Appendix A. List of Variables, Parameters, and Functions

s Index of region ($s = 1, 2$)

i Index of local differentiated goods ($i \in [0, M]$)

j Index of transport services ($j = 1, 2$)

u^s A consumer's utility in region s

v^s A consumer's indirect utility in region s

z^s A consumer's consumption of the numeraire good in region s

h^s A consumer's consumption of the land for housing in region s

R^s Land rent in region s

x_i^s A consumer's consumption of local differentiated goods i in region s

M^s Range of available local differentiated goods in region s

$\mathbf{x}^s \equiv \left\{ x_i^s \right\}_{i \in [0, M^s]}$

Vector of a consumer's consumption of local differentiated goods i in region s

p_i^s Price of local differentiated goods i in region s

$\mathbf{p}^s \equiv \left\{ p_i^s \right\}_{i \in [0, M^s]}$

Vector of prices of local differentiated good i in region s

$\overline{L}$ Total amount of time

$p_{Tj}^s \equiv mp_{Tj}^s + wtime_{Tj}^s(T_j^s, k_j^s)$

Generalized price of transport service j in region s

mp_{Tj}^s Monetary price of transport service j in region s

w^s Wage rate in region s

$time^s_{Tj}(T^s_j, k^s_j)$

Required time to use one unit of transport service j in region s

$T^s_j \equiv \int_{i=0}^{M} N^s x^s_i t^s_{ji} di$

Total demand for transport service j in region s

N^s Number of consumers in region s

t^s_{ji} Amount of transport service j needed for one unit of consumption of local differentiated good i in region s

k^s_j Capacity of transport service j in region s

$q^s_i(p^s_i, p^s_{T1}, p^s_{T2})$

Price of consuming one unit of local differentiated goods i in region s (including transportation costs)

$f^s_i(t^s_{1i}, t^s_{2i})$

Unit production function of transport necessary for one unit of consumption of local differentiated goods in region s

π^s_i Profits of the firm producing local differentiated good i in region s

Y^s_i Total production of the local differentiated good i in region s

l^s Number of working hours in region s

n^s_i Number of workers producing local differentiated good i in region s

$g_i^s(l^s n_i^s)$

Production function of the local differentiated good i in region s

π_{Tj}^s Profits of the firm that supplies transport service j in region s

$c_{Tj}^s(T_j^s, k_j^s)$

Total cost of the firm that supplies transport service j in region s

$land_j^s$ Land for capacity of transport service j in region s

cc_{Tj}^s Capacity cost of transport service j in region s

$\overline{H}^s$ Total area of land in region s

$\overline{N}$ Total number of consumers

$\mathbf{k} \equiv \left\{k_1^1, k_2^1, k_1^2, k_2^2\right\}$

Vector of capacity of transport services

SS Total social surplus

ΔSS Change in the total social surplus

ΔCS^s Change in consumers' surpluses from travelling and enjoying the local differentiated goods in region s

ΔBV^s Consumers' benefits from the change in the range of varieties of local differentiated goods in region s

ΔPS_Y^s Change in producers' surpluses (that is, the change in profits) from the local differentiated goods in region s

ΔPS_{Tj}^s Change in producers' surpluses (that is, the change in profits) from transport service j in region s

ΔWS^s Change in producers' (workers') surpluses caused by a change in the wage rate in region s

ΔCC_{T1}^1 Change in the capacity cost of transport service 1 in region 1

ΔCS_{Tj}^s Change in consumers' surpluses from transport service j in region s

ΔCS_Y^s Change in consumers' surpluses from the local differentiated goods in region s

ΔDWL_Y^s

Change in the dead-weight losses caused by the gap between the price and the marginal cost of the local differentiated goods in region s

ΔDWL_M^s

Change in the dead-weight losses caused by the gap between the shadow price and the marginal cost of the variety of the local differentiated goods in region s

ΔDWL_N^s

Change in the dead-weight losses caused by the gap between the marginal social value of labour and the wage rate in region s

$sc_{Tj}^s \equiv w^s time_{Tj}^s T_j^s + c_j^s$

The social cost of transport service j in region s

$$mc_{Tj}^s \equiv \frac{dsc_{Tj}^s}{dT_j^s} = w^s time_{Tj}^s + \frac{d\left(w^s time_{Tj}^s\right)}{dT_j^s} T_j^s + \frac{dc_j^s}{dT_j^s}$$

Marginal social cost of transport service j in region s

ΔDWL_{Tj}^s

Change in the dead-weight losses of transport service j in region s

ΔSC_{T1}^{1} Direct (that is, without considering the effects through transport demand and wage) change in the social costs of transport service 1 in region 1 from a change in the capacity of transport service 1 in region 1

$mc_{Tj}^{s}{}' \equiv \left.\dfrac{dsc_{Tj}^{s}}{dT_{j}^{s}}\right|_{w^s \text{ is fixed}} = w^{s}\left(time_{Tj}^{s} + \dfrac{dtime_{Tj}^{s}}{dT_{j}^{s}}T_{j}^{s}\right) + \dfrac{dc_{j}^{s}}{dT_{j}^{s}}$

Marginal social cost of transport service j in region s given the wage rate

$\Delta DWL_{Tj}^{s}{}'$

Change in the dead-weight losses of transport service j in region s given the wage rate

$\Delta DWL_{Y}^{s}{}'$

Change in the dead-weight losses caused by the gap between the price and the marginal cost of the local differentiated goods in region s, given the wage rate

$leisure^{s}$ Number of leisure hours in region s (in Appendix B)

x_{M+1}^{s} A consumer's consumption of the local final good in region s (in Appendix B)

p_{M+1}^{s} Price of the local final good in region s (in Appendix B)

v^{s} Number of firms producing the local final good in region s (in Appendix B)

π_{M+1}^{s} Profits of a firm that supplies the local final good in region s (in Appendix B)

y_{i}^{s} Input of the differentiated intermediate good i for the firm that produces the local final good in region s (in Appendix B)

$y_{M+1}^{s}(\{y_{i}^{s}\}_{i\in M^{s}})$

Each firm's production function of the local final good in region s (in Appendix B)

$c_i^s(Y_i^s, p_{T1}^s, p_{T2}^s)$

Total cost of the firm that supplies the differentiated intermediate good i in region s (in Appendix B)

$\hat{f}^s(t_{1i}^s, t_{2i}^s)$

Production function of the differentiated intermediate good i in region s (in Appendix B)

ΔCS_{M+1}^s Changes in consumers' surpluses from the local final good in region s (in Appendix B)

ΔPS_{M+1}^s Changes in producers' surpluses from the local final good in region s (in Appendix B)

$\Delta DWL_Y^{s}{}''$

Change in the dead-weight losses caused by the gap between the price and the marginal cost of the differentiated intermediate goods in region s, given the generalized prices of business journeys (in Appendix B)

Appendix B. Agglomeration Model from the Product Variety of Intermediate Goods

Applying Kanemoto (2013a, 2013b), we model an agglomeration economy with product varieties of intermediate goods. For simplicity, we basically use the same notation as in Sections 2 and 3, as long as it causes no possible confusion.

A consumer in each region is assumed to have the following quasilinear utility function

$$u = z + a(leisure, x_{M+1}, h)\,, \tag{B.1}$$

where $leisure$ and x_{M+1} are the number of leisure hours and the local final good, whose price is p_{M+1}. The budget constraint and the time constraint for a consumer are

$$z + p_{M+1}x_{M+1} + Rh = wl \text{ and} \tag{B.2}$$

$$leisure + l = \overline{L}\,. \tag{B.3}$$

Maximizing the utility function (B.1), subject to the budget constraint (B.2) and the time constraint (B.3), we derive the following demand functions for the numeraire good, leisure, the local final good, and land:

$$z = z(p_{M+1}, R, w)\,, \tag{B.4}$$

$$leisure = leisure(p_{M+1}, R, w)\,, \tag{B.5}$$

$$x_{M+1} = x_{M+1}(p_{M+1}, R, w)\,, \tag{B.6}$$

$$h = h(p_{M+1}, R, w)\,. \tag{B.7}$$

The local final good is produced under perfect competition with free entry and exit by symmetric firms, whose number is denoted by ν. The profit of each firm is

$$\pi_{M+1} = p_{M+1} y_{M+1}(\{y_i\}_{i\in M}) - \int_{i=0}^{M} p_i y_i di , \tag{B.8}$$

where y_i is the input of the differentiated intermediate good i used by each firm, and $y_{M+1}(\{y_i\}_{i\in M})$ is the production function of the local final good for each firm. The market clearing condition for the local final good is

$$\nu y_{M+1} = N x_{M+1} . \tag{B.9}$$

Each firm acts as a price taker, and thus profit maximization yields

$$p_{M+1} \frac{\partial y_{M+1}}{\partial y_i} - p_i = 0 . \tag{B.10}$$

Perfect competition with free entry and exit implies

$$\pi_{M+1} = p_{M+1} y_{M+1}(\{y_i\}_{i\in M}) - \int_{i=0}^{M} p_i y_i di = 0 . \tag{B.11}$$

The firm that produces the differentiated intermediate good i is assumed to be subject to monopolistic competition with increasing returns to scale. Each firm employs n_i workers, and because each worker (consumer) works l hours, the total number of working hours for the production of the differentiated intermediate good i is $n_i l$. We assume that the only input for the production of the differentiated intermediate good i is business journeys. The time constraint for the firm that produces the local differentiated good i is

$$time_{T1}(T_1, k_1)t_{1i} + time_{T2}(T_2, k_2)t_{2i} = n_i l \,, \tag{B.12}$$

where t_{ji} and T_j are defined in a slightly different manner from Section 2. t_{ji} denotes the demand for transport service j needed for the production of the differentiated intermediate good i and

$$T_j \equiv \int_{i=0}^{M} t_{ji} di \tag{B.13}$$

is the total demand for transport service j. The total cost of business journeys is the sum of the time costs of business journeys, $wn_i l$, and their monetary prices, $mp_{T1}t_{1i} + mp_{T2}t_{2i}$. Using (B.12), we rewrite the total costs of the firm that produce the differentiated intermediate good i as $p_{T1}t_{1i} + p_{T2}t_{2i}$, where p_{Tj}, the generalized price of transport service j, is defined in the same way as (5). Assuming that the firm that produces the differentiated intermediate good i minimizes the total costs, we derive the cost function

$$c_i(Y_i, p_{T1}, p_{T2}) \equiv \min_{t_{1i}, t_{2i}} \left\{ p_{T1}t_{1i} + p_{T2}t_{2i} : Y_i = \hat{f}(t_{1i}, t_{2i}) \right\}, \tag{B.14}$$

where $\hat{f}(t_{1i}, t_{2i})$ is the production function of the differentiated intermediate good i, which is supposed to be subject to increasing returns to scale. The market clearing condition for the differentiated intermediate good i is

$$Y_i = \nu y_i \,. \tag{B.15}$$

Applying Shephard's lemma to (B.14), we obtain the demand for transport service j as

$$\frac{\partial c_i(Y_i, p_{T1}, p_{T2})}{\partial p_{Tj}} = t_{ji} \,. \tag{B.16}$$

The profit function of the differentiated intermediate good i is can be written as

$$\pi_i = p_i Y_i - c_i(Y_i, p_{T1}, p_{T2}) . \tag{B.17}$$

The firms producing the differentiated intermediate goods are subject to monopolistic competition. Profit maximization, given the generalized price of transport service j, p_{Tj}, yields

$$p_i + \frac{\partial p_i}{\partial Y_i} Y_i - \frac{\partial c_i}{\partial Y_i} = 0 . \tag{B.18}$$

In addition, the profit of the marginal entrant is zero:

$$\pi_M = p_M Y_M - c_M(Y_M, p_{T1}, p_{T2}) = 0 . \tag{B.19}$$

The set-up in Sections 2.3 and 2.4 for the firms that provide transport services and the government is valid without modification. As in Section 2.5, solving (5), (17), (19)–(20), (B.3)–(B.7), (B.9)–(B.13), (B.15)–(B.16), and (B.18)–(B.19), we determine an allocation within a region; z, $leisure$, l, x_{M+1}, h, p_{M+1}, R, w, M, y_i, Y_i, p_i, n_i, p_{Tj}, mp_{Tj}, t_{ji}, T_j, and ν are derived as a function of N, k_1 and k_2. We then obtain an equilibrium where the utility levels of two regions are equalized, as in Section 2.6. Substituting $N^1(\mathbf{k})$ and $N^2(\mathbf{k})$, which are derived by solving (21) and (22), into all other endogenous variables (z^s, $leisure^s$, l^s, x^s_{M+1}, h^s, p^s_{M+1}, R^s, w^s, M^s, y^s_i, Y^s_i, p^s_i, n^s_i, p^s_{Tj}, mp^s_{Tj}, t^s_{ji}, T^s_j, and ν^s, where $s = 1, 2$), we finally derive them as a function of $\mathbf{k}$ only. The form of the total social surplus remains unchanged from (23).

The decomposition corresponding to (25), which focuses on the final good, is

$$\Delta SS = \sum_{s=1}^{2}\Delta CS_{M+1}^{s} + \sum_{s=1}^{2}\Delta PS_{Y}^{s} + \sum_{s=1}^{2}\sum_{j=1}^{2}\Delta PS_{Tj}^{s} + \sum_{s=1}^{2}\Delta WS^{s} - \Delta CC_{T1}^{1}, \qquad \text{(B.20)}$$

where

$\Delta CS_{M+1}^{s} \equiv \int_{k_1^1=k_1^{1W}}^{k_1^{1WO}} \left(N^s x_{M+1}^{s} \frac{dp_{M+1}^{s}}{dk_1^1} \right) dk_1^1$ is the change in consumers' surpluses from the local final good, and

$\Delta WS^{s} \equiv \int_{k_1^1=k_1^{1WO}}^{k_1^{1W}} \left(l^s N^s \frac{dw^s}{dk_1^1} \right) dk_1^1$ is the change in producers' (workers') surpluses caused by a change in the wage rate. In Section 3.1, we define ΔWS^{s} by $\Delta WS^{s} \equiv \int_{k_1^1=k_1^{1WO}}^{k_1^{1W}} \left(\overline{L} N^s \frac{dw^s}{dk_1^1} \right) dk_1^1$, but here we redefine ΔWS^{s} by $\Delta WS^{s} \equiv \int_{k_1^1=k_1^{1WO}}^{k_1^{1W}} \left(l^s N^s \frac{dw^s}{dk_1^1} \right) dk_1^1$, where the number of working hours, l^s, not the total available time for a consumer $\overline{L}$, is used. The reason for the difference is that we explicitly model leisure here so that the change in producers' (workers') surpluses for the total available time is directly offset by the change in the opportunity cost of leisure; that is, the wage rate. In the model used in Section 3.1, this cancelling-out works indirectly through the change in the full prices (that is, including time costs) of travelling and enjoying the local differentiated goods. The definitions for ΔPS_{Y}^{s}, ΔPS_{Tj}^{s}, and ΔCC_{T1}^{1} remain unchanged.

The results can easily be understood by itemizing the benefits. We would expect the benefits to consist of changes in consumers' and producers' surpluses from the local final good, those from the differentiated intermediate goods, those from transport services, and a change in wages. However, the change in producers' surpluses regarding the local final good is zero because of perfect competition. Changes in consumers' surpluses regarding the differentiated intermediate goods and those regarding transport services are also zero, because they are intermediate goods; that is, they are not directly demanded by consumers. Thus, the final benefits are a change in consumers' surpluses from the local final good, changes in producers' surpluses from the differentiated intermediate goods and transport services, and a change in wages.

The difference between (B.20) and (25) is that the term for consumers' benefits from the change in the range of varieties vanishes. This is because the consumption variety does not change here when the variety of available intermediate goods changes. The benefits from a change in the variety of available intermediate goods indeed constitute a part of the profits of the firms that produce the local final good, but those profits finally become zero through perfect competition with free entry and exit. Thus, when we consider a total change in the profits of the firms that produce the local final good, we have no term for a change in the variety of available intermediate goods in (B.20).

We have the following useful relationships for further transformation of (B.20):

$$\Delta PS_Y^s = \sum_{j=1}^{2} \Delta CS_{Tj}^s \text{, and} \tag{B.21}$$

$$\Delta CS_{M+1}^s + \Delta PS_Y^s = \Delta CS_{M+1}^s + \Delta PS_{M+1}^s + \Delta PS_Y^s = \Delta DWL_Y^s + \Delta DWL_M^s \text{ ,} \tag{B.22}$$

$$\Delta DWL_Y^s = \Delta DWL_Y^{s\,\prime\prime} + \sum_{j=1}^{2} \Delta CS_{Tj}^s \text{ ,} \tag{B.23}$$

where $\Delta PS^s_{M+1} \equiv \int_{k_1^1=k_1^{1WO}}^{k_1^{1W}} \left(\frac{d\left(\nu^s p^s_{M+1} y^s_{M+1}(\{y^s_i\}_{i\in M^s}) - \nu^s \int_{i=0}^{M^s} p^s_i y^s_i di \right)}{dk_1^1} \right) dk_1^1 = 0$ is the change in producers' surpluses from the local final good,

$\Delta DWL^s_Y \equiv \int_{k_1^1=k_1^{1WO}}^{k_1^{1W}} \left(\int_{i=0}^{M^s} \left(p^s_i - \frac{dc^s_i(Y^s_i, p^s_{T1}, p^s_{T2})}{dY^s_i} \right) \frac{dY^s_i}{dk_1^1} di \right) dk_1^1$ is the change in the dead-weight losses caused by the gap between the price and the marginal cost of the differentiated intermediate goods,

$\Delta DWL^s_M \equiv \int_{k_1^1=k_1^{1WO}}^{k_1^{1W}} \left(\nu^s \left(\frac{d\left(p^s_{M+1} y^s_{M+1}\right)}{dM^s} - p^s_M y^s_M \right) \frac{dM^s}{dk_1^1} \right) dk_1^1$ is the change in the dead-weight losses caused by the gap between the shadow price and the marginal cost of the variety of the intermediate goods, and

$\Delta DWL^{s}_Y{}'' \equiv \int_{k_1^1=k_1^{1WO}}^{k_1^{1W}} \left(\int_{i=0}^{M^s} \left(p^s_i - \frac{\partial c^s_i(Y^s_i, p^s_{T1}, p^s_{T2})}{\partial Y^s_i} \right) \frac{dY^s_i}{dk_1^1} di \right) dk_1^1$ is the change in the dead-weight losses caused by the gap between the price and the marginal cost of the differentiated intermediate goods given the generalized prices of business journeys.

Eq. (B.21) is derived from (B.16)–(B.18). Eq. (B.22) follows from (B.10) and (B.11), noting that the change in the profits of the local final good, ΔPS^s_{M+1}, is always zero. In (B.22), we have two differences from the definitions in Section 3.3. First, the dead-weight losses of the differentiated goods, ΔDWL^s_Y, are those regarding firms' intermediate goods, not consumers' final goods. Second, in the dead-weight losses of the product varieties, ΔDWL^s_M, the shadow price of product variety is defined as $\frac{d\left(p^s_{M+1} y^s_{M+1}\right)}{dM^s}$, instead of $\frac{\partial u^s}{\partial M^s} N^s$, because we here consider the product varieties of differentiated input goods, not those of differentiated consumption goods. Eq. (B.23) holds because we can extract the effect caused by a change in the generalized prices of transport services from the total change in costs of intermediate goods, using (B.16).

Applying (B.21) to (B.20) immediately yields

$$\Delta SS = \sum_{s=1}^{2}\sum_{j=1}^{2}\Delta CS_{Tj}^{s} + \sum_{s=1}^{2}\sum_{j=1}^{2}\Delta PS_{Tj}^{s} + \sum_{s=1}^{2}\Delta CS_{M+1}^{s} + \sum_{s=1}^{2}\Delta WS^{s} - \Delta CC_{T1}^{1}, \tag{B.24}$$

where a change in consumers' surpluses regarding business journeys is made explicit. Eq. (B.24) is the counterpart of (26). We also derive the counterpart of (27), where a change in the dead-weight losses is focused on:

$$\Delta SS = \sum_{s=1}^{2}\sum_{j=1}^{2}\Delta CS_{Tj}^{s} + \sum_{s=1}^{2}\sum_{j=1}^{2}\Delta PS_{Tj}^{s} + \sum_{s=1}^{2}\Delta DWL_{Y}^{s\prime\prime} + \sum_{s=1}^{2}\Delta DWL_{M}^{s} + \sum_{s=1}^{2}\Delta DWL_{N}^{s} - \Delta CC_{T1}^{1}, \tag{B.25}$$

in which (B.22) and (B.23) are applied to (B.20), and ΔWS^{s} in (B.20) is transformed to ΔDWL_{N}^{s}, as in Section 3.3. $\Delta DWL_{N}^{s} \equiv \int_{k_1^1=k_1^{1WO}}^{k_1^{1W}} \left(l^{s}\left(\frac{d(w^{s}N^{s})}{dN^{s}} - w^{s} \right)\frac{dN^{s}}{dk_1^1} \right) dk_1^1$ is the change in the dead-weight losses caused by the gap between the marginal social value of labour and the wage rate. The only difference from (27) is that we use the change in the dead-weight losses regarding the differentiated intermediate goods given the generalized prices of business journeys. This is because, as we know from (B.23), a change in consumers' surpluses regarding the business journeys constitutes a part of the total change in costs of intermediate goods.

Regarding consumers' and producers' surpluses in the transport markets, we have the same relationship as (31) and (33). Accordingly, (B.25) is further transformed to

$$\Delta SS = \sum_{j=1}^{2} \Delta CS_{Tj}^{1} + \sum_{j=1}^{2} \Delta PS_{Tj}^{1} + \sum_{j=1}^{2} \Delta DWL_{Tj}^{2} + \sum_{s=1}^{2} \Delta DWL_{Y}^{s}{}'' + \sum_{s=1}^{2} \Delta DWL_{M}^{s} + \sum_{s=1}^{2} \Delta DWL_{N}^{s} - \Delta CC_{T1}^{1} \tag{B.26}$$

and

$$\Delta SS = \Delta SC_{T1}^{1} + \sum_{s=1}^{2} \sum_{j=1}^{2} \Delta DWL_{Tj}^{s} + \sum_{s=1}^{2} \Delta DWL_{Y}^{s}{}'' + \sum_{s=1}^{2} \Delta DWL_{M}^{s} + \sum_{s=1}^{2} \Delta DWL_{N}^{s} - \Delta CC_{T1}^{1}. \tag{B.27}$$

As the increase in the wage income because of an agglomeration is cancelled out by increases in the time costs of business journeys, using (B.12), we also obtain the relationship

$$\sum_{s=1}^{2} \sum_{j=1}^{2} \Delta DWL_{Tj}^{s} + \sum_{s=1}^{2} \Delta DWL_{N}^{s} = \sum_{s=1}^{2} \sum_{j=1}^{2} \Delta DWL_{Tj}^{s}{}'. \tag{B.28}$$

Applying (B.28) to (B.27), we derive the counterpart of (36) as

$$\Delta SS = \Delta SC_{T1}^{1} + \sum_{s=1}^{2} \sum_{j=1}^{2} \Delta DWL_{Tj}^{s}{}' + \sum_{s=1}^{2} \Delta DWL_{Y}^{s}{}'' + \sum_{s=1}^{2} \Delta DWL_{M}^{s} - \Delta CC_{T1}^{1}. \tag{B.29}$$