice), and pattern (c'), A $\to$ D $\to$ A $\to$ D $\to \cdots \to$ D (this implies that XX and YY in Fig. 2(c) might intersect more than once).

Similarly, pattern (c) can be observed when the degree of taste heterogeneity is low enough. Figure 2(c) shows that XX and YY intersect once at T^*. In this case, a market-mediated agglomeration force is so strong that it can destabilize the symmetric geographic structure, even for sufficiently high transportation costs since $(1/\beta)(1/(\sigma-1)) > 2^{1/(\sigma-1)}$. Thus, the economy changes its geographic structure from agglomeration to dispersion according to the decline in transportation costs. In the case of $\sigma = 1.25$ and $\beta = 0.25$, the critical value is $T^* = 1.74$.[12]

In our model, the effect of transportation costs on the geographic distribution of economic activities is different from the one in Krugman [18] and Fujita et al. [5, Chapter 5]. There are several reasons worth noting. First, in the existing literature, unless the "no-black-hole" condition is satisfied, a market-mediated agglomeration force is so strong that it can destabilize the symmetric equilibrium regardless of transportation costs. In contrast, pattern (a) in Corollary 1 implies that, when a dispersion force due to taste heterogeneity is strong enough, the symmetric equilibrium is stable regardless of transportation costs.

Secondly, when transportation costs are sufficiently low, the "core–periphery" pattern is inevitable in Krugman [18] and Fujita et al. [5, Chapter 5], whereas the symmetric structure is inevitable in the present model. As mentioned above, in the present model the decline in transportation costs weakens the agglomeration force by reducing the larger region's advantage in transportation costs through the relative rate of change $A'(\lambda)/A(\lambda)|_{\lambda=1/2}$, whereas it strengthens the agglomeration force by magnifying the larger region's advantage through the rise in the absolute level of the indirect utility from differentiated goods in each region $\widetilde{U}_r(\lambda)|_{\lambda=1/2}$ (see Eqs. (12) and (13)). Our result is obtained since the former effect unambiguously dominates the latter one when transportation costs are sufficiently low. Such dispersion for low transportation costs seems more plausible when we consider the recent tendency in some developed countries (see Geyer and Kontuly [6]).[13]

Third, when transportation costs are sufficiently high, the symmetric equilibrium is never broken in the existing literature. In fact, Krugman [18] and Fujita et al. [5, Chapter 5] precluded such a case by imposing the "no-black-hole" condition, since the geographic structure remains unchanged in response to the decline in transportation costs. Unlike these models, the present model can yield the case where the "core–periphery" pattern is sustainable for high transportation costs, and not sustainable for low transportation costs, that is, pattern (c) in Corollary 1.

[12] One may argue that other equilibria also exist under the parameter values used in explaining patterns (a)–(c). However, we can numerically confirm the followings: whenever $\lambda = 1/2$ is stable, there is no other (stable or unstable) equilibrium. On the other hand, whenever $\lambda = 1/2$ is unstable, there are only two stable equilibria (there is no equilibrium other than the three).

[13] The dispersion properties for low transportation costs were modeled by Helpman [13] and Tabuchi [37] where commuting and land costs are dispersion forces. In addition, Krugman and Venables [19] analyzed redispersion of firms in the international framework where workers are immobile between countries, but mobile between industries. Note that in contrast to these models, dispersion in the present model is derived from taste heterogeneity in residential location.

4. Welfare

This section compares the equilibrium outcomes with the social optimum. The social welfare function must incorporate both taste for diversity and taste heterogeneity. Small and Rosen [36] showed that in a logit model with the choice probabilities (7) and (8), the individual welfare can be written as:

$$W(\lambda) = \beta \ln\left[\exp\left(\frac{\widetilde{U}_1(\lambda)}{\beta}\right) + \exp\left(\frac{\widetilde{U}_2(\lambda)}{\beta}\right)\right], \tag{14}$$

where we evaluate prices at the equilibrium levels. We define social welfare as the sum of the individual utility levels, which is exactly the same as Eq. (14) since we normalize the number of workers as unity. By using Eq. (14) we first compare the equilibrium outcomes with the local optimum.

Proposition 4. *Let β^{opt} (respectively β^{eqm}) denote the smallest value of β, for which the locally optimal (respectively equilibrium) symmetric geographic structure is stable. Then $\beta^{\mathrm{eqm}} < \beta^{\mathrm{opt}}$, which implies that the equilibrium symmetric structure entails inefficient dispersion for β such that $\beta^{\mathrm{eqm}} < \beta < \beta^{\mathrm{opt}}$.*

Proof. By differentiating (14) with respect to λ,

$$\begin{aligned} W'(\lambda) &= \frac{\exp(\Delta\widetilde{U}(\lambda)/\beta)}{\exp(\Delta\widetilde{U}(\lambda)/\beta)+1}\frac{\mathrm{d}\widetilde{U}_1(\lambda)}{\mathrm{d}\lambda} + \frac{1}{\exp(\Delta\widetilde{U}(\lambda)/\beta)+1}\frac{\mathrm{d}\widetilde{U}_2(\lambda)}{\mathrm{d}\lambda} \\ &= G(\lambda)\frac{\mathrm{d}\Delta\widetilde{U}(\lambda)}{\mathrm{d}\lambda} + \lambda\frac{\mathrm{d}\widetilde{U}_1(\lambda)}{\mathrm{d}\lambda} + (1-\lambda)\frac{\mathrm{d}\widetilde{U}_2(\lambda)}{\mathrm{d}\lambda}. \end{aligned} \tag{15}$$

Since $G(1/2) = 0$ and $\mathrm{d}\widetilde{U}_1(\lambda)/\mathrm{d}\lambda|_{\lambda=1/2} = -\mathrm{d}\widetilde{U}_2(\lambda)/\mathrm{d}\lambda|_{\lambda=1/2}$, we know that $\lambda = 1/2$ is an extreme value. In addition, if $W''(1/2) < 0$, then the symmetric geographic structure achieves the local maximum. By differentiating $W(\lambda)$ twice and evaluating at $\lambda = 1/2$, we obtain:

$$\begin{aligned} W''(1/2) &= G'(1/2)\frac{\mathrm{d}\Delta\widetilde{U}(\lambda)}{\mathrm{d}\lambda}\bigg|_{\lambda=1/2} + \frac{\mathrm{d}\Delta\widetilde{U}(\lambda)}{\mathrm{d}\lambda}\bigg|_{\lambda=1/2} \\ &\quad + \frac{1}{2}\left\{\frac{\mathrm{d}^2\widetilde{U}_1(\lambda)}{\mathrm{d}\lambda^2}\bigg|_{\lambda=1/2} + \frac{\mathrm{d}^2\widetilde{U}_2(\lambda)}{\mathrm{d}\lambda^2}\bigg|_{\lambda=1/2}\right\}, \end{aligned} \tag{16}$$

where

$$\frac{\mathrm{d}\Delta\widetilde{U}(\lambda)}{\mathrm{d}\lambda}\bigg|_{\lambda=1/2} = \frac{4(1-T^{1-\sigma})(2\sigma-1)}{(\sigma-1)[(2\sigma-1)+T^{1-\sigma}]}\left(\frac{1+T^{1-\sigma}}{2}\right)^{\frac{1}{\sigma-1}},$$

$$\begin{aligned} &\frac{1}{2}\left\{\frac{\mathrm{d}^2\widetilde{U}_1(\lambda)}{\mathrm{d}\lambda^2}\bigg|_{\lambda=1/2} + \frac{\mathrm{d}^2\widetilde{U}_2(\lambda)}{\mathrm{d}\lambda^2}\bigg|_{\lambda=1/2}\right\} \\ &\quad = \frac{4(1-T^{1-\sigma})(2\sigma-1)^2}{(\sigma-1)^2[(2\sigma-1)+T^{1-\sigma}]^2}\left(\frac{1+T^{1-\sigma}}{2}\right)^{\frac{1}{\sigma-1}} \\ &\quad\quad \times\left\{(2-\sigma) - T^{1-\sigma}\left[1-\frac{\sigma-1}{(2\sigma-1)^2}\right]\right\}, \end{aligned}$$

and $G'(1/2)$ is given by Eq. (11). Thus, Eq. (16) can be rewritten as

$$W''(1/2) = \left\{G'(1/2) + \frac{(2\sigma-1)^2 - T^{1-\sigma}[\sigma^2 + (\sigma-1)^2]}{(\sigma-1)(2\sigma-1)[(2\sigma-1)+T^{1-\sigma}]}\right\} \frac{\mathrm{d}\Delta\widetilde{U}(\lambda)}{\mathrm{d}\lambda}\bigg|_{\lambda=1/2}.$$

Since $\mathrm{d}\Delta\widetilde{U}(\lambda)/\mathrm{d}\lambda|_{\lambda=1/2} > 0$, we have

$$\operatorname{sgn}\{W''(1/2)\} = \operatorname{sgn}\left\{G'(1/2) + \frac{(2\sigma-1)^2 - T^{1-\sigma}[\sigma^2 + (\sigma-1)^2]}{(\sigma-1)(2\sigma-1)[(2\sigma-1)+T^{1-\sigma}]}\right\}. \tag{17}$$

By definition, β^{opt} is β that makes $W''(1/2) = 0$, whereas β^{eqm} is obtained by setting $G'(1/2) = 0$. Thus, the discrepancy between the equilibrium outcomes and the local optimum arises solely due to the second term in the braces in the RHS in Eq. (17). In addition, noting that $T > 1$, we have

$$(2\sigma-1)^2 - T^{1-\sigma}\big[\sigma^2 + (\sigma-1)^2\big] > 2\sigma(\sigma-1) > 0.$$

Thus, whenever $W''(1/2) = 0$, the sign of $G'(1/2)$ must be negative, which implies $\beta^{\mathrm{opt}} > \beta^{\mathrm{eqm}}$. □

The intuition of Proposition 4 can be understood by noting that the discrepancy between the equilibrium outcomes and the local optimum arises solely due to the second term in the braces in Eq. (17), which, in turn, comes from the second and third terms in Eq. (16). These terms reflect the fact that, in equilibrium, each individual chooses each residential location without considering how each decision affects the indirect utility from differentiated goods in each region $\widetilde{U}_r(\lambda)$, whereas the planner maximizes the welfare level by considering it. Since all pecuniary externalities generated by market interactions in our model are positive, all inefficient equilibrium outcomes must entail undesirable dispersion.

Now we examine numerically whether equilibrium geographic structures attain the global (social) optimum or not. Figure 3 summarizes some results, where β^{opt} and β^{eqm} are given by 0.558 and 0.310, respectively. The upper parts of Fig. 3 represent the motion of mobile workers in region 1, $G(\lambda)$, whereas the lower parts represent social welfare $W(\lambda)$ evaluated at the equilibrium prices. If the degree of taste heterogeneity is high ($\beta = 0.75$), then the equilibrium geographic structure is symmetric and coincides with the social optimum. On the other hand, if the degree of taste heterogeneity is intermediate ($\beta = 0.5$), then the equilibrium geographic structure is symmetric, as before. However, partial agglomeration is more desirable from the social welfare point of view. Thus, we obtain inefficient equilibrium dispersion. Finally, in the case of a low degree of taste heterogeneity ($\beta = 0.25$), not only the socially optimal geographic distribution but also stable equilibria are not symmetric, although the social optimum requires a less even geographic distribution of workers. Thus, we observe inefficient equilibrium dispersion again.

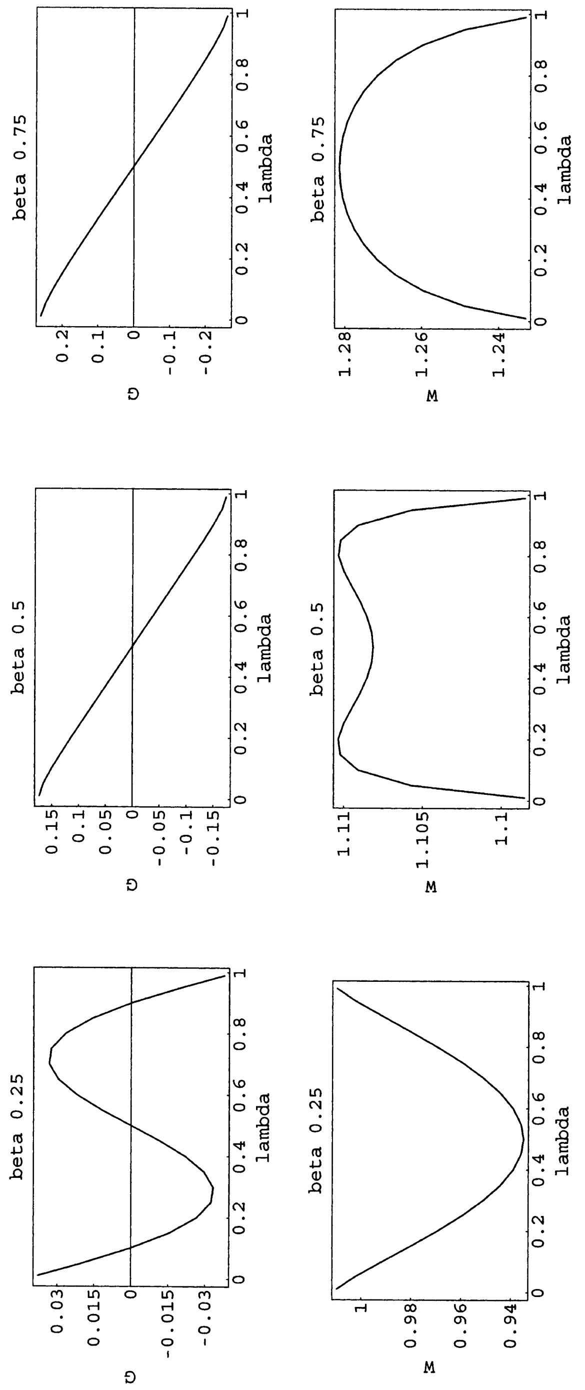

Fig. 3. Optimality vs. equilibrium ($\sigma = 3$ and $T = 2.5$).

5. Discussion

This section relates the prediction of the present model to the classical literature on the determinants of interregional wage differentials. In this model, the nominal wage differentials can be expressed as a function of mobile workers in region 1, $\omega(\lambda)$. The number of mobile workers in region 1, λ, is, in turn, determined by market and non-market factors (i.e., σ and β, respectively), together with transportation costs T. As was shown above, if $\beta \to 0$ then the equilibrium geographic structures are extreme ($\lambda = 0$ and $\lambda = 1$), whereas if $\beta \to \infty$ then the equilibrium geographic structure is symmetric ($\lambda = 1/2$). In these cases, no regional differences in the nominal wage rate can arise. Thus, the interregional wage differentials are due to the coexistence of taste for diversity and taste heterogeneity. This is consistent with the description by Hicks [14], where he regarded both "differences in the cost of living" and "indirect attractions of living in certain localities" as causes of the persistence of the interregional wage differentials.

Furthermore, we can relate the patterns of agglomeration in Corollary 1 to the interregional wage differentials. The most interesting case is the one with intermediate taste heterogeneity, Fig. 2(b). In this case, as the economy develops (measured in the decline in transportation costs), the equilibrium geographic structure changes from dispersion to agglomeration and to redispersion. Associated with these changes, the nominal wage differentials first increase and then decrease, which implies an inverted U-shaped curve, as described by Kuznets [20]. In his numerical example, Kuznets derived the inverted U-shaped curve by raising the urban-to-rural population ratio with the income levels of agricultural (rural) and non-agricultural (urban) sectors held constant, whereas the present model endogenously derives both income levels in the "core" and "periphery" and the "core–periphery" structure itself from market and non-market interactions. Therefore, the present model suggests that the uneven income distribution may be interrelated with the uneven geographic distribution of economic activities.[14]

6. Concluding remarks

Based on the theoretical underpinning of new economic geography and probabilistic migration, this article reincorporates both market and non-market interactions into a unified framework in the spirit of Hicks, Jacobs, and Sjaastad. It shows that market-mediated product diversity yields an agglomeration force through the home market effect, whereas taste heterogeneity due to non-market interactions serves as a "probabilistic immobile factor" and induces a dispersion force.

[14] The importance was already stressed by Alonso [1]. He regarded the following five bell-shaped (inverted U-shaped) curves as "propositions" found in the course of development: development stages, social inequality, regional inequality, geographic concentration, and demographic transition. Furthermore, he stated that "(b)ecause all of these processes are fundamentally important, however, and because they are concurrent in development, it seems unlikely that we can gain a sufficient understanding of any one of them without simultaneous consideration of the others" (p. 7).

Unlike much of the existing new economic geography literature, we obtain a more plausible result that the nominal wage rate is always *higher* in a *larger* region. In addition, we characterize the number and stability of equilibria with three parameters: taste for product diversity, taste heterogeneity, and transportation costs. The decline in transportation costs affects the relative importance of taste for product diversity and taste heterogeneity and yields different patterns of agglomeration. These patterns of agglomeration are, in turn, associated with the changes in the interregional wage differentials. In particular, we find that the uneven geographic distribution is interrelated with the uneven income distribution.

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