論 説

Urban Agglomeration and Industrial Upgrading

Ji Wang*
Xiao-Ping Zheng**

Abstract

In this paper, we propose a two-industry model of urban system to investigate the relationship between urban agglomeration and industrial upgrading. Assuming that the major channels of agglomeration economies are labor pooling, knowledge spillovers, and the sharing of specialized local services, our model shows that urban agglomeration will bring about comparative advantage for industries and cities will specialize in those industries that are intensive in skilled labor, scientific research and education, as well as information and communications. Then, we develop an industrial stage index (IS) to reflect an industry's input intensity in high-tech production activities (involving skilled labor, scientific research and education, and information and communications). Multiplying this industrial stage index to the industrial employment share of the city where the industry is located, we build an urban industrial stage index (UIS) to reflect a city's intensity in high-tech production activities. The association between urban agglomeration (represented by total employment or employment density) and urban industrial upgrading (represented by UIS) is verified through econometrical estimation on the city-level panel data collected from the Japanese economic census.

Keywords: Agglomeration economies; Urban agglomeration; Urban industrial upgrading; Japanese urban system

JEL Codes: R11, R12, O12.

1. Introduction

It is well know that industrial upgrading plays a critical role in economic growth. As

* The corresponding author. Doctoral Candidate, Graduate School of Economics, Ritsumeikan University, Shiga, Japan. E-mail: nr0254ph@ed.ritsumei.ac.jp

** Faculty of Economics, Ritsumeikan University, Shiga, Japan. E-mail: zheng@ec.ritsumei.ac.jp

Schumpeter (1942, pp. 82-83) noted,

> "The essential point to grasp is that in dealing with capitalism we are dealing with an evolutionary process …. The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new forms of industrial organization that capitalist enterprise create."

Aghion and Howitt (1990) and Grossman and Helpman (1991) modeled Schumpeter's process of creative destruction. Ozawa (2005) further empirically studied the process of creative destruction and proposed the "leading-growth sector stages" theory along the lines of Schumpeter, in which a sequence of growth is punctuated by stages in the wake of the "perennial gale of creative destruction". In each stage, a certain industrial sector can be identified as the main engine of structural transformation enabling the economy to scale the ladder of industrial development.

However, the abovementioned theories fail to consider the effect of spatial distribution of economic activities on industrial upgrading, despite the fact that the role of urban agglomerations in industrial upgrading has been discussed for a long time (Jacob, 1969; Moretti, 2012).

Jacob (1969, pp. 1-48) illustrated that new production activities are generally bred in urban agglomerations and are then transplanted from agglomerations to the peripheries, thereby highlighting the role of urban agglomerations in the nursery of innovations. Through a comparison between traditional manufacturing cities and cities dominated by high-tech industries, Moretti (2012) demonstrated that the growth or decline of a city lies in whether it can upgrade its industrial structure. He also noted that it is hard to predict which city will experience industrial upgrading.

Unfortunately, the majority of the models of urban system fail to analyze the industrial composition in cities. For example, the famous model of urban system (Henderson, 1974) assumed that a firm enjoys positive externalities from only the intra-industry spatial concentration of economic activities, so each city specializes only in one industry. That framework cogently explained the urban productivity premium. It is, however, ill-suited to explain the formation of urban industrial composition.[1] Indeed, some other models of urban system do have taken the production diversity into consideration. Abdel-Rahman and Fujita (1993) introduced inter-industry agglomeration economies into the Henderson (1974) model, illustrating that if intra-industry agglomeration economies[2] dominate the inter-industry agglomeration economies, cities will specialize, if not, they will diversify. Anas and Xiong (2003) further considered the trade costs of manufactures and services, theoretically showing that a lower cost of trading manufactures favors a system of specialized cities, while a high cost of trading services favors a system of diversified cities. However, these models have overwhelmingly described sectoral composition in polarized terms, as noted in Abdel-Rahman and Anas (2004, p. 2313) as follows,

> "If a city contains only one industry, it is referred to as a specialized city; if it contains all of the modeled industries (or at least more than one), it is called a diversified city. All models of city system have either specialized or diversified cities."

In this sense, they lack the implications on the specific industrial compositions of cities, without answering the following question raised by Abdel-Rahman and Anas (2004, p. 2313):

> "Are cities in the system identical in size and in industrial composition or are they different ?"

As far as we know, the study of Davis and Dingel (2014) is the only exception that proposed a multi-sector linking urban sectoral composition to city size and skill composition. Specifically, their model assumed that the individual with higher skill is more productive in the sector with high skill-intensity (the productivity of an individual in a sector is log-supermodular in the individual's skill level and the sector's skill intensity), and hence a sector consists of only the individuals with a certain skill level corresponding to the sector's skill intensity. Then, with the existence of congestion costs, larger cities are skill-abundant and specialize in skill-intensive activities. However, this assumption does not correspond with the empirical findings in Henderics (2011), which showed that 80% of cross-city education gaps are due to within-industry variation and only the remaining 20% are due to industrial specialization. That is, each sector hires individuals with variant skill-levels. Moreover, in Davis and Dingel (2014), all sectors in a city are still assumed to be equally affected by common city-dependent agglomeration economies.[3] Regarding this assumption, however, many empirical studies have confirmed that high-tech industries benefit more from agglomeration economies.

For instance, Henderson et al. (1995) found that the diversity of manufacturing activities encourages growth for high-technology firms but not for machinery industries. Henderson (2003) showed that high-tech industries are more agglomerated than machinery industries and that the number of other plants in the same industry has strong effects on the productivity of high-tech but not machinery industries. Duranton and Puga (2001) showed that innovative industries (research and development (R&D), pharmaceuticals and cosmetics, information technology (IT), consultancy services, and business services) benefit most from urban diversity. Rosenthal and Strange (2003) observed that the magnitude of spillover effects in fabricated metal and machinery industries tends to be approximately only 20% of that in software industries. Porter (1998) argued that the effect of sharing specialized services is more significant in the fields of "advanced and specialized inputs involving embedded technology, information, and service content."

Given that high-tech industries use skilled labor, scientific research and education, and information and communications more intensively than low-tech industries, and that the major channels of agglomeration economies are labor pooling, knowledge spillovers and sharing in specialized services (Duranton and Puga, 2004), it is natural to infer that high-tech industries will rely on agglomeration economies more intensively. In this regard, in light of Davis and Dingel (2014), this paper characterizes industries according to their dependence on agglomeration economies.

Specifically, Section 2 introduces two industries and the industry-specific agglomeration economies into the Henderson model of urban system (1974) to show that cities with larger scale of employment have comparative advantages and specialize in the production of high-tech goods.

To verify the theoretical propositions, Subsection 3 develops an industrial stage index for each industry based on its employment share of engineers, administrative and managerial workers, its input coefficient of scientific research and education, and its input coefficient of information and communications. It then builds an urban industrial stage index for a city based on the city's employment composition and the developed industrial stage index. Regarding this index, we propose some regression equations using the theoretical model, and provide the estimated results and the related interpretations in Section 4. Finally, we conclude the paper in Section 5.

2. A Two-Industry Model of Urban System

Like Henderson (1974), we consider a closed economy with cities where a exogenously given number of national households are free to live in any city. In each city, two tradable goods — high-tech and low-tech goods — are produced, which is different from Henderson (1974). The production of the high-tech goods is supposed to depend on agglomeration economies more intensively than does the production of the low-tech goods. It is also assumed that each household consumes a fixed unit of land and is endowed with one unit of time. Labor supplied by households (net of deductions for the communication costs[4]) is the only production factor, and the wage of labor is equal across industries (because of the homogenous labor).

Each industry consists of homogenous production firms and each firm produces one kind of tradable goods using agglomeration economies that are external to the firm but internal to the city in which it is located.[5] Under this externality specification, each firm views itself as having a production function with constant returns to scale, which ensures the perfect competition.[6)]

In a city, denoted by i, the production activities of individual firms can be represented by the following aggregate production functions for the two industries:

$$HT_i = A_{HTi} L_{HTi} \tag{1}$$

$$LT_i = A_{LTi} L_{LTi} \tag{2}$$

$$A_{HTi} = R_{HTi} L_i^{\alpha_{HT}} \tag{3}$$

$$A_{LTi} = R_{LTi} L_i^{\alpha_{LT}} \tag{4}$$

$$\alpha_{HT} > \alpha_{LT} > 0 \tag{5}$$

where L_i is the aggregate labor supply or total employment in the city. L_{HTi} (L_{LTi}) is the amount of labor inputted in the high-tech (low-tech) industry in city i. Thus, $L_{HTi} + L_{LTi} = L_i$. HT_i (LT_i) is the amount of high-tech (low-tech) goods produced in city i. A_{HTi} (A_{LTi}) represents the labor productivity of the high-tech (low-tech) industry. R_{HTi} (R_{LTi}) is the exogenous first nature of city i for the high-tech (low-tech) industry.[7)] Equations (3) and (4) imply the agglomeration economies (see Duranton and Puga (2004) regarding the micro economic foundations of agglomeration economies), where α_{HT} (α_{LT}) is the intensity of agglomeration economies used in the high-tech (low-tech) industry. In particular, we impose an important assumption that $\alpha_{HT} > \alpha_{LT} > 0$. That is, the high-tech industry benefits more from agglomeration economies than does the low-tech industry.

Since labor is movable across industries, the wage of labor of city i (W_i) will be equal across the two industries, that is:

$$W_{HTi} = W_{LTi} = W_i \tag{6}$$

where W_{HTi} (W_{LTi}) is the wage of the high-tech (low-tech) industry in city i. From Equations (1), (2), (3) and (4), the average production cost of the high-tech goods, denoted by C_{HTi}, and that of the low-tech goods, denoted by C_{LTi}, can be expressed as:

$$C_{HTi} = \frac{W_i}{R_{HTi} L_i^{\alpha_{HT}}} \tag{7}$$

$$C_{LTi} = \frac{W_i}{R_{LTi} L_i^{\alpha_{LT}}} \tag{8}$$

Furthermore, using Equations (7) and (8), the relative production cost of high-tech goods in terms of that of low-tech goods, denoted by C_{HLi}, can be written as:

$$C_{HLi} = \frac{C_{HTi}}{C_{LTi}} = \frac{R_{LTi}}{R_{HTi}} L_i^{\alpha_{LT} - \alpha_{HT}} \tag{9}$$

Differentiating Equation (9) with respect to L_i yields yields $\frac{d(C_{HLi})}{d(L_i)} < 0$, which means that the relative production cost of high-tech goods in terms of that of low-tech goods increases with the city's total employment. Using the comparative advantage theory (Ricardo, 1817), we obtain the following proposition:

Proposition 1. *The more (less) total employment a city has, the larger comparative advantage it will have in the high-tech (low-tech) industry.*

Next, we turn to analyze the consumption. Suppose that every household (consumer) shares the same utility function as follows:

$$U=[(\sum_{j=1}^{M} HT_j^{\frac{\sigma}{\sigma-1}})^{\frac{\sigma-1}{\sigma}}]^{\gamma}[(\sum_{j=1}^{M} LT_j^{\frac{\sigma}{\sigma-1}})^{\frac{\sigma-1}{\sigma}}]^{1-\gamma},\ 0<\gamma<1 \text{ and } \sigma>1 \qquad (10)$$

where HT_j (LT_j) is the consumption amount of high-tech (low-tech) goods produced in city j. γ is the expenditure share of high-tech goods of the consumer, and $1-\gamma$ is that of the low-tech goods. Furthermore, we assume that every household (consumer) has the Armington (1969) type of constant elasticity of substitution (CES) sub-utility function about the two goods. That is, each city produces a differentiated high-tech good and a differentiated low-tech good.[8] σ (>1) represents the elasticity of substitution between any pair of high-tech (low-tech) goods produced in different cities (the elasticity of substitution among high-tech goods is assumed to be equal to that among low-tech goods).

Household's problem of city i is to maximize the utility function subject to a budget constraint, which can be expressed as follows:

$$\begin{aligned}&\mathrm{Max}\,U_i=[(\sum_{j=1}^{M} HT_{ji}^{\frac{\sigma}{\sigma-1}})^{\frac{\sigma-1}{\sigma}}]^{\gamma}[(\sum_{j=1}^{M} LT_{ji}^{\frac{\sigma}{\sigma-1}})^{\frac{\sigma-1}{\sigma}}]^{1-\gamma}\\ &\text{s.t. } Y_i=\sum_{j=1}^{M} HT_{ji}P_{HTji}+\sum_{i=1}^{M} LT_{ji}P_{LTji}\end{aligned} \qquad (11)$$

where Y_i is the aggregate disposable income or total expenditure of city i. HT_{ji} (LT_{ji}) is city i's consumption amount of the high-tech (low-tech) goods produced in city j. P_{HTji} (P_{LTji}) is the price of high-tech (low-tech) goods produced in city j and sold in city i.

Suppose that intercity transport costs take the iceberg form (Krugman, 1991). That is, when transporting one unit of high-tech (low-tech) goods from city i to city j, only a fraction τ_{HTij} (τ_{LTij}) of them arrive, while the rest "melt" during the transporting. So, the price of high-tech (low-tech) goods produced in city j and sold in city i can be written as:

$$P_{HTji}=P_{HTjj}\tau_{HTji},\ 0<\tau_{HTji}<1 \text{ and } \tau_{HTii}=0 \qquad (12)$$

$$P_{LTji}=P_{LTjj}\tau_{LTji},\ 0<\tau_{HTji}<1 \text{ and } \tau_{LTii}=0 \qquad (13)$$

Using Equations (12) and (13), we can see that the first order condition of the maximization problem (11) yields city i's demand amounts for the high-tech goods and the low-tech goods produced in city j as follows, respectively:

$$HT_{ji}=(P_{HTjj}\tau_{HTji})^{-\sigma}\gamma Y_i G_{HTi}{}^{\sigma-1} \tag{14}$$

$$LT_{ji}=(P_{LTjj}\tau_{LTji})^{-\sigma}(1-\gamma)Y_i G_{LTi}{}^{\sigma-1} \tag{15}$$

where G_{HTi} (G_{LTi}) is the price index of high-tech (low-tech) goods sold in city i, which can be written as follows:

$$G_{HTi}=[\sum_{j=1}^{M}(P_{HTjj}\tau_{HTji})^{1-\sigma}]^{\frac{1}{1-\sigma}} \tag{16}$$

$$G_{LTi}=[\sum_{j=1}^{M}P_{LTjj}\tau_{LTji})^{1-\sigma}]^{\frac{1}{1-\sigma}} \tag{17}$$

where P_{HTjj} (P_{LTjj}) is the price of high-tech (low-tech) goods produced in city j and sold locally. Under the perfect competition, the prices equal the local production cost of the high-tech (low-tech) goods, respectively. So, from Equation (7) (Equation (8)), P_{HTjj} (P_{LTjj}) can be expressed as follows:

$$P_{HTjj}=C_{HTj}=\frac{W_j}{R_{HTj}L_j{}^{\alpha_{HT}}} \tag{18}$$

$$P_{LTjj}=C_{LTj}=\frac{W_j}{R_{LTj}L_j{}^{\alpha_{LT}}} \tag{19}$$

Substituting Equation (18) into Equation (16) yields:

$$G_{HTi}=\left[\sum_{j=1}^{M}\left(\tau_{HTji}\frac{W_j}{R_{HTj}L_j{}^{\alpha_{HT}}}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{20}$$

Similarly, substituting Equation (19) into Equation (17) yields:

$$G_{LTi}=\left[\sum_{j=1}^{M}\left(\tau_{LTji}\frac{W_j}{R_{LTj}L_j{}^{\alpha_{HT}}}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{21}$$

Multiplying the demand amounts ((14) and (15)) by the corresponding prices ((12) and (13)) yields city i's nominal demand amounts for the two goods produced in city j, which can be expressed as follows, respectively:

$$Y_{HTji}=\gamma(\tau_{HTji}P_{HTjj})^{1-\sigma}G_{HTi}{}^{\sigma-1}\mathrm{Y}_i \tag{22}$$

$$Y_{LTji}=(1-\gamma)(\tau_{LTji}P_{LTjj})^{1-\sigma}G_{LTi}{}^{\sigma-1}\mathrm{Y}_i \tag{23}$$

where Y_{HTji} (Y_{LTji}) is city i's nominal demand for the high-tech (low-tech) goods produced in city j.

Aggregating each city's nominal demands for the high-tech goods produced in city j (Equation (22)) yields the aggregate nominal demand for the high-tech goods produced in city j (or the total revenue of the high-tech industry in city j), denoted as Y_{HTj}, as follows:

$$Y_{HTj}=\sum_{i=1}^{M}\gamma(\tau_{HTji}P_{HTjj})^{1-\sigma}G_{HTi}{}^{\sigma-1}\mathrm{Y}_i)=\gamma P_{HTjj}{}^{1-\sigma}\sum_{i=1}^{M}(G_{HTi}{}^{\sigma-1}\tau_{HTji}{}^{1-\sigma}\mathrm{Y}_i) \tag{24}$$

Similarly, the aggregate nominal demand for the low-tech goods produced in city j (or the total revenue of high-tech industry in city j), denoted as Y_{LTj}, can be obtained as:

$$Y_{LTj}=(1-\gamma)P_{LTjj}{}^{1-\sigma}\sum_{i=1}^{M}(G_{LTi}{}^{\sigma-1}\tau_{LTji}{}^{1-\sigma}Y_i) \tag{25}$$

Using Equations (24) and (25), the industrial composition in city j can be expressed as follows:

$$\frac{Y_{HTj}}{Y_{LTj}}=\frac{\gamma}{1-\gamma}\left(\frac{P_{HTjj}}{P_{LTjj}}\right)^{1-\sigma}\frac{FMA_{HTj}}{FMA_{LTj}} \tag{26}$$

where $FMA_{HTj}\equiv\sum_{j=1}^{M}(G_{HTi}{}^{\sigma-1}\tau_{HTji}{}^{1-\sigma}Y_i)$ and $FMA_{LTj}\equiv\sum_{j=1}^{M}(G_{LTi}{}^{\sigma-1}\tau_{LTji}{}^{1-\sigma}Y_i)$, which are city j's firm market accesses of the high-tech industry and the low-tech industry, respectively.[9] Due to the perfect competition, each industry's total revenue equals its total labor payment. Additionally, recall that labor wages are equal across industries. So, in city j, the total revenue ratio of the high-tech and low-tech industries equals the employment ratio of them, that is:

$$\frac{L_{HTj}}{L_{LTj}}=\frac{Y_{HTj}}{Y_{LTj}}=\frac{\gamma}{1-\gamma}\left(\frac{P_{HTjj}}{P_{LTjj}}\right)^{1-\sigma}\frac{FMA_{HTj}}{FMA_{LTj}} \tag{27}$$

Substituting the local prices, expressed by Equations (18) and (19), into (27), the employment ratio of the high-tech and low-tech industries can be given as follows:

$$\frac{L_{HTj}}{L_{LTj}}=\frac{\gamma}{1-\gamma}\left(\frac{R_{LTj}}{R_{HTj}}L_j{}^{\alpha_{LT}-\alpha_{HT}}\right)^{1-\sigma}\frac{FMA_{HTj}}{FMA_{LTj}} \tag{28}$$

Equation (28) can be further manipulated to yield the following share of the high-tech industry in the total employment of the city:

$$\frac{L_{HTj}}{L_j}=\frac{L_{HTj}}{L_{HTj}+L_{LTj}}=\frac{\frac{\gamma}{1-\gamma}\left(\frac{R_{LTj}}{R_{HTj}}L_j{}^{\alpha_{LT}-\alpha_{HT}}\right)^{1-\sigma}\frac{FMA_{HTj}}{FMA_{LTj}}}{\frac{\gamma}{1-\gamma}\left(\frac{R_{LTj}}{R_{HTj}}L_j{}^{\alpha_{LT}-\alpha_{HT}}\right)^{1-\sigma}\frac{FMA_{HTj}}{FMA_{LTj}}+1} \tag{29}$$

Given that $\alpha_{LT}-\alpha_{HT}<0$ and $1-\sigma<0$, we can prove that $\dfrac{d\left(\frac{L_{HTj}}{L_j}\right)}{dL_j}>0$. So we obtain the following proposition.

Proposition 2. *Given the first nature and firm market accesses for the high-tech and low-tech industries, the more total employment a city has, the larger employment share the high-tech industry will have.*

In the model of Davis and Dingel (2014), it is shown that the land price of a location in a larger city is higher than that of a similar location (e. g., with similar distance to CBD) in a smaller city. Since the higher land price must be compensated for by the saving of commuting cost (in proportion to the distance to CBD and the skill-specific wage), the labor in a larger city will have a higher skill level than the labor locating in a similar location in a smaller city. That is, large cities will have a *factor-driven comparative advantage in skill-intensive industries*. Different from their model, this paper focuses on the role of the agglomeration economies. So, we show that the city with a larger total employment will be more attractive to the high-tech industries, which depend more intensively on agglomeration economies. The clarification of the relationship between urban agglomeration and the level of industrial upgrading can be considered a contribution to the literature of urban economics.

3. Data and Estimation Methods

3.1 The Industrial Stage Index and Urban Industrial Stage Index

To empirically verify Proposition 2, we need to quantify the employment share of high-tech activities in cities. In this regard, we first quantify the industrial stage for these activities.

To compile statistics on high-tech activities, EU uses the index of *technological intensity* (R&D expenditure/value added)[10] to classify manufacturing industries of low-technology and high-technology. However, this classification has the following two defects. (a) Besides the R&D expenditure, input intensities regarding skilled labor and IT are also important in the industrial upgrading and should be considered in the evaluation of an industry's industrial stage. *OECD Science, Technology and Innovation Outlook 2016* showed that IT industries have a significant influence on the modern global economy. Ozawa (2005) and Baumol (2002) noted that modern economic growth was driven by the IT-related industries. In addition, Moretti (2012) accentuated the role of human capital in urban industrial upgrading. For these reasons, the input intensities regarding information and communications and skilled labor should be taken into consideration. (b) EU only classifies manufacturing industries, without the consideration of service industries. In fact, service industries account for the largest proportion in the modern global economy, especially in urban areas. In this sense, service industries should be included in the evaluation of urban industrial upgrading. In this regard, this paper develops an industrial stage index for two-digit industries (including agriculture industries and service industries) using the following three factors, (i) input intensity of scientific research and education, (ii) input intensity of information and communications, and (iii) employment shares of engineers, administrative and managerial workers. The three components of the industrial stage index also correspond to the well-known three channels of agglomeration economies, i. e., knowledge spillover, sharing of specialized service and labor pooling. Thai is, high-tech industries benefit more from agglomeration economies.

Specifically, to define the industrial stage index (IS_k) for industry k, we average the standardized values of its employment share of engineers, administrative and managerial workers, its input coefficient of scientific research and education, and its input coefficient of information and communications.[11] Specifically, the industrial stage index (IS_k) is constituted as follows:

$$IS_k = \left(\frac{R\&D_k}{\overline{R\&D}} + \frac{IT_k}{\overline{IT}} + \frac{SL_k}{\overline{SL}} \right) / 3 \quad (30)$$

where $R\&D_k$ is the input coefficient of education and scientific research of industry k; IT_k is the input coefficient of information and communications, and SL_k is the employment share of engineers, administrative and managerial workers of the industry. $\overline{R\&D}$, $\overline{I\&C}$, and $\overline{SL}$ are the averages of these coefficients and shares of all industries. That is, $\overline{R\&D} = \frac{\sum_k R\&D_k}{35}$, $\overline{I\&C} = \frac{\sum_k I\&C_k}{35}$, $\overline{SL} = \frac{\sum_k SL_k}{35}$, where 35 is the total number of all industries. The data are collected from the 2014 Labor Force Survey for Japan and the Input-Output Tables for Japan (2011). The details of the industrial stage index calculated for these industries are given in Table 1.

Ozawa (2005, pp. 14-15) analyzed the process of industrial upgrading using the following five Tiers (Stages):

Tier I "Heckscher-Ohlin" endowment-driven industries (textiles)→

Tier II "nondifferentiated Smithian" scale-driven industries (steel and chemicals)→

Tier III "differentiated Smithian" assembly-based industries (automobiles)→

Tier IV "Schumpeterian R&D-driven industries" (microchips and computers)→

Tier IV-A "McLuhan" internet-based industries (information).

The industrial stage index defined seems to well reflect Ozawa's analysis. It is also in line with OECD classification of manufacturing industries in terms of low-tech and high-tech activities. In this regard, the industrial stage index developed in this paper can be considered an appropriate indicator that reflects intensity in high-tech activities.

With the calculated industrial stage index, we build an urban industrial stage index (UIS) by adding up the product of an industry's employment share of a city and its industrial stage index to represent the city's intensity in high-tech activities, which is written as follows:

$$UIS_i = \sum_k IS_k * ES_{ki} \quad (31)$$

Table 1 The details of the industrial stage index calculated for all industries

Names of industry	SL_k	$R\&D_k$	IT_k	IS_k
Information and communications	0.616	0.019	0.152	4.425
Manufacture of information and communication electronics equipment	0.286	0.072	0.022	2.324
Scientific research and education	0.733	0.003	0.024	2.126
Manufacture of chemical and allied products	0.197	0.080	0.012	2.073
Business services	0.219	0.003	0.072	1.820
Electronic parts, devices and electronic circuits	0.180	0.069	0.010	1.811
Manufacture of business oriented machinery	0.222	0.065	0.008	1.801
Manufacture of electrical machinery, equipment and supplies	0.188	0.057	0.013	1.663
Medical, health care and welfare	0.495	0.003	0.014	1.422
Manufacture of production machinery	0.171	0.036	0.011	1.208
Finance and insurance	0.058	0.001	0.059	1.197
Manufacture of transportation equipment	0.127	0.040	0.003	1.052
Water supply	0.138	0.000	0.041	1.052
Manufacture of general-purpose machinery	0.143	0.026	0.008	0.926
Wholesale and retail trade	0.054	0.003	0.040	0.892
Manufacture of plastic and rubber products	0.079	0.024	0.006	0.715
Electricity, gas, heat supply	0.138	0.007	0.012	0.656
Manufacture of non-ferrous metals and products	0.125	0.016	0.004	0.639
Manufacture of ceramic, stone and clay products	0.065	0.020	0.007	0.630
Miscellaneous manufacturing industries	0.071	0.015	0.007	0.548
Manufacture of textile mill products	0.055	0.016	0.007	0.520
Personal services	0.039	0.001	0.020	0.456
Manufacture of fabricated metal products	0.064	0.009	0.006	0.416
Construction	0.095	0.002	0.009	0.407
Manufacture of pulp, paper and wood products	0.055	0.007	0.006	0.353
Mining	0.000	0.009	0.010	0.333
Real estate	0.105	0.000	0.004	0.309
Transport and postal activities	0.027	0.002	0.011	0.304
Manufacture of food and beverage	0.034	0.006	0.005	0.279
Waste disposal business	0.031	0.000	0.010	0.251
Manufacture of iron and steel	0.042	0.007	0.002	0.250
Agriculture, forestry and fisheries	0.009	0.001	0.003	0.096
Manufacture of petroleum and coal products	0.000	0.002	0.001	0.047

Notes: Industries are ranked based on the industrial stage index (IS_k).

where ES_{ki} is the employment share of industry k in city i. ES_{ki} means the value of $\frac{L_{ki}}{L_i}$, where L_{ki} is the employment amount of industry k in city i, and L_i is the total employment of city i. If a city specializes completely in the information and communications industry, it will be standing at the highest industrial stage, with the highest value of UIS equal to 4.425. In contrast, if a city specializes completely in the manufacturing of petroleum and coal products, it will remain at the lowest industrial stage, with the lowest value of UIS equal to 0.047 (See Table 1). Since the UIS reflects a city's employment share of high-tech activities, in the following subsection, it will be used as the dependent variable, corresponding to the term of $\frac{L_{HTi}}{L_i}$ in Equation (29).

In the exist literature, industrial structural transformation generally refers to the reallocation of economic activity across the broad sectors such as agriculture, manufacturing and services.[12] Although such reallocation coincides with the process of economic growth, it cannot reflect the technological upgrading very well.[13] As far as we know, this paper could be considered as the first attempt to explicitly quantify a city's industrial employment share of the high-tech activities. The UIS developed in this paper can be used in the evaluation of urban industrial composition and related industrial upgrading policies.

3.2 The Explanatory Variables and Estimation Functions

From Equation (29), we know that the employment share of high-tech industries of a city (represented by the UIS) is a nonlinear function of the city's agglomeration scale (L_j), firm market accesses of high-tech and low-tech industries $\left(\frac{FMA_{HTj}}{FMA_{LTj}}\right)$, and the city's first natures provided for high-tech and low-tech industries $\left(\frac{R_{LTj}}{R_{HTj}}\right)$. Our focus is on the effect of urban agglomeration. We begin to search the proxies for these factors.

First, we look for the proxy for urban agglomeration. Generally, there have been two measures for urban agglomeration: (a) total employment or population and (b) employment or population density (Melo et al., 2009). The initial and common approach was to use total population and employment (e. g., Aberg, 1973; Sveikauskas, 1975; Moomaw, 1981; Moomaw, 1983; Moomaw, 1985; Nakamura, 1985; Sveikauskas et al., 1988; Zheng, 2001) to represent the level of urban agglomeration. Ciccone and Hall (1996) and Zheng (2007) introduced the use of employment density and/or population density. Ciccone and Hall illustrated that density is a better measurement than the total number since it represents the intensity of labor and human capital relative to physical space. However, Combes and Gobillon (2015, p. 24) noted that both of the measures are important.

Here, we use both of total employment (em) and employment density (ed) to represent Urban agglomeration. We expect the effects of them to be positive for the UIS since it increases with agglomeration economies, as shown in Equation (29).

Second, we use four indicators to control for the effects of firm market accesses (FMA_{HTi} and FMA_{LTi}). They are the city's port accessibility (pa), airport accessibility (aa), high-speed railway station (hr), and location in any metropolitan areas (kantome, kinkime, nagoyame, otherme). Concerning the first nature effects, the city's administrative property (whether is a designated city or not (dec)) will be used.

From the above discussion, we can define the following two basic estimation functions, in which except for dummy variables, all variables take the log value:

$$lnUIS=\alpha*lnem+\beta*lnpa+\gamma*lnaa+\delta*lnhr+\varepsilon*kantome$$
$$+\epsilon*kinkime+\theta*nagoyame+\mu*otherme+\varphi*dec+\alpha_0+\varepsilon_1 \quad (32)$$
$$lnUIS=a*lned+b*lnpa+c*lnaa+d*lnhr+e*kantome$$
$$+f*kinkime+g*nagoyame+h*otherme+i*dec+a_0+\varepsilon_2 \quad (33)$$

where the signs of α and a are expected to be positive. α_0 and a_0 are intercept terms, and ε_1 and ε_2 are error terms.

Furthermore, as Davis and Dingel (2014) modeled, intercity gaps of land prices and wages generate factor driven comparative advantage. To distinguish the effects of urban agglomeration from those of land price and wages, the city's average land price (lp) and annual incomes of taxpayers (in) will also be introduced in the extended versions of the above functions. We use two-period panel data (year 2006 and 2009) on 266 Japanese cities with total employment larger than 30,000 in the year 2006 (The cities having administrative area change during the period are excluded). The details of all the variables in (32) and (33) are given in the Appendix.

4. Estimated Results

Table 2 presents the estimated results concerning the regression functions (32) and (33) and their extended versions using Ordinary Least Squares (OLS).

Columns (1) and (4) correspond to the basic regression functions (32) and (33). In Columns (2) and (5), annual incomes of taxpayers are introduced. In Columns (3) and (6), land prices are further added. Columns (1), (2) and (3) focus on the effect of total employment (em), Columns (4), (5) and (6) represent the effect of employment density (ed).

All of the estimated results show the coefficients of urban agglomeration (i. e., lnem and lned) are significantly positive. Thus, the core proposition of this paper, that is, urban agglomeration (reflected by total employment or employment density) positively contributes to the urban industrial upgrading (reflected by the urban industrial stage index), is confirmed. In other words, a percentage of increase in total employment (employment density) increases the urban industrial stage index by 0.018-0.050% (0.017-0.041%), ceteris paribus.

Moreover, Columns (2), (3), (5) and (6) indicate the coefficients of annual incomes of taxpayers (i. e., lnin) are significantly positive, but average land price (i. e., lnlp) are not. In this sense, the theoretical model developed in this paper can be considered as a sound basis to study the effects of urban agglomeration on the industrial upgrading in Japan, which seems to be able to explain the mechanism of urban industrial upgrading better than the model of Davis and Dingel (2014), which focuses on the effects of land price and

Table 2 Estimated results of the urban industrial stage (UIS)

	(1)	(2)	(3)	(4)	(5)	(6)
Explanatory Variables	lnUIS	lnUIS	lnUIS	lnUIS	lnUIS	lnUIS
Intercept	−1.022*** (−6.24)	−4.932*** (−11.06)	−4.622*** (−9.75)	−0.555*** (−4.46)	−4.416*** (−9.22)	−4.328*** (−9.88)
lnem	0.050*** (5.06)	0.023** (2.41)	0.018* (1.81)			
lned				0.041*** (6.87)	0.021*** (3.34)	0.017** (2.42)
lnin		0.596*** (9.29)	0.532*** (7.37)		0.553*** (8.31)	0.526*** (7.29)
lnlp			0.024 (1.91)			0.014 (0.99)
lnpa	0.015 (0.85)	0.000 (0.00)	−0.004 (−0.24)	0.011 (0.65)	−0.001 (−0.05)	−0.003 (−0.18)
lnaa	0.015 (0.83)	−0.012 (−0.70)	−0.008 (−0.46)	0.008 (0.49)	−0.013 (−0.78)	−0.010 (−0.62)
hr	−0.004 (−0.21)	−0.002 (−0.13)	−0.004 (−0.21)	0.014 (0.78)	0.007 (0.39)	0.005 (0.27)
kantome	−0.014 (−0.66)	−0.080*** (−3.81)	−0.091*** (−4.91)	−0.077*** (−3.38)	−0.107*** (−4.92)	−0.109*** (−5.00)
kinkime	−0.040* (−1.94)	−0.076*** (−3.87)	−0.083*** (−4.18)	−0.094*** (−4.41)	−0.100*** (−4.98)	−0.101*** (−5.00)
nagoyame	0.006 (0.19)	−0.055* (−1.88)	−0.050* (−1.69)	−0.040 (−1.28)	−0.074** (−2.51)	−0.068** (−2.26)
otherme	−0.014 (−0.63)	−0.037* (−1.73)	−0.036* (−1.70)	−0.041* (−1.84)	−0.048** (−2.30)	−0.046** (−2.19)
dec	−0.029 (−0.81)	−0.048 (−1.45)	−0.051 (−1.52)	0.001 (0.04)	−0.032 (−1.08)	−0.034 (−1.16)
Year 2006	0.049*** (4.39)	0.043*** (4.10)	0.043*** (4.17)	0.050*** (4.56)	0.044*** (4.21)	0.044*** (4.22)
Number of observations	532	532	532	532	532	532
R^2	0.159	0.264	0.267	0.191	0.271	0.271

Notes: t values are in parentheses. ***, ** and * indicate significance at the levels of 1%, 5% and 10%, respectively. Except for the dummy variables, all variables use the log values.

wage of labor.

Unfortunately, the coefficients of port accessibility (i. e., lnpa) and airport accessibility (i. e., lnaa) are not significant.

The coefficients of high-speed railway dummy (i. e., hr) are neither significant. This result is contrary to the common sense that the connection to high-speed railway stations stimulates knowledge spillover and innovation (Inoue et al, 2017). One explanation for this result could be that the connection to high-speed railway stations attracts rather low-tech service activities such as personal services and wholesale and retail trade than high-tech activities. But, this interpretation requires further analysis, which is beyond the scope of this paper.

The coefficients of all the metropolitan area dummies have negative signs in all of the regressions. Most coefficients of the two largest metropolitan area dummies (i. e., kantome and kinkime) are significant at the 1% level. That is, the cities located in larger metropolitan areas (especially Tokyo and Osaka) tend to have lower urban industrial stage indexes, ceteris paribus. Two explanations could be considered. (a) A periphery city's closer connection to a metropolis may lead to the movement of skilled-labor and high-tech activities from it to the metropolis because they could benefit more from urban agglomerated economies. Faber (2014) and Qin (2017) showed that the improvement of transportation led to a reduction in GDP growth in peripheral counties in China. (b) A better transportation network between metropolis and peripheral counties would cause the relocation of the low-tech but land-intensive activities from the metropolis to peripheral counties. Baum-Snow et al (2017) found that the construction of transportation facilities decentralizes service and manufacturing activities away from the central city to suburban regions.

5. Conclusion

This paper presented a two-industry model of urban system to show that urban agglomeration (reflected by total employment or employment density) contributes to the industrial upgrading, because high-tech industries benefit more from agglomeration economies. To verify this theoretical conclusion, we developed an industrial stage index using the industry's employment share of engineers, administrative and managerial workers, input coefficient of education and scientific research, and input coefficient of information and communication. Based on it, we defined an urban industrial stage index (UIS) by adding up the product of an industry's employment share of a city and its industrial stage index, to reflect the city's intensity in high-tech activities. Regression functions based on the theoretical conclusion were estimated via OLS using city-level data from Japan's economic census. The estimated results showed that a percentage of increase in total employment (employment density) increases the urban industrial stage index by 0.018%-0.050% (0.017%-0.041%), ceteris paribus.

The present paper indicated the importance of urban employment agglomeration in the industrial upgrading process. This implies that to keep the industrial upgrading in cities, it is needed to allow population agglomerate in larger cities and to centralize population.

Moreover, the findings of this paper could be applied to explaining the failure of Japan's 'technopolis' project.[14] As Ozawa (2005, p. 99) noted:

> "The technopolises were soon found to be incapable of attaining the critical mass needed to generate the *agglomeration effect*."

The reason of the failure, i. e., the lack of agglomeration economies, was also accentuated by Tatsuno (1990, p. 97) using the following words:

> "Another setback was that regional governments initially focused their effects on 'hard' infrastructure projects, such as roads, airports, and highways, and underestimated the difficulty of developing the 'soft' infrastructure of R&D consortia, venture capital funds, and university research needed to drive the engineers who still prefer to live and work in the Tokyo area, whose wealth of educational and culture resources attracts 80 percent of the nation's researchers. Unlike Tokyo or Silicon Valley, the technopolises are not beneficiaries of a natural flow of people and jobs."

Similarly, the failure of the "regional research core" program[15)] is another example. In fact, the main aim of these projects and programs was to disperse industrial concentration away from overcrowded Tokyo, promoting better allocation of industrial activities throughout the country for both environmental and economic efficiency reasons. However, due to the failure of considering the agglomeration economies, dispersion of economic activity may have impeded the industrial upgrading in Japan. These are the policy implications based on the theoretical and empirical results of this paper.

Appendix. The Descriptions of the Variables

Table A The definitions of variables and sources of data

UIS	The urban industrial stage of a city, defined in Equation (31)	*Japan Economic Census for Business Frame, years 2006, 2009*
em	Total employment (employed in privately owned establishments) in a city	*Japan Economic Census for Business Frame, years 2006, 2009*
ed	Total employment per total administrative area	*Japan Economic Census for Business Frame, years 2006, 2009*
in	The annual incomes of taxpayers	*Investigation of Taxation of Municipality, years 2006, 2009*
lp	Average land price of all kinds of usage in a city	*Average price and average change to previous year of use-specific land of municipalities and prefecture, years 2006, 2009*
aa	The summation of the passengers of the five international airports divided by the distances between them and the city hall of the city in question. See Equation (A. 6)	*Investigation of Airport, years 2006, 2009*
pa	The summation of the trade values of the five international ports divided by the distances between them and the city hall of the city in question. See Equation (A. 8).	*Port Statistics, years 2006, 2009*
hr	Be 1 if the city in question has at least one Shinkansen station within its administrative area in year 2006 and 2009, or be 0 otherwise	*Wikipedia pages of on 266 observation cities, Wikipedia pages of shinkansen, the history graph of shinkansen, year 2017*
dec	Be 1 if the city in question is a designated city in year 2017, or be 0 otherwise	*Wikipedia page on Cities designated by government ordinance for Japan, year 2017*
kantome	Be 1 if the city in question (except designated cities) is in Kanto metropolitan area in year 2013, or be 0 otherwise	*Names of Shi, Machi and Mura of Major Metropolitan Areas, year 2013*
kinkime	Be 1 if the city in question (except designated cities) is in Kinki metropolitan area in year 2013, or be 0 otherwise	*Names of Shi, Machi and Mura of Major Metropolitan Areas, year 2013*
chukyome	Be 1 if the city in question (except designated cities) is in Chukyo metropolitan area in year 2013, or be 0 otherwise	*Names of Shi, Machi and Mura of Major Metropolitan Areas, year 2013*
otherme	Be 1 if the city in question (except designated cities) is in the other metropolitan areas (except Kanto, Kinki, Chukyo) in year 2013, or be 0 otherwise	*Names of Shi, Machi and Mura of Major Metropolitan Areas, year 2013*

$$aa_i=\sum_{a=1}^{5}\frac{total\ passengers\ in\ 2015_a}{distance_{ia}} \tag{A.6}$$

where *total passengers in* 2015_a is the total passengers (person) of one of the five international airports (Narita International Airport, Tokyo International Airport, Chubu International Airport, Osaka International Airport, Kansai International Airport) in year 2015. $distance_{ia}$ is the distance between the city hall of city i and international airport a, which is calculated by the following spherical law of cosines:

$$distance_{ia}=6371\times\arccos[\sin lat_i\times\sin lat_a+\cos lat_i\times\cos lat_a\times\sin(lon_i-lon_a)] \tag{A.7}$$

where 6371 is the mean earth radius (6371 km), lat_i is latitude in radians of the city hall of city i, lon_i is longitude in radians of it. lat_a is latitude in radians of airport a and lon_a is the longitude in radians of it. The data are collected from the Wikipedia pages on the 266 cities and the five international airports.

$$pa_i=\sum_{p=1}^{5}\frac{total\ trade\ value\ in\ 2015_p}{distance_{ip}} \tag{A.8}$$

where *total trade value in* 2015_p is the total trade value (billion yen) of Port p of the five major ports (Port of Tokyo, Port of Yokohama, Port of Nagoya, Port of Osaka, Port of Kobe) in year 2015, and $distance_{ip}$ is the distance between the city hall of city i and Port p, which is calculated similarly using Equation (A.7).

Notes

1) In another vein of regional economics, Fujita et al. (1999, pp. 181-213) extended the canonical New Economic Geography model of Krugman (1991) to a "hierarchical urban system", which shows that a city with a larger size does everything a smaller city does, and more. However, their model focuses on the inter-city interaction and does not take account of internal city structure when dealing with city systems.
2) Generally, the intra- and inter-industry externalities are called localization economies and urbanization economies, respectively (See Rosenthal and Strange (2004) for a literature review).
3) In their model, city-dependent agglomeration economies (reflected by the total employment in the city) are embedded in production functions as a common multiplier; therefore, the elasticity of city size to productivity is equal across all economic sectors with different skill intensities.
4) See Abdel-Rahman and Anas (2004).
5) See Chipman (1970) and Henderson (1974).
6) See Chipman (1970, pp. 347-350).
7) Gonzalez-Val and Pueyo (2010) defined first nature as follows: "There are many factors influencing the distribution of economic activity. It is traditional to distinguish between characteristics linked to the physical landscape, such as temperature, rainfall, access to the sea,

the presence of natural resources or the availability of arable land, and factors relating to human actions and economic incentives (for example, scale economies or knowledge spillovers). The first group of factors, related to natural geographical circumstances, are called 'first nature causes', and the second group are called 'second nature causes'." Their definition is close to the meaning of first nature referred in this paper.

8) The Armington (1969) assumption is widely used in New Trade Theory, New Economic Geography, and urban systems models [see Overman, Redding and Venables (2003) and Head and Mayer (2004) for reviews].

9) The expression of firm market access is drawn from Redding and Sturn (2008, p. 1772).

10) See http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:High-tech_classification_of_manufacturing_industries

11) The industrial classification and input coefficients are based on the Input-Output Tables for Japan (2011).

12) See Herrendorf et, al (2013) for a review.

13) Just consider the tourist cities/countries, which have large shares in the service sector but have low intensities in technological activities.

14) The technopolis project was initiated in 1984 under the Technopolis Law of 1983. It was designed to set up twenty 'technopolises' across Japan's archipelago corridor. Each technopolis is an integrated complex of high-tech industries, research universities, local supporting industries, housing, and communications and transportation facilities, a high-tech cluster that engenders economies of linkage and agglomeration.

15) The regional research core project was introduced by MITI (Ministry of International Trade and Industry) in 1986. Twenty-eight core clusters were set up at the end of 1980s. However, they failed to create the intended viable research clusters, since business services and amenities are not available in those isolated rural locations chosen by the MITI's regional research core project (Ozawa 2005, pp. 99-101).

Reference

Abdel-Rahman, H. M. (1996) "Why Do Cities Specialize in Production ?", *Regional Science and Urban Economics*, Vol. 26, pp. 1-22.

Abdel-Rahman, H. M. and Anas, A. (2004) " Theories of Systems of Cities", *Handbook of Regional and Urban Economics*, Vol. 4, Ch. 52, pp. 2293-2339.

Abdel-Rahman, H. M. and Fujita, M. (1993) "Specialization and Diversification in a System of Cities", *Journal of Urban Economics*, Vol. 33, pp. 258-276.

Aghion, P. and Howitt, P. (1990) "A Model of Growth through Creative Destruction", *NBER WORKING PAPER SERIES*, No. w3223.

Anas, A. and Xiong, K. (2003) "Intercity Trade and the Industrial Diversification of Cities", *Journal of Urban Economics*, Vol. 54, pp. 258-276.

Andini, M., Blasio, G., Duranton, G., and Strange, W. C. (2013) "Marshallian Labour Market Pooling: Evidence from Italy", *Regional Science and Urban Economics*, Vol. 43, pp. 1008-1022.

Armington, P. (1969) "A Theory of Demand for Products Distinguished by Place of Production", *International Monetary Fund Staff Papers* XVI, pp. 159-178.

Baumol, W. J. (2002) *The Free-Market Innovation Machine; Analyzing the Growth Miracle of Capitalism*, New Jersey: Princeton University Press.

Baum-Snow, N. and Pavan, R. (2013) "Inequality and City Size", *Review of Economics and Statistics*, Vol. 95, pp. 1535-1548.

Carlino, G. and Kerr, W. R. (2015) "Agglomeration and Innovation", *Handbook of Regional and Urban Economics*, Vol. 5, Ch. 6, pp. 349-404.

Chipman, J. S. (1970) "External Economies of Scale and Competitive Equilibrium", *Quarterly Journal of Economics*, Vol. 84, pp. 347-385.

Combes, P., Gobillon. L. (2015) "The Empirics of Agglomeration Economies", *Handbook of Regional and Urban Economics*, Vol. 5, Ch. 5, pp. 247-348.

Davis, D. R. and Dingel, J. I. (2014) "The Comparative Advantage of Cities", *NBER WORKING PAPER SERIES*, No. w20602.

Di Addario, S. (2011) "Job Search in Thick Markets", *Journal of Urban Economics*, Vol. 69, pp. 303-318.

Duranton, G. and Puga, D. (2000) "Diversity and Specialization in Cities: Why, Where and When Does it Matter ?", *Urban Studies*, Vol. 37, pp. 533-555.

—— (2001) "Nursery Cities: Urban Diversity, Process Innovation, and the Life Cycle of Products", *The American economic Review*, Vol. 91, pp. 1454-1477.

—— (2004) "Micro-foundations of Urban Agglomeration Economies", *Handbook of Regional and Urban Economics*, Vol. 4, Ch. 48, pp. 2063-2117.

—— (2004) "From Sectoral to Functional Urban Specialization", *Journal of Urban Economics*, Vol. 57, pp. 343-370.

Ellison, G., Glaeser, E. L. and Kerr, W. R. (2010) "What Causes Industry Agglomeration ? Evidence from Coagglomeration Patterns", *The American Economic Review*, Vol. 100, pp. 1195-1213.

Faber, B. (2014) "Trade Integration, Market Size, and Industrialization: Evidence from China's National Trunk Highway System", *Review of Economic Studies*, Vol. 81, pp. 1046-1070.

Feldman, M. (2008) "Job Hopping, Earnings Dynamics, and Industrial Agglomeration in the Software Publishing Industry", *Journal of Urban Economics*, Vol. 64, pp. 590-600.

Fujita, M., Krugman, P. and Venables, A. J. (1999) *The Spatial Economy: Cities, Regions, and International Trade*, MIT: MIT Press.

González-Val, R. and Pueyo, F (2010) "First Nnature vs. Second Nature Causes: Industry Location and Growth in the Presence of an Open-access Renewable Resource", *EB Working Paper*, No. 2010/39.

Grossman, G. M. and Helpman, E. "Quality Ladders in the Theory of Growth", *The Review of Economic Studies*, Vol. 58, pp. 43-61.

Head, K., Mayer, T. (2004) "The Empirics of Agglomeration and Trade", *Handbook of Regional and Urban Economics*, Vol. 4, Ch. 59, pp. 2609-2669.

Hendrics, L. (2011) "The Skill Composition of U. S. Cities", *International Economic Review*, Vol. 52, pp. 1-32.

Henderson, J. V. (1974) "The Sizes and Types of Cities", *The American Economic Review*, Vol. 64, pp. 640-656.

—— (1997) "Medium Size Cities", *Regional Science and Urban Economics*, Vol. 27, pp. 583-612.

—— (2003) "Marshall's Scale Economies", *Journal of Urban Economics*, Vol. 53, pp. 1-28.

Henderson, J. V., Kuncoro, A. and Turner, M. (1995) "Industrial Development in Cities", *Journal of Political Economy*, Vol. 103, pp. 1067-1090.

Herrendorf, B., Rogerson, R. and Valentinyi, Á. (2013) "Growth and Structural Transformation", *NBER WORKING PAPER SERIES*, No. w18996.

—— (1999) "Regions, Resources, and Economic Geography: Sources of U. S. Regional Comparative

Advantage, 1880-1987", *Regional Science and Urban Economics*, Vol. 29, pp. 1-32.

Inoue, H., Nakajima, N., and Umeno, S. (2017) "The Impact of the Opening of High-Speed Rail on Innovation", *RIETI Discussion Paper Series*, No. 17-E-034.

Krugman, P. (1991) "Increasing Returns and Economic Geography", *Journal of Political Economy*, Vol. 99, pp. 483-499.

Melo, P. C., Graham, D. J., and Noland, R. B. (2009) "A Meta-analysis of Estimates of Urban Agglomeration Economies", *Regional Science and Urban Economics*, Vol. 39, pp. 332-342.

Moomaw, R. L., (1981) "Productivity and City Size: A Critique of the Evidence", *Quarterly Journal of Economics*, Vol. 96, pp. 675-688.

—— (1983) "Is Population Scale a Worthless Surrogate for Business Agglomeration Economies?", *Regional Science and Urban Economics*, Vol. 13, pp. 525-545.

—— (1985) "Firm Location and City Size: Reduced Productivity Advantages as A Factor in the Decline of Manufacturing in Urban Areas", *Journal of Urban Economics*, Vol. 17, pp. 73-89.

Moretti, E. (2012) *New Geography of Jobs*, New York: Houghton Mifflin Harcout Press.

Nakamura, R. (1985) "Agglomeration Economies in Urban Manufacturing Industries: A Case for Japanese Cities", *Journal of Urban Economics*, Vol. 17, pp. 108-124.

OECD (2016) *OECD Science, Technology and Innovation Outlook 2016*, OECD publishing, Paris.

Ozawa, T. (2005) *Institutions, Industrial Upgrading, and Economic Performance in Japan*, Massachusetts: Edward Elgar Press.

Porter, M. (1990) *The Competitive Advantage of Nations*. New York: The Free Press.

—— (1998) "Clusters and the New Economics of Competition", *Harvard Business Review*, November-December, pp. 77-90.

Qin, Y. (2017) "'No County Left Behind?' The Distributional Impact of High-speed Rail Upgrades in China", *Journal of Economic Geography*, Vol. 17, pp. 489-520.

Redding, S. J. and Sturm, D. M. (2008) "The Costs of Remoteness: Evidence from German Division and Reunification", *The American Economic Review*, Vol. 98, pp. 1766-1797.

Ricardo, D. (1817) *The Principles of Trade and Taxation*. London: John Murray Press.

Rosenthal, S. and Strange, W. C. (2004) "Evidence on the Nature and Sources of Agglomeration Economies", *Handbook of Regional and Urban Economics*, Vol. 4, Ch. 49, pp. 2119-2171.

Rosenthal, S. and Strange, W. C. (2003) "Geography, Industrial Organization, and Agglomeration", *Review of Economics and Statistics*, Vol. 85, pp. 377-393.

Schumpeter, J. A. (1942) *Capitalism, Socialism and Democracy*, New York: Harper&Row press.

Sveikauskas, L. (1975) "The Productivity of Cities", *The Quarterly Journal of Economics*, Vol. 89, pp. 393-413.

Sveikauskas, L., Gowdy, J. and Funk, M. (1988) "Urban Productivity: City Size or Industry Size?", *Journal of Regional Science* Vol. 28, pp. 185-202.

Tatsuno, S. M. (1990) *Created in Japan: From Imitators to World-Class Innovators*, New York: Ballinger Press.

Wheeler, C. (2001) "Search, Sorting, and Urban Agglomeration", *Journal of Labor Economics*, Vol. 19, pp. 879-99.

Zheng, X.-P. (2001) "Determinants of Agglomeration Economies and Diseconomies: Empirical Evidence from Tokyo", *Socio-Economic Planning Sciences*, Vol. 35, pp. 131-144.

Zheng, X.-P. (2007) "Economies of Network, Urban Agglomeration, and Regional Development: A Theoretical Model and Empirical Evidence", *Regional Studies*, Vol. 41, pp. 559-569.

Data Sources

(1) *Input-Output Tables for Japan, Years 1985, 1990, 1995, 2000, 2011,* Ministry of Internal Affairs and Communications http://www.soumu.go.jp/toukei_toukatsu/data/io/ichiran.htm

(2) *Labor Force Survey for Japan, Year 2014,* Ministry of Internal Affairs and Communications, http://www.e-stat.go.jp/

(3) *Population Census, Year 2015,* Ministry of Internal Affairs and Communications, http://www.e-stat.go.jp/

(4) *Economic Census for Business Frame for Japan, Years 1996, 2001, 2006, 2009,* Statistics Bureau, Ministry of Internal Affairs and Communications, http://www.stat.go.jp/data/ecensus/2014/kekka.htm

(5) *Annual Survey of Management Conditions of Airports* Ministry of Land, Infrastructure, Transport and Tourism, http://www.mlit.go.jp/common/001250438.xlsx

(6) *Port Statistics, Years 2006, 2009,* http://www.e-stat.go.jp/

(7) *Average Price and Average Change to Previous Year of Use-specific Land of Municipalities and Prefecture Graph, Year 2014,* Land Information Center, http://www.lic.or.jp/landinfo/pdf/kouji/K2014.pdf

(8) *Names of Shi, Machi and Mura of Major Metropolitan Areas, Year 2013,* Ministry of Internal Affairs and Communications, http://www.stat.go.jp/data/jyutaku/2013/pdf/daitoshi-i.pdf