Working Paper

Inter-regional Transportation and Economic Development: A Case Study of Regional Agglomeration Economies in Japan

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Abstract.

This study investigates the benefit from transportation to economy through agglomeration. We analyze empirically the impacts of agglomeration on regional economic return using an econometric approach assuming three types of agglomeration economics: localization agglomeration, urbanization agglomeration, and mixed agglomeration. We estimate the agglomeration elasticities of 11 industries using inter-regional transportation network data and regional socio-economic panel data for 1981, 1986, 1991, 1996, 2001, and 2006, covering 47 prefectures in Japan. Our results show that, on average, the indirect benefit of productivity improvement through localization agglomeration tends to be more significant than that through urbanization agglomeration. We also find that while mining enjoys significant benefit from urbanization rather than localization agglomeration and the transportation/communication industry enjoys significant benefit from localization rather than urbanization agglomeration, finance/insurance and real estate might benefit from both agglomeration economies. We further find negative elasticities in the agriculture and service industries; this could be partly due to the industries' characteristics.

Keywords: Inter-regional transportation, economic development, agglomeration, Japan, panel data

1. Introduction

Prolonged economic stagnation has raised global concerns about infrastructure investment, with better ability to recover debt and higher rate of return from investment being the main policy agenda for the coming years. In line with this agenda, transportation infrastructure investment has been given high priority in both the developing and developed world. Generally, the marginal gain from new transportation investment could to be smaller in developed regions that already have well-established transportation networks; thus, new transportation investment is less likely to be accepted through conventional appraisal. Consequently, the additional benefits to an economy not captured previously by the conventional method are now being proposed and are introduced into project appraisal in some developed countries. For instance, in the United Kingdom, potentially additional benefits are calculated separately and evaluated using sensitivity analysis in addition to the conventional cost-benefit analysis (Department for Transport, 2014a). In their pioneering discussions, SACTRA (1999) portrayed certain indirect benefits, which were later incorporated into a guideline (Department for Transport, 2014b), the so called "Wider Impact" (WI). The United Kingdom's WI relates to the agglomeration effect, additional benefits from imperfect market competition, and tax benefits from additional labor from transportation improvement. A multi-criteria analysis has been widely adopted in the US context, whereby different states follow different criteria and ratings in the appraisal procedure (Weisbrod, 2015). However, Weisbrod et al. (2014) pointed out that WI can help quantify the economic impacts of transportation into monetary terms and thus make it more appealing to decision makers for projects where economic development is the main investment target. However, note that criticisms of bias and double-counting effect have been generally raised in WI estimations. Thus, the concept itself needs to be extensively studied and we still require rigid evidence to prove its existence in the various cost and benefit gains from transportation investment.

As regards the relationship between transportation and economic development, Lakshmanan (2011) showed the economic consequences of transportation investment to consist of gains from trade, technology diffusion, and the coordination from the "Big Push" effect as well as from agglomeration. Litman (2010) discussed how transportation affects economic development: as the transportation system's efficiency improves, the transportation cost decreases and producers can yield more output per unit. In a broader sense, the production of more goods and services from the gains of transportation development leads to economic development. Rephann and Isserman (1994) categorized the economic effects of highways into four types: the temporal effects stemming from construction processes; the industrial effects varying through time and across types of industries; the spatial effect in local and regional scales; and a synthesis of the temporal, industrial, and spatial effects. From these studies, we can summarize that the economic impacts of transportation development emerge from the premium in accessibility and transportation cost, or, in general, from the reduction in generalized cost leading to a more productive economy. Numerous studies have supported with evidence the hypothesis of transportation impacts on economic development. From ancient times, Roman highways were built primarily for military logistics, although they also indirectly benefited the economy through the expansion of inter-regional trade and services, such as mail and private transportation (Berechman, 2003). Following the pioneering empirical work of Aschauer (1989) suggesting an expected return of up to 24% from investment in the core US infrastructure during 1949–1985, Canning and Fay (1993) unveiled the positive and significant impact of transportation infrastructure on national economic growth by estimating the total factor productivity in the Cobb–Douglas production function. Furthermore, Chandra and Thompson (2000) used the age of interstate highway as transportation factor, suggesting that the presence of highways affect industrial growth in various sectors, although economic activities remain closer to the highway. These results of positive returns from highways concur with the results of Duranton and Turner (2012), who stated that an increase in interstate highway stock leads to city employment growth by around 15%. A recent study by Farhadi (2015) also investigated the transportation infrastructure effect across the OECD countries, and concluded that transportation investment results in positive returns to GDP, especially future GDP, although the effect is still less compared to other infrastructure investments. Additionally, the World Bank (1994) and Canning (1998) also showed a positive relationship between GDP and infrastructure stock, with higher GDP per capita in countries with higher infrastructure stock per capita.

Although several studies addressed the relationship between transportation investment and economic development, its mechanism has not been explained. Agglomeration could be one of the factors for the relationship, as proposed in the United Kingdom's WI. An agglomeration economy is typically defined as the benefit from firms staying close together. The concept of industrial scale of economies in Marshall (1920) has been further formulated into three factors that lead to agglomeration economies, all closely related to transportation service. First, agglomeration creates clusters of firms wherein producers, suppliers, and customers are located together; this reduces the cost of goods, materials, and even services. Better transportation services could create more opportunities for firms to access better and cheaper input material. Second, this effect is observed in the case of workers as well. A larger pool of workers for access by firms enables a better matching of firms and workers, which improves productivity, because skilled workers can better match their work with their skills. Since better accessibility inspires workers to work away from home, larger agglomeration can be attained in labor pooling through better transportation. Third, the so-called "knowledge spillover" can be expected in agglomerated areas. One of the most famous examples is the Silicon Valley; many firms including semiconductor manufacturers and IT firms are located together here, leading to an environment of mutual learning and assistance. Again, better transportation encourages more meetings, discussions, or even workshops for individuals, and this hastens the learning process, accelerates firms' technology, and results in better productivity.

One modern application of agglomeration to economic theory is the "New Economic Geography" (NEG), originally proposed by Krugman (1991). According to Ascani et al. (2012), the NEG consists of four important elements. The first is the increasing return to scale; this highlights the spatial unevenness of economic activity. However, such agglomeration should be carefully investigated since the NEG is modeled assuming an almost single region. The benefits of clustering typically matter less if dispersion force from agglomeration is dominated (Brakman et al., 2004). The second element comprises the economic terms defined in the functions, including the number of varieties or firms, using the Dixit–Stiglitz monopolistic competition model (Dixit and Stiglitz, 1977). The third is transportation cost, defined as an iceberg-type cost function (Samuelson, 1954); this plays a crucial role in the choice of location. The iceberg cost function in the NEG model implies that the transportation cost increases exponentially with distance, contradicting the evidence that delivered prices tend to be concave rather than convex with distance (McCann, 2005). The fourth element is the pecuniary externalities that the NEG considers for industry localization. Such agglomeration externalities, as mentioned earlier for the first element, can be represented by the benefits of labor market pooling, availability of intermediates, and technological spillover effects. However, how does the agglomeration structure influence productivity in practice? To understand this mechanism from an empirical perspective, past studies have categorized agglomeration in different ways. For instance, from a time scale perspective, agglomeration is categorized into static and dynamic agglomeration. McDonald and McMillen (2007) explained that static agglomeration indicates a one-time change in production due to agglomeration whereas dynamic agglomeration means a continuous effect of agglomeration on productivity over time. From a variety-in-industry viewpoint, agglomeration may also be categorized into localization and urbanization agglomeration. In localization agglomeration, firms in the same industry located together gain from agglomeration. From Marshall's economy of scale, firms benefit from supplier sharing or even technology transfer through localization. In urbanization agglomeration, firms in general, for instance, in bigger cities, improve their productivity as the total market expands through urbanization; this leads to larger labor pooling and cross-industry activities, and further to productivity improvement.

Empirical studies have reported the impacts of agglomeration following these categories. For example, Henderson (2003) found that high-tech industries benefit more from localization economies whereas machinery industries do not. In contrast, Gleaser et al. (1992) claimed that industrial diversity promotes city employment growth rather than specialization. Transportation studies such as Graham (2007), Graham et al. (2009), Melo et al. (2012, 2013) also examined the contribution of transportation to productivity, considering transportation as one of the factors for agglomeration economies; they showed that improvement in accessibility from transportation in term of "Effective Density", could create a better agglomeration environment. However, most of these studies investigated the firm- or national-level effect of agglomeration. Therefore, we analyze the regional-level effect of agglomeration on economic productivity rather than firm- or national-level effect. This is mainly because many countries have recently raised policy concerns about the regional impacts of inter-regional transportation infrastructure such as high-speed rail. This study examines three types of agglomeration through an empirical econometric analysis where the productivity elasticities of agglomeration by industry are estimated using inter-regional Japanese data.

This paper is structured as follows. The next section presents the methodology used, including the formulation of regional production function and definition of agglomeration. Section 3 presents empirical data with uncontrolled relationships between agglomeration and economic development. Section 4 presents the results of econometric model estimation of the impacts of agglomeration on economic productivity. Finally, Section 5 summarizes our conclusions and further issues.

2. Methodology

2.1. Production Function

This paper empirically analyzes the impact of agglomeration on regional productivity by estimating the regional production function. We assume a generalized Cobb–Douglas function for the regional production function as follows:

$$GDP_{ni} = A^{\rho} K_{ni}^{\beta_k} L_{ni}^{\beta_l} , \tag{1}$$

where GDP_{ni} represents the GDP of zone *i* in industry sector *n*; A represents technology (total factor productivity or TFP); K_{ni} and L_{ni} represent respectively the capital and labor input of zone *i* in industry sector *n*; and ρ, β_k, and β_l represent the elasticities pertaining to technology, capital, and labor, respectively. By using the natural log, we can re-write Eq. (1) as

$$gdp_{ni} = \rho a + \beta_k k_{ni} + \beta_l l_{ni} , \tag{2}$$

where the lowercase gdp_{ni}, a, k_{ni}, and l_{ni} represent the logarithmic GDP, logarithmic technology, logarithmic capital, and logarithmic labor, respectively.

One issue to be addressed in econometric estimation is the endogeneity effect. This could arise with reverse causality and omitted variables. This study assumes that agglomeration affects productivity. On the other hand, reverse causation, which can be reasonably expected when a region with higher productivity attracts more firms and workers, leads to further agglomeration. The most popular technique to deal with the endogeneity problem in regression analysis is the instrumental variable (IV) approach; this technique assumes that agglomeration can be explained by other IV factors. Although we tried various IVs for our empirical analysis, including past data, as proposed by Arellano and Bond (1991), and the generalized method of moments (GMM) technique, unfortunately, we could not find any appropriate IVs and GMM yielded unpromising result. For more details of other model estimation trials, see Appendix A.

Another possible source of endogeneity is omitted variables. Following several trials and numerous errors in our estimation, we finally could assume that the technology term can be explained by agglomeration; here, agglomeration can be represented by effective density, *ED*, and other independent variables, ϕ. We define effective density in the next subsection. We then challenge the following semi-parametric approach, which is similar to Graham et al.'s (2009) method:

$$gdp_{ni} = A[ED, \phi] + \beta_k k_{ni} + \beta_l l_{ni} . \tag{3}$$

As for the TFP function $A[\cdot]$, capital and investment are the proxy variables, apart from effective density, following the original work of Olley and Pakes (1996):

$$gdp_{ni} = \rho ED + \phi(k_{ni}, v_{ni}) + \beta_k k_{ni} + \beta_l l_{ni} , \tag{4}$$

where v_{ni} represents the investment of zone *i* in industry sector *n*. In our regression process, $\phi(k_{ni}, v_{ni})$ is specified as a third-order bivariate polynomial expansion of the Cobb–Douglas function:

$$gdp_{ni} = \rho ED + \beta_k k_{ni} + \beta_l l_{ni} + \beta_v v_{ni} + \beta_{kk} (k_{ni})^2 + \beta_{vv} (v_{ni})^2 + \beta_{kv} k_{ni} v_{ni} + \beta_{kkv} (k_{ni})^2 v_{ni} + \beta_{kvv} k_{ni} (v_{ni})^2 + \beta_{kkk} (k_{ni})^3 + \beta_{vvv} (v_{ni})^3 . \tag{5}$$

2.2. Effective Density

This study assumes three types of effective densities to represent agglomeration. The first follows the concept of *urbanization agglomeration;* here, the benefits of agglomeration, as described in Jacobs (1969), emerge from the different sector's knowledge spillover supporting one another. Moreover, innovation growth is believed to be stimulated by a variety of industrialization approaches since different ideas and information can be synthesized through variety rather than specialization. Gleaser et al. (1992) showed that the economic growth of cities can be developed through urbanization agglomeration; in sum, they explained this by the cross-fertilization of ideas, implying that urbanization can lead to more labor mobility. The effective density used in this study applies a gravity-like model, as proposed by the Department for Transport (DfT) Wider Impact Guideline (Department for Transport, 2014b) for incorporating transportation into agglomeration. The effective density of zone *i* is defined as the sum of the mass of employment in another zone *j* and the travel time between zone *i* and zone *j*. This formulation depicts agglomeration in two ways: the mass of employment gives the amount of activities generated by a particular zone *j*, and travel time represents the attractiveness of zone *j*'s activities from the viewpoint of zone *i*. The effective density under urbanization agglomeration can be formulated as

$$ED_i^t = \sum_j \frac{E_j^t}{g_{ij}^t}, \tag{6}$$

where ED_i^t represents the effective density of zone *i* at a time *t*, E_j^t represents the total employment in zone *j* at time *t*, and g_{ij}^t represents the travel time between zone *i* and zone *j* at time *t*. In this case, the first term on the right-hand side of Eqs. (4) and (5) satisfy $\rho ED = \rho_{ni} ED_i$ in the estimation process.

The second type of effective density follows the concept of *localization agglomeration*. The concept of localized industries was proposed by Marshall (1920) and expanded into a more sophisticated formalization by Arrow (1962) and Romer (1986); the accumulation of knowledge spillover within the same industry is now known as Marshall–Arrow–Romer externalities. The effective density under localization agglomeration can be formulated as

$$ED_{ni}^t = \sum_j \frac{E_{nj}^t}{g_{ij}^t}, \tag{7}$$

where ED_{ni}^t represents the effective density of zone *i* in industry sector *n* and E_{nj}^t represents the employment of zone *i* in industry sector *n*. Here, the first term on the right-hand side of Eqs. (4) and (5) satisfy $\rho ED = \rho_{ni} ED_{ni}$ in the estimation process.

The third type of effective density follows *mixed agglomeration,* which includes urbanization and localization. Under Marshall's proposal, more interaction between industries can lead to better returns for both parties. However, localization considers the interaction between the same type of industries and ignores the interaction between different types of industries. On the contrary, urbanization considers the whole economy, ignoring the economic structure. Zones with different industries types and industrial share can have different effects from agglomeration as well. For a better understanding of the whole agglomeration economy, we define the *weighted effective density* under mixed agglomeration by assuming a weight parameter of γ_{nm} for each pair of industry as

$$ED_{ni}^t = \sum_j \sum_m \frac{\gamma_{nm} E_{mj}^t}{g_{ij}^t}, \tag{8}$$

where γ_{nm} is the effective density's weight parameter to explain the degree of industrial interaction between sector *n* and sector *m*. From this formulation, we can explain agglomeration at a point between localization and urbanization through the weight γ_{nm}, which roughly represents the productivity of joint activities and/or interactions between industries *n* and *m;* weight γ_{nm} is formulated modifying the co-agglomeration index proposed by Ellison and Glaeser (1997) as

$$\gamma_{nm} = \exp\left[\frac{\sum_{i}(s_{ni} - x_i)(s_{mi} - x_i)}{1 - \sum_{i} x_i^2}\right], \tag{9}$$

where s_{ni} and s_{mi} are the respective shares of employment in industries *n* and *m* out of the total employment in zone *i*, and x_i is the mean share of employment in zone *i* out of the national employment across all industries. Note that Ellison and Glaeser's co-agglomeration index ignores the real spatial interaction agglomeration in terms of distance between firms (Duranton and Overman, 2005). Thus, the co-agglomeration index in a spacious zone becomes the same as that in a smaller zone if both zones have the same number of firms, but in reality, the smaller zone can attain better agglomeration benefits from the shorter distance between firms. Despite such methodological disadvantages, our analysis uses this index for analytical simplicity. In this case, we assume that the first term on the right-hand side of Eqs. (4) and (5) satisfy $\rho ED = \rho_{ni} ED_{ni}$ in the estimation process, as in analysis of localization agglomeration.

3. Data

We use the inter-regional transportation data of Japan for our empirical analysis. Since inter-regional transportation connects one region with another, its impact on productivity can be felt across regions rather than within a region. Thus, we obtain data at the prefectural level (first-level administrative division in Japan, approximately equivalent to NUTS2[1] in the European Union) for our dataset, although, in reality, urbanization in the prefectural context might vary over prefectures. For instance, the built-up areas in mega cities such as Tokyo and Osaka could cover multiple prefectures whereas the built-up areas in less urbanized prefectures might cover only small towns in a single prefecture. Thus, agglomeration in our data may be regarded as macroscopic approximation at the regional level. Our dataset covers 11 industrial sectors (agriculture; mining; manufacturing; construction; electricity/gas/water; retail; finance/insurance; real estate; transportation/communication; service; and government service) in 47 prefectures for six years at five-year intervals: 1981, 1986, 1991, 1996, 2001, and 2006. Socio-demographic and socioeconomic data, such as prefectural population, GDP, employees, wage, capital and investment stock by industry, etc., were derived from the Statistic Bureau and Cabinet office of Japan. Note that all economic data were adjusted to the year 2000. As for transportation data, the travel time between each prefecture pair was estimated as the shortest travel time incorporating the six travel modes of high-speed rail, conventional rail, air, ferry, inter-city bus, and private car. We used the National Integrated Transport Analysis System (NITAS) software developed by the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) of Japan to search for the shortest path. Note that the transportation network varies over six times since the transportation infrastructure had been developed gradually over time.

Figure 1 illustrates the relationship between three types of prefectural effective density and prefectural GDP. For the localization and mixed agglomeration cases, we present the prefectural GDP for the manufacturing industry as example. Although the later years indicate less production, a comparison of the data for the same time-period show the prefectures with more effective density to have higher GDP, implying agglomeration leads to higher overall production. This may be rather reasonable because effective density includes the number of workers and hence influences positively the prefectural GDP. Next, Figure 2 illustrates the relationship between prefectural effective density and prefectural GDP *per worker.* The figure shows the prefectures with higher effective density to have higher GDP *per worker.* This could imply that more agglomeration leads to higher productivity, concurring with Tabuchi and Yoshida (2000), who suggested an expected 10% wage increase when the city population of Japan doubles. These uncontrolled for analyses clearly suggest a relationship between agglomeration and productivity. However, to find the return to productivity that can be expected from agglomeration, we need a controlled analysis.

[1] NUTS or Nomenclature of Territorial Units for Statistics, a subdivision code uses in EU. NUTS2 level contains around 800,000 – 3,000,000 of population. Population in Prefecture Level (都道府県) of Japan covers a range of 600,000 – 12,000,000.

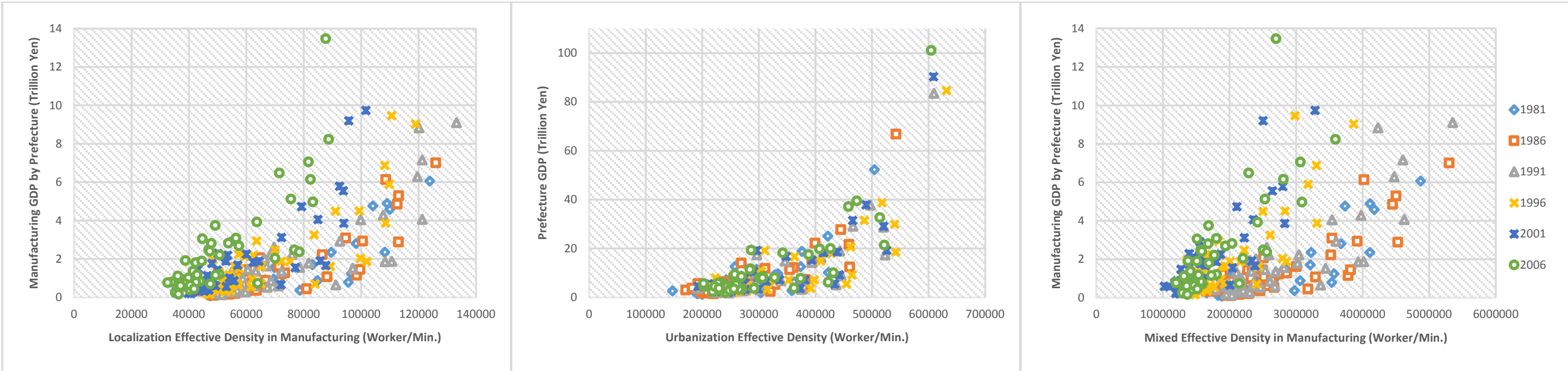

Figure 1 Localization, Urbanization, and Mixed Agglomerations versus Prefectural GDP.

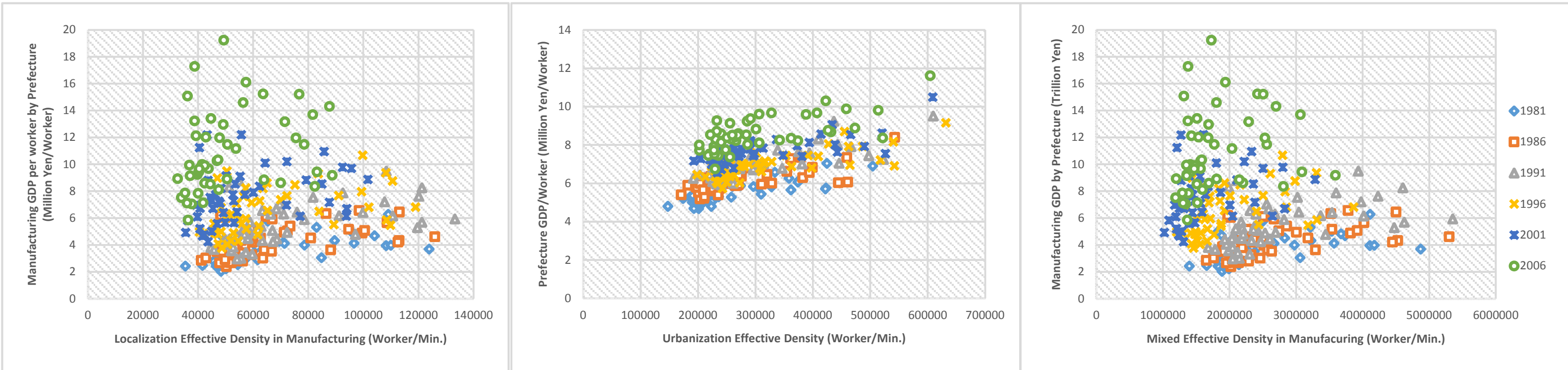

Figure 2 Localization, Urbanization, and Mixed Agglomerations versus Prefectural GDP per worker

4. Results

4.1. Estimation Results

We estimate three models in regression processes, the prefectural fixed effect model ("prefecture controlled"), the time-period fixed effect model ("time controlled"), and the prefectural and time-period fixed effect model ("two-way-controlled"), for each type of production function. Tables 1, 2, and 3 give the estimation results, highlighting the elasticities of effective density for each model. See Appendix B for the entire results.

Table 1 summarizes the estimation results for the 3 regression models using urbanization agglomeration in 11 industries, assuming Eq. (5) for effective density. For all industries, from the degree of freedom, model fitness is the highest in the time-controlled model, followed by the prefecture-controlled model and the two-way-controlled model. First, the prefecture-controlled model shows that effective density has significantly positive impacts on mining and finance/insurance but significantly negative impacts on real estate and government service industries. Next, the time-controlled model shows that effective density has a significantly positive impact on real estate by a significantly negative impact on agriculture industry. Finally, the two-way-controlled model shows that effective density has no impact on any industry.

Table 2 summarizes the estimation results of the three regression models using mixed agglomeration in eleven industries, assuming Eq. (8) for effective density. Models assuming mixed effective density tend to perform better than assuming urbanization agglomeration, although the results are generally the same as for earlier models. First, the prefecture-controlled model shows that effective density has significantly positive impacts on mining, finance/insurance, and transportation/communication but significantly negative impacts on the service industry. Next, the time-controlled model shows that effective density has a significantly positive impact on real estate but negative impacts on the agriculture industry. Finally, the two-way-controlled model shows that effective density has a significantly positive impact on government service.

Table 3 summarizes the estimation results of the three regression models using localization agglomeration in eleven industries, assuming Eq. (7) for effective density. First, the prefecture-controlled model shows that effective density has significantly positive impacts on construction, retailing, finance/insurance, and transportation/communication industries but significantly negative impacts on manufacturing, electricity/gas/water, and service industries. Next, the time-controlled model shows that effective density has a significantly positive impact on real estate but a significantly negative impact on the agriculture industry. Finally, the two-way-controlled model shows that effective density has a significantly positive impact on mining industry.

Our major findings based on the above estimation results can be summarized as follows:

The prefecture-controlled model shows that

(1) both urbanization and localization agglomerations have a positive influence on regional productivity in the finance/insurance industry;

(2) urbanization agglomeration tends to have a positive influence on regional productivity in the mining industry;

(3) localization agglomeration tends to have a positive influence on regional productivity in the transportation/communication industry; and

(4) localization agglomeration tends to have a negative influence on regional productivity in the services industry.

The time-controlled model shows that

(5) both urbanization and localization agglomerations have a positive influence on regional productivity in the real estate industry; and

(6) both urbanization and localization agglomerations have a negative influence on regional productivity in the agriculture industry.

Note that the above findings assume that a significant result from the models of both urbanization and mixed agglomerations imply influence from urbanization agglomeration, whereas a significant result from the models of both localization and mixed agglomerations imply influence from localization agglomeration. Note also that the prefecture-controlled model excludes the impacts of the unique prefecture-related factor by introducing constants to each prefecture whereas the time-controlled model excludes the impacts of the unique time-related factor by introducing constants to each time. Findings (1) to (4) are based on observations of the prefecture-controlled model only, meaning that the results could hold true across prefectures but could be affected by the time factor. Findings (5) and (6) are based on observations of the time-controlled model only, meaning that the results could hold true across time but could be affected by prefectural factor.

4.2. Discussion

From the results, the fitness of the estimated models assuming localization agglomeration tend to be higher than that for the other two models in any industry. The number of industries with significant estimates for agglomeration is also largest in the localization models. This could imply that localization agglomeration has a higher influence on economic production than urbanization agglomeration. However, the results also show that agglomeration has different effects for each industry.

First, the positive impacts of both urbanization and localization agglomeration on regional productivity in the finance/insurance and real estate industries, or the so-called FIRE industry, may be explained reasonably using Marshall's theory. Since the FIRE industry should have customers from many other industries, a higher density of potential customers from various industries could give more business opportunities to them; this may be one of the sources of external benefit from urbanization agglomeration. As the FIRE industry particularly needs the latest information about local/regional/global markets, the social network of workers in the same industry could effectively contribute to sharing knowledge through meetings. Because communication opportunities such as seminars and informal meetings could attract businesspeople from across the regions, a higher density of colleagues in the FIRE industry could provide more knowledge spillover through communication; this is one of the sources of external benefit from localization agglomeration. Localization agglomeration also affects the labor pool as well as procurement of high-standard service, because the FIRE industry requires skillful labor and efficient business environment for attaining higher productivity. A significant impact in the finance/insurance industry could be found only with the prefecture-controlled model, probably because its impact considerably varies across prefectures. Significant impact could be found in the real estate industry with the time-controlled model, probably because the real estate market in Japan was influenced by conditions in the national economic market rather than by each prefecture's unique condition, although the significance in the prefecture-controlled model is relatively strong as well. Note that the estimated elasticities in the finance/insurance industry with respect to urbanization, mixed, and localization agglomerations are 0.935, 1.264, and 0.750, respectively, and those in real estate industry are 0.291, 0.294, and 0.244, respectively. This could suggest that urbanization agglomeration may have a greater influence on productivity than localization agglomeration in those industries.

Second, the positive impact of localization agglomeration on regional productivity in mining may be explained from the natural resource as well as market perspective. Mining products usually come directly from natural resources, which are typically located in limited areas based on geographical conditions of resource availability. Since the unit freight transportation cost of mining products is expected to be higher than that of other goods because of the nature of large volume transport, mining industries tend to locate near the natural resource sites. This is the case in Japan too, where the areas rich in natural resources attract more mining industries. Thus, closeness to natural resource sites itself generates higher productivity, leading to localization agglomeration in the mining industry. On the other hand, localization agglomeration may also generate external effects, such as benefits from cost savings in the joint procurement of machines and skilled labors and from technology transfer among mining firms. Knowledge sharing on local conditions may be critical for the mining industry because their business depends significantly on the unique local geographical environment. A significant impact of agglomeration on mining could be found only with the prefecture-controlled model because its impact varies considerably across prefectures because of the geographically uneven availability of natural resources. However, reverse causation from the effect of "natural advantages" could lead to better productivity, and agglomeration could merely be the result of that productivity. As Ellison and Glaeser (1997) show, natural resources can be treated as natural advantages for the mining sector. As a place with abundant natural resources could provide better economies of scale, producers tend to be attracted, resulting in agglomeration of the mining industry.

Third, the positive impact of localization agglomeration on regional productivity in transportation/communication may reflect regional market characteristics. For instance, when transportation firms are located closely, trucks/vans or drivers can be easily shared among them, thus reducing their potential business risk due to demand fluctuation in the transportation market. The network economy may also work in transportation/communication businesses that particularly use physical network. For example, multiple public transit operators working closely together can form a wider transportation network covering vast areas and thus enhance accessibility and the mobility of passengers; this could improve the productivity of public transit operators from the complementarity of services. A significant impact of agglomeration was found in the transportation/communication industry only with the prefecture-controlled model because its impact considerably varies over prefectures owing to the geographically uneven availability of natural resources.

Fourth, localization agglomeration negatively influences regional productivity in the service industry. Generally, negative productivity elasticities of agglomeration are found when the centrifugal forces stemming from agglomeration are stronger than the centripetal forces (Fujita et al., 1999). The centrifugal force or diseconomies from agglomeration may arise from higher land rent, an increase in living expenses, or even more congestion from a denser population. One possible reason for negative elasticity in the service industry is that agglomeration of the same service firms causes serious market competition among them, which could lose the additional benefit of the imperfect competitive market. Agglomeration could even lead to overcompetition, generating negative external effects such as a weaker position in business contracts with their clients or customers, while less agglomerated firms could enjoy higher market power. Negative impact to some industry can be supported by Combes et al. (2012), where the firm selection process[2] has no impact on spatial productivity difference.

Fifth, both urbanization and localization agglomerations have a negative influence on regional productivity in the agriculture industry. One of the possible explanations is that the economy of geographical scale works well in agricultural business because it typically requires larger land for better production. Larger area of land decreases the average cost of production, meaning better productivity, and leads to less agglomeration. Another possible reason particularly for the poor impact of localization agglomeration is the negative external effect of agglomeration. For example, densely agglomerated agricultural businesses can consume excessive natural resources such as water, wood, and fish and thus reduce the performance of agricultural production.

Finally, industries other than FIRE, transportation/communication, service, and agriculture may not have notable impacts from agglomeration. Particularly, the poor significance of agglomeration in electricity/gas/water, retail, and government service industries could be explained by the characteristics of such services and/or goods. As these are necessary goods/services for people's daily life, the industries producing such commodities are essentially required to be distributed evenly. Government service is a typical case, and the retail and electricity/gas/water industries also have to run their businesses even if their profit is near zero. More positively, these industries themselves distribute evenly based on the distribution of population, and so regional agglomeration may make less sense in these industries.

[2] The firm selection approach explains that the better productivity from agglomeration is due to the intensive competition in larger markets. Only the best firms can survive competition, resulting in better overall productivity in a large market compared to a smaller market.

Table 1 Estimated elasticities of productivity with respect to effective density based on urbanization agglomeration (N=282)

Semi-parameter (Eq. (5)) - Prefecture control																				
	Agriculture					Mining					Manufacturing					Construction				
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)	
ln(ED)	0.090	0.155	0.582	0.561		1.267	0.178	7.126	0.000	***	-0.032	0.155	-0.205	0.838		-0.011	0.184	-0.058	0.954	
ln(L)	0.195	0.041	4.740	0.000	***	0.286	0.033	8.779	0.000	***	0.411	0.123	3.337	0.001	***	0.574	0.050	11.447	0.000	***
Adj. R^2	0.429					0.510					0.727					0.642				
	Elec, Gas & Water					Retail					Finance & Insur					Real Estate				
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)	
ln(ED)	0.175	0.148	1.180	0.239		-0.055	0.113	-0.488	0.626		0.935	0.198	4.719	0.000	***	-0.417	0.138	-3.026	0.003	**
ln(L)	-0.123	0.076	-1.613	0.108		0.269	0.025	10.848	0.000	***	0.548	0.063	8.726	0.000	***	0.636	0.075	8.460	0.000	***
Adj. R^2	0.706					0.745					0.699					0.730				
	Transport & Comm					Service					Gov. Service									
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)						
ln(ED)	-0.051	0.155	-0.330	0.742		0.066	0.083	0.795	0.427		-0.195	0.054	-3.641	0.000	***					
ln(L)	0.220	0.064	3.448	0.001	***	0.080	0.036	2.227	0.027	*	0.549	0.056	9.888	0.000	***					
Adj. R^2	0.721					0.771					0.747									
Semi-parameter (Eq. (5)) - Time control																				
	Agriculture					Mining					Manufacturing					Construction				
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)	
ln(ED)	-0.296	0.059	-5.002	0.000	***	0.011	0.053	0.202	0.840		0.095	0.047	2.001	0.046	*	-0.101	0.045	-2.272	0.024	*
ln(L)	0.331	0.038	8.783	0.000	***	0.053	0.038	1.389	0.166		0.574	0.027	21.029	0.000	***	0.253	0.060	4.249	0.000	***
Adj. R^2	0.777					0.885					0.928					0.915				
	Elec, Gas & Water					Retail					Finance & Insur					Real Estate				
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)	
ln(ED)	0.002	0.030	0.065	0.949		0.033	0.037	0.904	0.367		0.062	0.041	1.534	0.126		0.292	0.072	4.086	0.000	***
ln(L)	0.111	0.027	4.104	0.000	***	0.212	0.043	4.948	0.000	***	0.194	0.058	3.363	0.001	***	0.090	0.181	0.496	0.620	
Adj. R^2	0.927					0.930					0.926					0.893				
	Transport & Comm					Service					Gov. Service									
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)						
ln(ED)	0.016	0.031	0.528	0.598		0.021	0.019	1.118	0.265		0.001	0.027	0.039	0.969						
ln(L)	0.009	0.046	0.191	0.849		0.159	0.032	4.942	0.000	***	0.963	0.040	24.367	0.000	***					
Adj. R^2	0.930					0.936					0.929									
Semi-parameter (Eq. (5)) - Two-way control																				
	Agriculture					Mining					Manufacturing					Construction				
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)	
ln(ED)	-0.199	0.230	-0.863	0.389		0.460	0.286	1.609	0.109		0.097	0.201	0.483	0.630		-0.298	0.191	-1.555	0.121	
ln(L)	0.206	0.037	5.602	0.000	***	0.158	0.046	3.457	0.001	***	0.376	0.112	3.346	0.001	***	0.172	0.074	2.341	0.020	*
Adj. R^2	0.185					0.611					0.330					0.295				
	Elec, Gas & Water					Retail					Finance & Insur					Real Estate				
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)	
ln(ED)	0.062	0.149	0.418	0.676		0.057	0.115	0.501	0.617		0.064	0.116	0.552	0.582		0.164	0.188	0.873	0.384	
ln(L)	0.073	0.047	1.549	0.123		0.064	0.038	1.671	0.096	.	0.062	0.044	1.413	0.159		0.585	0.119	4.910	0.000	***
Adj. R^2	0.617					0.557					0.537					0.284				
	Transport & Comm					Service					Gov. Service									
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)						
ln(ED)	0.222	0.118	1.870	0.063	.	0.005	0.076	0.060	0.952		0.095	0.068	1.411	0.160						
ln(L)	0.098	0.043	2.311	0.022	*	0.060	0.029	2.102	0.037	*	0.710	0.063	11.316	0.000	***					
Adj. R^2	0.490					0.630					0.372									

Note: ***p<0.001; **p<0.01, and *<0.05.

Table 2 Estimated elasticities of productivity with respect to effective density based on mixed agglomeration (N=282)

Semi-parameter (Eq. (5)) - Prefecture control

	Agriculture					Mining					Manufacturing					Construction				
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)	
ln(ED)	0.218	0.134	1.631	0.104		1.076	0.164	6.573	0.000	***	-0.037	0.057	-0.654	0.514		0.447	0.135	3.315	0.001	**
ln(L)	0.197	0.041	4.825	0.000	***	0.244	0.032	7.600	0.000	***	0.402	0.108	3.740	0.000	***	0.444	0.063	7.097	0.000	***
Adj. R^2	0.433					0.502					0.728					0.649				
	Elec, Gas & Water					Retail					Finance & Insur					Real Estate				
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)	
ln(ED)	-0.038	0.137	-0.277	0.782		0.127	0.039	3.226	0.001	**	1.214	0.150	8.100	0.000	***	-0.362	0.119	-3.029	0.003	**
ln(L)	-0.126	0.077	-1.648	0.101		0.169	0.036	4.654	0.000	***	0.355	0.065	5.489	0.000	***	0.627	0.075	8.313	0.000	***
Adj. R^2	0.706					0.747					0.713					0.73022				
	Transport & Comm					Service					Gov. Service									
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)						
ln(ED)	0.664	0.132	5.014	0.000	***	-0.042	0.008	-5.537	0.000	***	-0.052	0.075	-0.699	0.486						
ln(L)	0.198	0.061	3.267	0.001	**	0.050	0.033	1.522	0.129		0.464	0.053	8.826	0.000	***					
Adj. R^2	0.729					0.773					0.744									

Semi-parameter (Eq. (5)) - Time control

	Agriculture					Mining					Manufacturing					Construction				
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)	
ln(ED)	-0.297	0.059	-5.005	0.000	***	0.011	0.053	0.203	0.839		0.100	0.046	2.155	0.032	*	-0.102	0.044	-2.302	0.022	*
ln(L)	0.331	0.038	8.790	0.000	***	0.053	0.038	1.389	0.166		0.572	0.027	20.992	0.000	***	0.253	0.060	4.245	0.000	***
Adj. R^2	0.777					0.885					0.928					0.915				
	Elec, Gas & Water					Retail					Finance & Insur					Real Estate				
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)	
ln(ED)	0.002	0.030	0.060	0.952		0.031	0.036	0.857	0.392		0.062	0.041	1.534	0.126		0.294	0.072	4.101	0.000	***
ln(L)	0.111	0.027	4.104	0.000	***	0.213	0.043	4.991	0.000	***	0.194	0.058	3.364	0.001	***	0.089	0.181	0.493	0.622	
Adj. R^2	0.927					0.930					0.926					0.893				
	Transport & Comm					Service					Gov. Service									
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)						
ln(ED)	0.016	0.031	0.514	0.608		0.021	0.019	1.130	0.260		0.000	0.026	0.013	0.990						
ln(L)	0.009	0.046	0.189	0.850		0.159	0.032	4.929	0.000	***	0.963	0.040	24.369	0.000	***					
Adj. R^2	0.930					0.936					0.929									

Semi-parameter (Eq. (5)) - Two-way control

	Agriculture					Mining					Manufacturing					Construction				
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)	
ln(ED)	0.000	0.000	-2.307	0.022	*	0.000	0.000	1.380	0.169		0.000	0.000	0.581	0.562		0.000	0.000	0.590	0.556	
ln(L)	0.181	0.094	1.914	0.057	.	0.040	0.092	0.433	0.665		0.151	0.130	1.166	0.245		0.173	0.121	1.428	0.155	
Adj. R^2	0.005					0.485					0.253					0.125				
	Elec, Gas & Water					Retail					Finance & Insur					Real Estate				
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)	
ln(ED)	0.000	0.000	-0.685	0.494		0.000	0.000	0.482	0.631		0.000	0.000	1.598	0.112		0.000	0.000	2.526	0.012	*
ln(L)	0.262	0.380	0.689	0.492		-0.167	0.490	-0.341	0.733		-0.029	0.075	-0.393	0.695		0.372	0.303	1.228	0.221	
Adj. R^2	0.114					0.017					0.372					0.070				
	Transport & Comm					Service					Gov. Service									
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)						
ln(ED)	0.000	0.000	1.007	0.315		0.000	0.000	1.005	0.317		0.000	0.000	3.404	0.001	***					
ln(L)	-0.209	0.300	-0.698	0.486		0.029	0.049	0.585	0.560		0.311	0.124	2.512	0.013	*					
Adj. R^2	0.163					0.426					0.191									

Note: ***p<0.001; **p<0.01, and *<0.05.

Table 3 Estimated elasticities of productivities with respect to effective density based on localization agglomeration (N=282)

Semi-parameter (Eq. (5)) - Prefecture control

	Agriculture					Mining					Manufacturing					Construction				
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)	
ln(ED)	-0.121	0.212	-0.570	0.569		0.060	0.091	0.657	0.512		-0.274	0.067	-4.078	0.000	***	0.532	0.107	4.986	0.000	***
ln(L)	0.209	0.050	4.207	0.000	***	0.180	0.078	2.290	0.023	*	0.570	0.112	5.091	0.000	***	0.321	0.069	4.620	0.000	***
Adj. R^2	0.429					0.447					0.732					0.657				
	Elec, Gas & Water					Retail					Finance & Insur					Real Estate				
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)	
ln(ED)	-1.324	0.151	-8.765	0.000	***	0.203	0.058	3.502	0.001	***	0.750	0.106	7.064	0.000	***	0.153	0.121	1.259	0.209	
ln(L)	0.117	0.072	1.636	0.103		0.131	0.043	3.012	0.003	**	0.256	0.082	3.110	0.002	**	0.647	0.076	8.470	0.000	***
Adj. R^2	0.728					0.747					0.709					0.728				
	Transport & Comm					Service					Gov. Service									
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)						
ln(ED)	0.520	0.055	9.511	0.000	***	-0.478	0.057	-8.366	0.000	***	-0.207	0.073	-2.846	0.005	**					
ln(L)	0.141	0.055	2.583	0.010	*	0.152	0.031	4.936	0.000	***	0.563	0.063	8.985	0.000	***					
Adj. R^2	0.742					0.776					0.745									

Semi-parameter (Eq. (5)) - Time control

	Agriculture					Mining					Manufacturing					Construction				
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)	
ln(ED)	-0.470	0.108	-4.357	0.000	***	0.142	0.090	1.571	0.117		0.109	0.044	2.453	0.015	*	-0.106	0.053	-1.991	0.048	*
ln(L)	0.401	0.036	10.992	0.000	***	0.045	0.038	1.196	0.233		0.567	0.027	20.721	0.000	***	0.262	0.059	4.421	0.000	***
Adj. R^2	0.773					0.886					0.928					0.915				
	Elec, Gas & Water					Retail					Finance & Insur					Real Estate				
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)	
ln(ED)	0.008	0.032	0.255	0.799		0.024	0.036	0.678	0.499		0.061	0.040	1.528	0.128		0.244	0.066	3.685	0.000	***
ln(L)	0.111	0.027	4.070	0.000	***	0.217	0.043	5.085	0.000	***	0.190	0.057	3.318	0.001	**	0.083	0.182	0.457	0.648	
Adj. R^2	0.927					0.930					0.926					0.892				
	Transport & Comm					Service					Gov. Service									
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)						
ln(ED)	0.013	0.031	0.434	0.665		0.018	0.020	0.939	0.349		-0.007	0.029	-0.235	0.814						
ln(L)	0.007	0.046	0.161	0.872		0.161	0.032	5.008	0.000	***	0.964	0.040	24.316	<2e-16	***					
Adj. R^2	0.930					0.936					0.929									

Semi-parameter (Eq. (5)) - Two-way control

	Agriculture					Mining					Manufacturing					Construction				
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)	
ln(ED)	-0.575	0.253	-2.276	0.024	*	1.073	0.209	5.122	0.000	***	0.274	0.195	1.406	0.161		-0.254	0.207	-1.232	0.219	
ln(L)	0.267	0.045	5.860	0.000	***	0.014	0.052	0.269	0.788		0.364	0.112	3.239	0.001	**	0.177	0.074	2.398	0.017	*
Adj. R^2	0.197					0.627					0.333					0.293				
	Elec, Gas & Water					Retail					Finance & Insur					Real Estate				
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)	
ln(ED)	0.155	0.155	1.004	0.317		0.029	0.111	0.262	0.794		0.060	0.104	0.576	0.565		0.292	0.187	1.566	0.119	
ln(L)	0.057	0.050	1.141	0.255		0.066	0.038	1.720	0.087	.	0.060	0.044	1.372	0.171		0.570	0.118	4.832	0.000	***
Adj. R^2	0.618					0.557					0.537					0.287				
	Transport & Comm					Service					Gov. Service									
	Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)		Estimate	Std.Error	t	Pr(>|t|)						
ln(ED)	0.221	0.097	2.268	0.024	*	0.026	0.075	0.350	0.727		0.054	0.074	0.737	0.462						
ln(L)	0.071	0.045	1.576	0.117		0.060	0.029	2.109	0.036	*	0.711	0.063	11.222	0.000	***					
Adj. R^2	0.492					0.630					0.370									

Note: ***p<0.001; **p<0.01, and *<0.05.

5. Conclusion

This study provided empirical evidence of the impacts of agglomeration on regional development using Japanese historical data. Our results showed that on average, the indirect benefit stemming from productivity improvement through localization agglomeration tends to be more significant than that through urbanization agglomeration although their robustness indicates that each industry utilizes agglomeration in different ways. From our results for industries, mining enjoys significant benefit from urbanization rather than localization, transportation/communication enjoys significant benefit from localization rather than urbanization, and FIRE could benefit from both types of agglomeration economies. Negative elasticities were found for agriculture and service industries, but this could be due partly to the industries' characteristics.

This study also partly discussed the factors that could lead to agglomeration. As shown in our discussions on the mining industry, the geographical distribution of natural resources is one of the factors. Although we tried to analyze the potential reverse causality and explain the agglomeration with other factors, our attempts failed of our limited dataset. This could be partly because of the unique policy implemented earlier by the national government in the 1980s to 1990s in Japan. Although in the early stages after World War II, a series of expressways and high-speed railways had been successfully introduced to expand the transportation network and meet the challenges of the rapid economic growth, the government gradually shifted its policy goal from national economic development to regional economic development under the concept of the "regionally balanced national development policy" in the 1980s to 1990s. During that period in Japan, the investment of inter-regional transportation infrastructure or development of regional industries may have been determined through political debates rather than on a consistent decision-making process, thus making it difficult for us to interpret the mechanism of regional agglomeration in Japan. Note that the formal cost-benefit analysis guideline for transportation investment was introduced in Japan around 2000.

Although this study contributed to validate the assumption that improved regional accessibility promoted economic development through agglomeration, several further issues remain to be addressed. First, from a technical perspective, one of the issues is the rationale for using "effective density" to explain agglomeration. Kanemoto (2013) mentioned that the concept of effective density might not be justified in some cases. For example, the effective density in Eq. (6) follows the urbanization agglomeration neglecting industrial structure. Thus, a problem could arise, for example, when a zone with 90% employment in industry *n* and 10% employment in industry *m* has the same effective density as another zone with 10% employment in industry *n* and 90% in industry *m,* although clearly the productivity between them should be different. This is the main reason we introduce the weighted effective density in our analysis, although the result could imply that applying the Ellison and Glaeser co-agglomeration index is not promising, at least with our specification and dataset. Further examination would be required for the definition of agglomeration. Yet, our result could give some suggestion to transportation planner regarding agglomeration to a certain extend. Relationship between transportation investment and economy, through agglomeration, could be positive, negative, or not related, depending on the distribution of industrial sector

Additionally, our results could also suggest that the externalities to production may not be explained by agglomeration only. In this analysis, because of our small sample size (N=282), our data correlation, which is always one of main concerns, restricts us from introducing more independent variables in the model estimation. We can have a more sophisticated analysis by using firm-level data rather than macroscopic data, which would enable a more precise estimation. However, such firm-level data can typically be obtained for only a single city. It would not be reasonable to consider the agglomeration impact in a single city since the benefit of agglomeration in such a city could be the result of a loss in other cities, particularly in the context of inter-regional transportation investment. However, as criticized in Duranton and Overman (2005), our estimation used data based on administrative division, thus ignoring the actual spatial interaction between firms. Such spatial interaction could play an important role in agglomeration and macroscopic analysis because the spatial consideration of firms can give more definite explanations for agglomeration economies.

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Appendix A: Agglomeration Elasticity Estimation Using Other Econometric Approaches

Apart from the semi-parametric approach shown earlier in this paper, we estimate model parameters using other econometric approaches as well. First, we assume that a in Eq. (2) is explained by effective density. Now, a simple Cobb–Douglas function would be

$$gdp_{ni} = \rho ED_i + \beta_k k_{ni} + \beta_l l_{ni} \, . \quad \text{(A1).}$$

To generalize the Cobb–Douglas function, we test the transcendental logarithmic (trans-log) function as in Graham (2007) as follows:

$$gdp_{ni} = \rho ED_i + \beta_k k_{ni} + \beta_l l_{ni} + \beta_{kk} k_{ni}^2 + \beta_{ll} l_{ni}^2 + \beta_{kl} k_{ni} l_{ni} \quad \text{(A2)}$$

We formulate another specification for the semi-parametric approach as a time-difference model. This specification ignores the initial state of variables, and we might obtain better results because we determine the elasticity in marginal terms. We derive a time-different model from the same specification of Eq. (5) by using time-difference terms for both dependent and independent variables as follows:

$$\Delta gdp_{ni} = \rho \Delta ED + \beta_k \Delta k_{ni} + \beta_l \Delta l_{ni} + \beta_v \Delta v_{ni} + \beta_{kk} (\Delta k_{ni})^2 + \beta_{vv} (\Delta v_{ni})^2 + \beta_{kv} \Delta k_{ni} \Delta v_{ni} + \beta_{kkv} (\Delta k_{ni})^2 \Delta v_{ni} + \beta_{kvv} \Delta k_{ni} (\Delta v_{ni})^2 + \beta_{kkk} (\Delta k_{ni})^3 + \beta_{vvv} (\Delta v_{ni})^3 \, , \quad \text{(A3)}$$

where Δ represents the difference between the present and previous time frame.

Next, we examine the potential reverse causation stemming from the endogenous factors by using the IV method. In one of our trials, we estimate the effective density with a lagged GDP in the past period and other independent variables in the first stage, and use the estimated effective density from the first stage for effective density in the second stage as follows:

$$gdp_{ni} = \rho \overline{ED} + \phi(k_{ni}, v_{ni}) + \beta_k k_{ni} + \beta_l l_{ni} \, , \quad \text{(A4)}$$

where $\overline{ED}$ represents the estimated effective density from the first stage estimation. In another trial with the IV method, we use the GMM to estimate a model where GDP is explained by a one-period lagged GDP with other independent variables, following Arellano and Bond (1991). In this estimation, we ignore the polynomial expansion term ϕ to obtain better significance as follows:

$$gdp_{ni}^t = \beta_{gdp} gdp_{ni}^{t-1} + \rho_i \overline{ED}_i^t + \beta_k k_{ni}^t + \beta_l l_{ni}^t \quad \text{(A5)}$$

The estimation results of these models are summarized in Tables A1 to A4. The tables show that the simplest model and translog model have higher significance results in many industries. However, these results can be biased because they are not controlled for with prefectural or time effects. We believe that the time-difference model would give less biased results because it ignores the initial state in each prefecture, but, unfortunately, this model gives poor significance results. The results were even worst for the IV model, where only agriculture, real estate, and service industries achieved significant results. The results estimated using the GMM model was in the expected range, but the significance obtained was somewhat undesirable.

Appendix B: Full Estimation Results of Semi-parametric Models Using Eq. (5)

Tables 1, 2, and 3 show the estimation results of only a few variables including the effective density. The model estimation results for all variables are shown in Tables A5, A6, and A7.

Table A1 Estimation Results of Simplest, Translog, and Time Different Models using Effective Density based on Urbanization Agglomeration (N=282)

	Agriculture	*Mining*	*Manufacturing*	*Construction*	*Elec/Gas/Water*	*Retail*	*Finance/Insur*	*Real Estate*	*Transport/Comm*	*Service*	*Gov. Service*
					Simplest (Eq. (A1)) - Pooled						
(Intercept)	14.864 ***	4.241 ***	-0.921 *	2.164 ***	2.111 **	0.967 *	-1.388 **	12.516 ***	9.961 ***	2.881 ***	7.455 ***
ED	-0.321 ***	-0.022	0.012	0.179 **	-0.021	-0.078	0.196 ***	0.264 ***	0.085 .	-0.046	0.049 .
L	0.509 ***	0.278 ***	0.583 ***	0.997 ***	0.156 ***	0.546 ***	0.593 ***	0.441 ***	0.676 ***	0.934 ***	0.694 ***
K	0.367 ***	0.699 ***	0.437 ***	-0.143 ***	0.816 ***	0.449 ***	0.395 ***	0.280 ***	0.300 ***	-0.007	0.385 ***
Adj R^2	0.727	0.812	0.984	0.939	0.943	0.970	0.971	0.948	0.974	0.966	0.981
					Translog (Eq. (A2)) - Pooled						
(Intercept)	226.551 **	-2.125	-16.718 **	13.651	88.509 ***	34.259 ***	11.385 *	73.036 **	21.410 **	25.931 ***	77.348 **
ED	-0.345 ***	0.031	0.047	0.180 **	0.047	-0.104 *	0.171 ***	0.293 ***	0.089 .	-0.055	0.045 .
L	-0.884	2.243 .	3.027 ***	1.817	10.409 ***	2.150 .	-0.157	7.225 *	2.333 **	-1.460	9.298 ***
K	-14.232 *	0.622	-0.786	-1.801 .	-8.440 ***	-3.492 ***	0.198	-6.742 *	-1.201 .	0.707	-7.618 **
$L^2/2$	-0.125	0.126	0.283 ***	-0.752 ***	0.436 **	-0.728 ***	-0.379 ***	0.312	0.118 .	0.549 **	0.690 ***
$K^2/2$	0.493 *	0.035	0.369 ***	-0.647 ***	0.477 ***	-0.512 **	-0.381 ***	0.397 *	0.097 *	0.422 **	0.483 ***
LK	0.086	-0.116 .	-0.349 ***	0.715 ***	-0.495 ***	0.662 ***	0.398 ***	-0.368 .	-0.107 *	-0.455 **	-0.555 ***
Adj R^2	0.742	0.813	0.985	0.942	0.948	0.976	0.973	0.949	0.975	0.968	0.983
					Time-Different Semi-parameter (Eq. (A3)) - Prefecture control						
ED	-0.050	0.450	0.409 .	-0.122	0.559 ***	-0.146	0.564 *	-0.080	0.187	-0.050	-0.021
L	0.230 ***	0.140	0.464 **	0.288 ***	-0.312 ***	0.137 ***	0.000	0.162 .	-0.039	0.037	0.333 ***
K	-86.875	-25.969	91.998 .	-11.842	-60.522	-104.342 **	-114.340 **	-12.592	20.956	-26.330	-92.515
I	47.470	-1.429	-7.496	28.376	34.776	71.237 ***	31.344	15.291 **	-24.417	34.112 *	-3.553
K^2	5.573	-0.983	-3.121	5.228 *	5.343	15.479 ***	18.842 **	1.293	3.840 *	8.204 **	2.126
I^2	1.108	-2.527 .	0.299	4.496 *	2.610	11.487 ***	15.462 *	0.355	6.553 **	7.411 *	-0.960 .
KI	-5.331	4.635	-0.089	-10.349 *	-6.991 .	-25.849 ***	-31.013 *	-1.804	-10.134 *	-15.952 **	1.988
K^3	-0.087	-0.074	0.086	-0.151	-0.025	-1.329 ***	-3.368 ***	-0.165 .	-0.725 ***	-0.431	0.009
I^3	-0.028	0.211 *	-0.073	-0.026	-0.123	1.202 ***	3.526 ***	0.181 .	0.766 ***	0.263	-0.014
K^2I	0.065	0.302	-0.168	0.280	-0.115	3.792 ***	10.159 ***	0.493 .	2.260 ***	1.127	-0.102
KI^2	0.035	-0.452 .	0.189	-0.095	0.251	-3.677 ***	-10.359 ***	-0.506 .	-2.305 ***	-0.954	0.073
Adj R^2	0.064	0.453	0.336	0.609	0.452	0.652	0.525	0.253	0.466	0.552	0.550
					Time-Difference Semi-parameter (Eq. (A3)) - Time control						
ED	0.311 .	-0.015	0.023	-0.066	0.045	-0.138	-0.037	0.023	0.032	0.035	0.073
L	0.164 ***	0.083 .	0.350 **	0.128 .	-0.012	0.023	0.025	0.327 **	0.033	0.075 **	0.322 ***
K	288.669 .	31.044	26.410	-1.314	9.408	-4.298	-2.782	-2.539	9.081	-16.435 .	-60.358 .
I	-57.846	-2.195	-6.803	20.750	-20.573	5.862	-7.080	10.278 *	-1.475	15.583 .	-5.958
K^2	-12.139 *	-1.913	-0.592	1.942	1.296	0.201	-3.731	-0.844	2.675 .	2.446	0.908
I^2	0.139	-0.644	0.571	1.462	2.930 ***	-0.122	-4.210 .	-1.578 *	3.684 *	1.667	-1.087 *
KI	3.828	1.414	-0.605	-4.161	-3.669 **	-0.099	8.332 .	2.070	-6.586 *	-4.078	2.418 .
K^3	0.163 .	-0.023	0.047	0.067	-0.028	0.089	0.232	0.166	-0.170	-0.183	0.021
I^3	0.003	0.094 *	-0.065	-0.161	-0.046	-0.118	-0.122	-0.173	0.085	0.148	-0.010
K^2I	-0.056	0.167	-0.134	-0.290	0.045	-0.299	-0.606	-0.516	0.453	0.504	-0.100
KI^2	-0.013	-0.223 .	0.158	0.394	0.020	0.328	0.491	0.528	-0.365	-0.469	0.064
Adj R^2	0.109	0.786	0.167	0.409	0.793		0.639	0.216	0.450	0.696	0.182
					Time-Difference Semi-parameter (Eq. (A3)) - Two-way control						
ED	0.401 .	-0.167	0.028	0.003	0.012	-0.181 .	-0.069	-0.012	-0.029	0.053	0.070
L	0.171 **	0.053	0.254 .	0.128	-0.028	0.007	0.015	0.158	-0.030	0.079 **	0.072
K	141.650	5.674	84.768 .	17.535	34.215	-35.434	-15.467	-5.014	5.220	20.125	-6.105
I	-47.096	-7.424	-9.323	26.026	-36.180 .	8.277	-8.802	10.410 .	-0.256	-5.748	20.653
K^2	-6.304	-1.176	-2.569	3.332	-1.306	1.566	-3.813	-1.076	2.686 .	-0.359	-0.010
I^2	0.389	-0.809	0.744	3.677 .	1.692 .	0.072	-4.812 .	-2.000 *	3.465 .	0.795	-0.934 .
KI	2.622	2.126	-0.745	-8.619 .	-0.264	-0.619	9.567 .	2.828 .	-6.280 .	-0.956	0.290
K^3	0.085	-0.051	0.061	-0.032	-0.007	0.047	0.283	0.178	-0.237 *	-0.238	0.020
I^3	0.001	0.130 **	-0.055	-0.116	0.015	-0.090	-0.168	-0.174	0.181	0.292	-0.010
K^2I	-0.031	0.231 .	-0.103	-0.022	0.088	-0.215	-0.769	-0.548	0.675 .	0.790	-0.061
KI^2	-0.017	-0.311 *	0.127	0.190	-0.099	0.245	0.643	0.548	-0.618	-0.837	0.061
Adj R^2	0.066	0.638	0.074	0.340	0.648	0.486	0.505	0.156	0.332	0.553	0.112

Note: ***$p<0.001$; **$p<0.01$, and *<0.05.

Table A2 Estimation Results of Instrumental Variable Models using Effective Density based on Urbanization Agglomeration (N=282)

	Agriculture	*Mining*	*Manufacturing*	*Construction*	*Elec/Gas/Water*	*Retail*	*Finance/Insur*	*Real Estate*	*Transport/Comm*	*Service*	*Gov. Service*
Instrumental Variable Semi-parameter (Eq. (A4)) - Prefecture Control											
ED	8.464	-2.697	-3.041	53.069	-0.718	-3.966	-19.560	-3.281 ***	-14.397	-0.474 *	-1.038 ***
L	0.461 .	0.302 ***	1.474	-2.494	-0.222 *	0.653 *	4.851	0.163	0.085	0.094 *	0.960 ***
K	1557.723	-28.266	33.646	44.243	27.378	-59.108	-120.303	-9.405	-176.366	-41.853 *	13.679
I	158.440	-24.966	6.579	156.079	37.931	77.816	30.847	0.426	232.190	40.658 .	-5.506
K^2	-50.986	0.609	-5.103	1.487	2.789	15.275	11.383	2.959	32.170	3.104	-1.642
I^2	-0.833	0.400	-4.988	-2.190	3.267	12.873	7.538	3.109 .	22.232	0.457	-1.157
KI	-9.682	1.519	8.660	-8.231	-8.325 *	-28.888	-15.407	-5.716 .	-56.857	-3.590	2.540
K^3	0.493	-0.226	0.167	-0.333	-0.112	-1.205 .	-3.335	-0.429 *	-0.544	1.550 *	0.026
I^3	0.104	0.341 .	-0.016	0.349	0.026	0.990 .	4.008	0.442 .	-0.482	-2.024 **	0.019
K^2I	0.376	0.753	-0.353	1.011	0.281	3.380 .	10.531	1.299 .	0.536	-5.133 **	-0.027
KI^2	-0.240	-0.905	0.220	-0.904	-0.169	-3.155 .	-11.248	-1.316 .	0.524	5.608 **	-0.016
Adj R^2	0.048	0.337	0.531	0.012	0.623	0.391	0.002	0.576 .	0.146	0.715	0.658
Instrumental Variable Semi-parameter (Eq. (A4)) - Time Control											
ED	-3.322 ***	-101.857	2.972 *	-3.103 *	-7.234	6.070	5.617	5.185 ***	-4.031	27.008 ***	-4.977
L	-0.389 .	-11.714	-0.332	-0.982	0.812	-3.226	1.307	2.487 *	-0.799	-15.466 ***	1.704 *
K	25.962	2893.378	72.191	-87.279	41.670	447.317	165.666	7.246	9.001	-1688.728 ***	-662.231
I	-96.057	-1303.748	-51.162	-21.903	-155.801	-141.685	34.172	102.301	-138.847	2657.903 ***	-166.833
K^2	17.778	-536.869	-10.413	14.835	-12.709	-58.162	-16.797	1.523	2.061	1.074	26.199
I^2	28.060 *	-472.571	-7.717	14.784	-7.693	-46.841	-13.984	-2.231	7.797	-163.623 ***	10.245
KI	-42.971	938.831	17.613	-25.483	24.401	94.550	23.137	-3.730	-4.875	122.444 ***	-8.739
K^3	-0.828	17.373	0.811	-0.574	0.641	2.938	1.691	0.644	1.893	52.565 ***	0.037
I^3	0.224	1.498	-0.707	0.146	-0.408	-1.827	-1.469	-0.919	-2.770	-63.013 ***	-0.595
K^2I	2.129 *	-33.567	-2.289	1.304	-1.643	-7.541	-4.769	-2.222	-6.403	-169.987 ***	-1.074
KI^2	-1.566 *	15.839	2.190	-0.927	1.366	6.552	4.643	2.555	7.215	180.959 ***	1.323
Adj R^2	0.337	0.001	0.782	0.640	0.228	0.469	0.461	0.505	0.558	0.998	0.379
Instrumental Variable Semi-parameter (Eq. (A4)) - Two-way Control											
ED	-12.306	3.620	2.201	-4.362	-15.252	4.231	7.323	12.818	3.118	3.851	8.837
L	0.289 .	0.130 *	0.163	0.236	0.166	-0.110	-0.142	-0.236	-0.040	0.093	-0.178
K	282.355	9.675	-19.599	2.395	-42.292	32.380	-12.668	49.725	6.513	-8.552	273.880
I	30.090	11.253	29.741	-3.981	0.874	-18.804	24.747	49.474	21.782	23.348	0.086
K^2	-8.092	-0.047	2.084	0.579	4.309	2.169	-3.364	-2.800	5.019	-2.426	-11.583
I^2	1.749	-0.083	0.502	1.017	3.386	4.725	-5.423	-3.220	5.513	-3.920	-2.780
KI	-4.895	-0.651	-2.989	-1.526	-6.105	-7.242	8.257	2.125	-11.580	5.776	5.180
K^3	0.048	0.006	0.203	-0.181	-0.339	-0.514	0.573	0.335	-0.137	0.912	0.236
I^3	0.021	-0.010	-0.323 .	0.219	0.307	0.528	-0.532	-0.344	-0.056	-1.016	-0.066
K^2I	0.182	-0.018	-0.745	0.586	0.959	1.602	-1.718	-0.996	0.252	-2.855	-0.344
KI^2	-0.117	0.032	0.871 .	-0.625	-0.947	-1.614	1.684	1.056	-0.047	2.966	0.277
Adj R^2	0.002	0.517	0.106	0.102	0.059	0.148	0.078	0.014	0.147	0.141	0.019
Generalized Method of Moments (Eq. (A5)) - Two-way Control											
GDP_{t-1}	0.489 *	-0.116	0.385	0.185	0.221 .	0.174	0.113	0.218	-0.142	0.130	0.213
ED	0.564 ***	0.545	-0.353 *	-0.403 .	-0.192	-0.267 *	0.251 **	-0.041	0.082 .	0.120 .	0.071
L	0.069	0.495 ***	0.301	0.151	0.103	-0.001	0.039	0.377 ***	0.212	0.140 *	0.371 ***
K	0.174	0.616 *	0.355	0.563 .	0.082	0.828 *	0.460 *	0.086	0.017	0.831 ***	0.224 **

Note: ***p<0.001; **p<0.01, and *<0.05.

Table A3 Estimation Results of Simplest, Translog, and Time Different Models using Effective Density based on Localization Agglomeration (N=282)

	Agriculture		*Mining*		*Manufacturing*		*Construction*		*Elec/Gas/Water*		*Retail*		*Finance/Insur*		*Real Estate*		*Transport/Comm*		*Service*		*Gov. Service*	
Simplest (Eq. (A1)) - Pooled																						
(Intercept)	12.675	***	1.955	.	-0.848	**	2.137	***	2.356	***	0.359		-0.599	*	14.757	***	9.916	***	3.596	***	7.515	***
ED	0.032		0.188	*	0.000		0.297	***	-0.091		0.042		0.240	***	0.187	**	0.151	***	-0.413	***	0.042	
L	0.570	***	0.171	**	0.586	***	0.930	***	0.176	***	0.489	***	0.524	***	0.487	***	0.668	***	0.845	***	0.693	***
K	0.276	***	0.768	***	0.437	***	-0.104	**	0.815	***	0.475	***	0.444	***	0.245	***	0.289	***	0.199	***	0.390	***
Adj R^2	0.706		0.815		0.984		0.942		0.944		0.970		0.972		0.947		0.975		0.978		0.981	
Translog (Eq. (A2)) - Pooled																						
(Intercept)	139.146	.	-11.900		-15.320	**	12.810		87.365	***	33.270	***	9.675	.	72.277	**	18.265	**	26.000	***	70.989	**
ED	-0.037		0.235	**	0.010		0.271	***	-0.041		-0.060		0.184	***	0.215	**	0.155	***	-0.412	***	0.033	
L	-4.510		1.838		2.908	***	1.848		9.928	***	2.300	.	-0.066		6.826	.	2.164	**	-1.837	.	8.726	***
K	-7.141		1.412		-0.745		-1.786	.	-8.169	***	-3.605	***	0.280		-6.378	*	-0.921		1.234		-6.957	**
$L^2/2$	-0.211	.	0.092		0.287	***	-0.650	***	0.424	**	-0.804	***	-0.320	**	0.279		0.083		0.596	***	0.672	***
$K^2/2$	0.190		0.001		0.367	***	-0.542	**	0.461	***	-0.578	**	-0.321	***	0.372	.	0.079	.	0.446	***	0.450	**
LK	0.243	.	-0.095		-0.348	***	0.610	***	-0.474	***	0.731	***	0.335	***	-0.340		-0.087	.	-0.491	***	-0.529	***
Adj R^2	0.720		0.819		0.985		0.945		0.948		0.975		0.974		0.947		0.975		0.980		0.983	
Time-Different Semi-parameter (Eq. (A3)) - Prefecture control																						
ED	0.582	*	1.822	***	0.385	*	0.229		-1.437	***	0.227	**	0.222		-0.277	**	0.062		-0.238	***	0.102	
L	0.160	*	-0.105		0.458	***	0.257	***	0.000		0.084	*	0.005		0.229	**	-0.032		0.116	**	0.249	***
K	-88.312		31.444		85.887		-2.889		-28.951		-108.502	***	-119.040	**	-9.265		19.634		-32.357	.	-86.963	
I	37.701		11.716		-6.211		26.438		23.077		72.122	***	31.497		12.284	*	-22.439		39.410	**	1.830	
K^2	5.231		-2.816		-2.748		4.659	.	2.473		16.225	***	19.090	**	0.439		4.408	*	11.533	***	2.122	
I^2	0.966		-2.436	.	0.466		4.281	.	1.067		12.180	***	15.541	*	-0.420		7.108	**	10.825	***	-0.936	.
KI	-4.395		3.435		-0.477		-9.821	*	-3.369		-27.181	***	-31.167	*	-0.182		-11.282	**	-22.668	***	1.573	
K^3	-0.078		-0.028		0.074		-0.128		0.083		-1.412	***	-3.331	***	-0.052		-0.749	***	-1.030	*	0.006	
I^3	-0.027		0.171	.	-0.068		-0.040		-0.180	*	1.279	***	3.472	***	0.064		0.773	***	0.869	.	-0.013	
K^2I	0.047		0.233		-0.143		0.229		-0.360		4.032	***	10.028	***	0.151		2.317	***	2.932	*	-0.091	
KI^2	0.036		-0.349		0.169		-0.050		0.456	.	-3.913	***	-10.214	***	-0.160		-2.345	***	-2.767	*	0.069	
Adj R^2	0.086		0.485		0.342		0.610		0.534		0.655		0.521		0.275		0.463		0.564		0.552	
Time-Difference Semi-parameter (Eq. (A3)) - Time control																						
ED	0.273		0.479	*	0.126		0.038		0.073		-0.130		-0.020		0.086		0.038		0.090		0.051	
L	0.137	**	0.030		0.346	**	0.127	.	-0.019		0.023		0.025		0.327	**	0.027		0.072	**	0.320	***
K	290.203	.	32.104		27.228		0.394		9.605		-4.391		-2.797		-2.549		8.832		-16.417	.	-61.194	.
I	-60.200		-0.190		-6.105		20.803		-21.121		5.748		-6.976		10.400	*	-1.280		15.884	.	-6.317	
K^2	-12.315	*	-1.901		-0.558		1.914		1.268		0.149		-3.716		-0.840		2.718	.	2.302		0.921	
I^2	0.082		-0.674		0.619		1.503		2.926	***	-0.184		-4.196	.	-1.578	*	3.717	*	1.490		-1.090	*
KI	4.094		1.309		-0.742		-4.240		-3.622	**	0.022		8.300	.	2.062		-6.660	*	-3.770		2.449	.
K^3	0.167	.	-0.026		0.047		0.069		-0.028		0.095		0.229		0.166		-0.170		-0.144		0.021	
I^3	0.003		0.098	*	-0.067		-0.164		-0.046		-0.123		-0.119		-0.173		0.083		0.105		-0.010	
K^2I	-0.063		0.176		-0.135		-0.295		0.045		-0.316		-0.598		-0.515		0.451		0.381		-0.101	
KI^2	-0.011		-0.231	.	0.162		0.401		0.020		0.344		0.483		0.527		-0.362		-0.342		0.064	
Adj R^2	0.104		0.789		0.168		0.409		0.793				0.639		0.217		0.450		0.698		0.179	
Time-Difference Semi-parameter (Eq. (A3)) - Two-way control																						
ED	0.497	.	0.257		0.081		0.133		0.023		-0.166	.	-0.051		0.041		-0.039		0.098		0.059	
L	0.123	*	0.029		0.252	.	0.125		-0.030		0.008		0.015		0.159		-0.025		0.075	**	0.066	
K	126.966		10.229		84.992	.	19.661		34.195		-35.273		-15.503		-5.065		5.377		19.865		-6.264	
I	-49.989		-5.328		-8.865		25.875		-36.325	.	8.140		-8.689		10.511	.	-0.415		-5.371		20.552	
K^2	-5.933		-1.313		-2.530		3.297		-1.309		1.491		-3.793		-1.085		2.642	.	-0.478		-0.013	
I^2	0.299		-0.842		0.784		3.737	.	1.693	.	-0.005		-4.795	.	-2.017	*	3.426	.	0.631		-0.939	.
KI	2.984		2.016		-0.850		-8.716	.	-0.254		-0.469		9.527	.	2.852	.	-6.197	.	-0.679		0.306	
K^3	0.083		-0.050		0.060		-0.031		-0.007		0.054		0.278		0.181	.	-0.237	*	-0.197		0.020	
I^3	0.002		0.131	**	-0.056		-0.119		0.015		-0.095		-0.163		-0.177		0.183		0.245		-0.011	
K^2I	-0.039		0.234	.	-0.101		-0.027		0.088		-0.234		-0.755		-0.555	.	0.676	.	0.661		-0.062	
KI^2	-0.015		-0.312	*	0.126		0.197		-0.099		0.263		0.628		0.555		-0.621		-0.703		0.062	
Adj R^2	0.065		0.638		0.074		0.340		0.648		0.485		0.505		0.156		0.332		0.554		0.111	

Note: ***p<0.001; **p<0.01, and *<0.05.

Table A4 Estimation Results of Instrumental Variable Models using Effective Density based on Localization Agglomeration (N=282)

	Agriculture	*Mining*	*Manufacturing*	*Construction*	*Elec/Gas/Water*	*Retail*	*Finance/Insur*	*Real Estate*	*Transport/Comm*	*Service*	*Gov. Service*
					Instrumental Variable Semi-parameter (Eq. (A4)) - Prefecture Control						
ED	-7.806 .	-0.648	-0.197	0.996 ***	5.786	1.590 .	-4.755	10.576	1.155 ***	6.810	-1.684 **
L	1.350 *	0.830 *	0.378	0.102	-1.233	-0.807	3.584	2.447 *	0.014	-1.422	1.367 ***
K	-47.497	8.489	11.212	59.595 .	84.189	-3.355	-90.520	12.221	-86.291 *	170.625	-5.721
I	256.407	-20.973	11.441	-28.792	53.273	-12.358	51.747	61.236	65.918	-93.803	-18.815
K^2	7.265	-4.319	-1.594	-5.101	0.889	5.633	10.665	-10.266	16.985 **	-174.497	-0.590
I^2	-3.054	-4.137	-1.935	-2.330	2.796	7.041	7.007	-14.627	14.305 **	-192.204	-0.220
KI	-12.610	9.147	2.712	6.355	-8.523	-11.978	-16.288	21.631	-30.676 **	363.142	1.678
K^3	-0.062	0.075	0.265	0.241	-0.574	-0.616	-1.591	2.404	-0.785 *	35.258	-0.008
I^3	-0.094	0.134	-0.284	-0.154	0.732	0.546	1.751	-2.746	0.381	-36.829	0.031
K^2I	-0.086	-0.047	-0.814 .	-0.584	1.927	1.806	4.843	-7.583	1.936 .	-107.520	0.048
KI^2	0.353	-0.173	0.843 .	0.510	-2.028	-1.746	-5.018	7.969	-1.539	109.139	-0.081
Adj R^2	0.055	0.429	0.652	0.641	0.202	0.539	0.010	0.206	0.620	0.162	0.630
					Instrumental Variable Semi-parameter (Eq. (A4)) - Time Control						
ED	-6.607 ***	19.449	2.814 *	-4.011 .	-8.594	7.161	5.144	5.317 **	-4.051	-108.388 ***	-4.576
L	0.451 **	-0.891	-0.354	-1.066	1.048	-3.839	0.942	2.769 *	-0.564	60.770 ***	1.846 *
K	1484.167	-220.670	64.326	-104.103	-65.566	546.799	88.739	-23.078	166.852	7168.242 ***	-401.296
I	363.597	-121.910	-69.250	-51.049	-171.164	-157.922	64.637	130.817	-274.628	-11015.790 ***	-212.528
K^2	-27.706	19.170	-11.608	11.421	-8.438	-66.150	-7.982	7.665	-13.452	4.955	14.308
I^2	18.235	17.786	-8.627	11.031	-6.590	-51.806	-8.118	2.629	1.199	696.796 ***	8.479
KI	-58.224	-20.763	20.654	-16.539	23.477	104.653	10.197	-14.659	16.803	-541.399 ***	-2.127
K^3	-0.204	-1.101	0.981	-0.305	0.653	3.216	0.990	0.629	2.203	-249.449 ***	0.098
I^3	0.115	0.718	-0.876	-0.042	-0.523	-1.955	-0.893	-1.175	-2.683	300.790 ***	-0.440
K^2I	1.849 .	2.789	-2.797	0.551	-1.860	-8.165	-2.847	-2.445	-6.806	806.905 ***	-0.837
KI^2	-0.936	-2.661	2.685	-0.278	1.631	7.060	2.825	3.048	7.223	-860.331 ***	0.947
Adj R^2	0.284	0.085	0.782	0.597	0.194	0.386	0.492	0.454	0.553	0.998	0.464
					Instrumental Variable Semi-parameter (Eq. (A4)) - Two-way Control						
ED	-6.887 *	2.495 .	3.124	-11.111	-26.851	4.405	6.495	9.051	1.539	-5.814	28.622
L	1.018 **	-0.217	0.050	0.415	2.425	-0.125	-0.293	-0.450	-0.201	0.082	-3.774
K	-137.086	-15.410	2.658	-80.474	-82.525	54.157	-0.411	36.666	-32.261	7.854	885.476
I	155.526	6.467	18.260	66.759	187.813	-23.966	9.207	48.802	33.053	-62.887	80.339
K^2	11.519	-0.028	0.568	9.557	13.591	2.006	-7.631	1.334	7.002	10.129	-39.613
I^2	2.533	-1.202	0.039	5.222	5.602	5.658	-9.265	1.229	5.756	14.467	-14.088
KI	-15.368	1.743	-1.347	-14.448	-23.414	-8.587	16.509	-5.918	-12.856	-22.388	21.039
K^3	-0.230	-0.060	0.262	-0.848	-0.528	-0.625	1.447	-0.373	-0.030	-2.294	0.917
I^3	-0.012	0.123	-0.361	0.810	0.251	0.655	-1.468	0.424	-0.250	2.383	-0.274
K^2I	0.325	0.203	-0.882	2.424	1.213	1.974	-4.390	1.187	-0.185	7.029	-1.515
KI^2	-0.061	-0.274	0.990	-2.387	-0.881	-1.996	4.417	-1.193	0.467	-7.146	1.242
Adj R^2	0.031	0.567	0.089	0.019	0.019	0.125	0.083	0.020	0.251	0.048	0.006
					Generalized Method of Moments (Eq. (A5)) - Two-way Control						
GDP_{t-1}	0.514 *	-0.147	0.400	0.191	0.225 .	0.167	0.100	0.224	-0.167	0.134	0.210
ED	0.249	0.882 *	-0.247	-0.312 .	-0.237	-0.294 **	0.261 **	0.044	0.026	0.189 *	0.058
L	0.044	0.390 ***	0.300	0.156	0.119	-0.001	0.036	0.371 ***	0.211	0.133 *	0.369 ***
K	0.181	0.608 *	0.345	0.576 .	0.080	0.826 *	0.470 **	0.084	0.022	0.822 ***	0.223 **

Note: ***p<0.001; **p<0.01, and *<0.05.

Table A5 Full Estimation Results Semi-parametric Models using Effective Density based on Urbanization Agglomeration (N=282)

	Agriculture	*Mining*	*Manufacturing*	*Construction*	*Elec/Gas/Water*	*Retail*	*Finance/Insur*	*Real Estate*	*Transport/Comm*	*Service*	*Gov. Service*
					Semi-parameter (equation 5) - Prefecture control						
ED	0.090	1.267 ***	-0.032	-0.011	0.175	-0.055	0.935 ***	-0.417 **	-0.051	0.066	-0.195 ***
L	0.195 ***	0.286 ***	0.411 ***	0.574 ***	-0.123	0.269 ***	0.548 ***	0.636 ***	0.220 ***	0.080 *	0.549 ***
K	310.567 *	28.328	18.897	46.162 *	-14.788	-25.593	-44.933 *	-12.914 *	-16.114	-37.815 **	-16.765
I	-48.528	19.593	-4.210	-26.146	25.770	53.137 **	36.457 .	21.755 **	18.043	36.356 *	-17.018
K^2	-14.415 **	-1.221	-2.324	-5.195 **	3.537 *	12.129 ***	18.296 **	2.464 *	11.956 ***	4.158	-0.588
I^2	-2.211	-0.973	-1.913	-3.130 .	2.830 .	11.535 ***	17.969 **	1.525	13.068 ***	2.057	-0.749
KI	7.318 .	0.230	3.743	7.638 *	-6.696 *	-24.692 ***	-35.936 **	-4.396 *	-25.043 ***	-6.229	2.492
K^3	0.251 ***	0.001	0.314 *	0.409 **	-0.095	-1.267 ***	-3.405 ***	-0.227 .	-1.126 ***	0.866 .	0.030
I^3	-0.031 .	0.044	-0.331 *	-0.361 **	0.007	1.173 ***	3.542 ***	0.212	0.968 ***	-1.198 *	-0.005
K^2I	-0.268 **	0.055	-0.949 *	-1.138 **	0.196	3.712 ***	10.332 ***	0.652	3.255 ***	-2.941 .	-0.077
KI^2	0.159 **	-0.073	0.971 *	1.098 **	-0.105	-3.605 ***	-10.473 ***	-0.632	-3.098 ***	3.274 *	0.038
Adj R^2	0.429	0.510	0.727	0.642	0.706	0.745	0.699	0.730	0.721	0.771	0.747
					Semi-parameter (equation 5) - Time control						
ED	-0.296 ***	0.011	0.095 *	-0.101 *	0.002	0.033	0.062	0.292 ***	0.016	0.021	0.001
L	0.331 ***	0.053	0.574 ***	0.253 ***	0.111 ***	0.212 ***	0.194 ***	0.090	0.009	0.159 ***	0.963 ***
K	-233.222	24.692	-1.612	41.281 .	5.677	31.455	17.610	-2.013	2.248	-32.139 *	17.766
I	-178.071 .	9.855	6.385	-26.006	-37.680 *	-1.324	-17.630	-1.502	-1.578	32.184 *	29.800
K^2	0.980	1.647	-1.860	-6.958 *	1.677	-6.111	-9.912	-5.008 .	2.926	8.349 *	-0.509
I^2	-1.874	3.027 *	-2.604	-5.409 *	3.912 **	-6.000	-10.114	-6.131 *	3.751	7.290 .	-1.035
KI	15.934 *	-6.067 *	4.288	11.851 *	-4.209 .	11.005	20.042	11.251 *	-6.634	-15.638 *	-0.140
K^3	0.134	0.034	0.391 *	0.586 **	0.060	0.629	0.457	0.694 .	0.150	-0.476	0.053
I^3	-0.064 .	-0.178 .	-0.425 *	-0.488 **	-0.200 *	-0.587	-0.127	-0.686	-0.350	0.269	-0.047
K^2I	-0.487 *	-0.187	-1.218 *	-1.636 **	-0.272	-1.840	-1.071	-2.097 .	-0.614	1.220	-0.154
KI^2	0.233 .	0.350	1.253 *	1.545 **	0.392	1.811	0.743	2.088 .	0.813	-1.012	0.168
Adj R^2	0.777	0.885	0.928	0.915	0.927	0.930	0.926	0.893	0.930	0.936	0.929
					Semi-parameter (equation 5) - Two-way control						
ED	-0.199	0.460	0.097	-0.298	0.062	0.057	0.064	0.164	0.222 .	0.005	0.095
L	0.206 ***	0.158 ***	0.376 ***	0.172 *	0.073	0.064 .	0.062	0.585 ***	0.098 *	0.060 *	0.710 ***
K	282.348 *	10.998	-6.013	20.200	14.025	17.196	-0.489	-5.855	-0.890	-10.643	-22.669
I	-66.712	15.202	6.956	-19.504	-3.456	-1.868	-6.101	16.455 *	10.080	10.020	-17.321
K^2	-13.443 **	0.852	0.258	-4.165 *	1.740 .	-2.497	-4.091	-0.335	3.642 *	4.559	-1.087
I^2	-1.426	0.981	-0.294	-3.267 *	3.002 **	-2.191	-4.560	-1.340	3.959 *	4.582	-1.510 **
KI	7.208 .	-2.851	0.008	7.433 *	-4.996 **	4.181	8.911	1.192	-7.920 *	-9.088	3.982 **
K^3	0.208 **	0.011	0.178	0.388 **	0.051	0.161	0.160	0.234	0.009	-0.390	0.053 .
I^3	0.007	-0.071	-0.235 .	-0.337 **	-0.176 *	-0.116	-0.012	-0.278	-0.187	0.313	-0.007
K^2I	-0.156	-0.076	-0.597	-1.101 **	-0.239	-0.434	-0.356	-0.759	-0.181	1.101	-0.133 .
KI^2	0.032	0.149	0.654 .	1.051 **	0.366 .	0.395	0.205	0.809	0.363	-1.024	0.070
Adj R^2	0.185	0.611	0.330	0.295	0.617	0.557	0.537	0.284	0.490	0.630	0.372

Note: ***p<0.001; **p<0.01, and *<0.05.

Table A6 Full Estimation Results of Semi-parametric Models using Effective Density based on Localization Agglomeration (N=282)

	Agriculture		*Mining*		*Manufacturing*		*Construction*		*Elec/Gas/Water*		*Retail*		*Finance/Insur*		*Real Estate*		*Transport/Comm*		*Service*		*Gov. Service*	
Semi-parameter (equation 5) - Prefecture control																						
ED	-0.121		0.060		-0.274	***	0.532	***	-1.324	***	0.203	***	0.750	***	0.153		0.520	***	-0.478	***	-0.207	**
L	0.209	***	0.180	*	0.570	***	0.321	***	0.117		0.131	**	0.256	**	0.647	***	0.141	*	0.152	***	0.563	***
K	300.647	*	23.703		15.057		44.074	*	-18.306		-30.319	.	-58.132	**	-13.018	*	-12.765		-63.226	***	-22.999	
I	-44.672		25.853		-2.449		-20.975		25.050		56.411	**	46.941	*	24.181	***	14.725		57.004	***	-16.483	
K^2	-13.983	**	-0.213		-2.251		-4.629	*	4.154	**	13.199	***	20.466	***	2.483	*	9.242	***	19.111	***	-0.292	
I^2	-2.259	.	-0.227		-2.068		-2.748	.	3.465	*	12.495	***	19.491	***	1.452		10.044	***	17.595	***	-0.670	
KI	7.131		-1.600		3.893		6.551	.	-7.798	**	-26.674	***	-39.541	***	-4.439	*	-19.321	***	-36.515	***	2.307	
K^3	0.246	***	-0.075		0.235	.	0.338	**	-0.051		-1.312	***	-3.498	***	-0.255	.	-0.723	***	-1.676	**	0.024	
I^3	-0.032	.	0.106		-0.224		-0.286	*	-0.086		1.189	***	3.574	***	0.252		0.552	**	1.363	*	-0.004	
K^2I	-0.269	**	0.267		-0.691		-0.925	**	0.020		3.819	***	10.543	***	0.747	.	2.028	***	4.710	**	-0.068	
KI^2	0.163	**	-0.270		0.684		0.883	**	0.119		-3.684	***	-10.623	***	-0.736	.	-1.857	***	-4.400	**	0.032	
Adj R^2	0.429		0.447		0.732		0.657		0.728		0.747		0.709		0.728		0.742		0.776		0.745	
Semi-parameter (equation 5) - Time control																						
ED	-0.470	***	0.142		0.109	*	-0.106	*	0.008		0.024		0.061		0.244	***	0.013		0.018		-0.007	
L	0.401	***	0.045		0.567	***	0.262	***	0.111	***	0.217	***	0.190	**	0.083		0.007		0.161	***	0.964	***
K	-129.546		22.813		-0.663		41.202	.	5.667		31.482		17.065		-3.670		2.087		-31.880	*	17.523	
I	-152.721		8.855		4.917		-26.088		-37.603	*	-1.570		-17.366		-1.604		-1.484		31.846	*	29.404	
K^2	-2.916		1.780		-2.004		-7.059	*	1.683		-6.096		-9.823		-4.806	.	2.942		8.338	*	-0.502	
I^2	-3.131		3.139	*	-2.677		-5.527	*	3.915	**	-5.970		-10.042		-5.959	*	3.759		7.300	.	-1.023	
KI	16.352	*	-6.179	*	4.527		12.076	*	-4.219	.	10.967		19.892		10.946	*	-6.655		-15.633	*	-0.137	
K^3	0.200		0.023		0.400	*	0.590	**	0.060		0.627		0.451		0.674	.	0.151		-0.475		0.054	
I^3	-0.072	.	-0.169	.	-0.431	*	-0.487	**	-0.200	*	-0.584		-0.123		-0.668		-0.352		0.267		-0.048	
K^2I	-0.552	**	-0.159		-1.240	**	-1.643	**	-0.272		-1.833		-1.056		-2.041	.	-0.619		1.217		-0.156	
KI^2	0.299	*	0.321		1.273	*	1.547	**	0.392		1.804		0.729		2.033		0.818		-1.009		0.170	
Adj R^2	0.773		0.886		0.928		0.915		0.927		0.930		0.926		0.892		0.930		0.936		0.929	
Semi-parameter (equation 5) - Two-way control																						
L	0.267	*	0.014		0.364	***	0.177	***	0.057		0.066	*	0.060		0.570	**	0.071		0.060	**	0.711	***
K	252.969		5.857		-2.960		20.583		14.420		16.875	***	-0.484	**	-5.791		-3.746		-10.722	.	-23.503	
I	-50.352		9.687		6.582		-18.435		-4.389		-1.705	***	-6.160		16.663	*	12.715		10.262	**	-17.967	
K^2	-11.743		0.423		0.052		-4.114	.	1.695		-2.466	***	-4.118	**	-0.253		3.882	*	4.528	***	-1.069	
I^2	-1.238		0.415	.	-0.398		-3.231	.	3.001		-2.174	***	-4.587	*	-1.248		4.018	**	4.534	***	-1.498	.
KI	5.722		-1.373		0.226		7.290	*	-4.927		4.139	***	8.967	*	1.008		-8.219	**	-9.015	***	4.004	
K^3	0.178		0.012		0.195		0.386		0.052		0.160	***	0.169	***	0.217		0.010	***	-0.383	*	0.053	
I^3	0.008		-0.043	.	-0.251		-0.337		-0.177	*	-0.115	***	-0.022	***	-0.258		-0.196	***	0.306	.	-0.007	
K^2I	-0.122		-0.061		-0.644		-1.097		-0.242		-0.431	***	-0.382	***	-0.703		-0.194	***	1.079	*	-0.132	
KI^2	0.023		0.098		0.701		1.049		0.368	.	0.392	***	0.233	***	0.752		0.383	***	-1.002	*	0.069	
Adj R^2	0.197		0.627		0.333		0.293		0.618		0.557		0.537		0.287		0.492		0.630		0.370	

Note: ***p<0.001; **p<0.01, and *<0.05.

Table A7 Full Estimation Results of Semi-parametric Models using Effective Density based on Mixed Agglomeration (N=282)

	Agriculture	*Mining*	*Manufacturing*	*Construction*	*Elec, Gas & Water*	*Retail*	*Finance & Insur*	*Real Estate*	*Transport & Comm*	*Service*	*Gov. Service*
					Semi-parameter (equation 7) - Prefecture control						
ED	0.218	1.076 ***	-0.037	0.447 **	-0.038	0.127 **	1.214 ***	-0.362 **	0.664 ***	-0.042 ***	-0.052
L	0.197 ***	0.244 ***	0.402 ***	0.444 ***	-0.126	0.169 ***	0.355 ***	0.627 ***	0.198 **	0.050	0.464 ***
K	323.667 *	26.294	19.501	48.566 **	-17.258	-33.271 .	-46.151 *	-12.705 *	-7.141	-57.406 ***	-25.396
I	-47.893	21.051	-4.871	-25.117	26.996	58.697 **	38.599 *	21.871 **	11.966	52.733 ***	-13.284
K^2	-14.860 **	-0.965	-2.383	-5.457 **	3.597 *	13.818 ***	18.919 ***	2.585 **	10.055 ***	13.435 ***	-0.192
I^2	-2.212 .	-0.819	-1.939	-3.381 *	2.749 .	13.014 ***	18.541 ***	1.675	11.389 ***	11.420 **	-0.765
KI	7.277 .	-0.163	3.831	8.010 *	-6.636 *	-27.791 ***	-37.170 ***	-4.678 *	-21.566 ***	-24.746 **	2.267
K^3	0.254 ***	0.001	0.311 *	0.408 ***	-0.066	-1.352 ***	-3.506 ***	-0.254 .	-0.985 ***	-0.605	0.026
I^3	-0.029	0.033	-0.325 *	-0.348 **	-0.033	1.216 ***	3.639 ***	0.243	0.857 ***	0.265	-0.007
K^2I	-0.263 *	0.043	-0.936 *	-1.126 **	0.095	3.925 ***	10.630 ***	0.739 .	2.865 ***	1.466	-0.079
KI^2	0.153 **	-0.050	0.955 *	1.076 **	0.007	-3.776 ***	-10.767 ***	-0.721 .	-2.735 ***	-1.126	0.045
Adj R^2	0.433	0.502	0.728	0.649	0.706	0.747	0.713	0.730	0.729	0.773	0.744
					Semi-parameter (equation 7) - Time control						
ED	-0.297 ***	0.011	0.100 *	-0.102 *	0.002	0.031	0.062	0.294 ***	0.016	0.021	0.000
L	0.331 ***	0.053	0.572 ***	0.253 ***	0.111 ***	0.213 ***	0.194 ***	0.089	0.009	0.159 ***	0.963 ***
K	-232.955	24.691	-1.609	41.378 .	5.679	31.363	17.626	-2.020	2.257	-32.188 *	17.728
I	-177.777 .	9.854	6.311	-26.110	-37.681 *	-1.300	-17.645	-1.471	-1.597	32.224 *	29.772
K^2	0.982	1.647	-1.858	-6.965 *	1.677	-6.099	-9.915	-5.002 .	2.926	8.347 *	-0.507
I^2	-1.871	3.027 *	-2.599	-5.408 *	3.912 **	-5.990	-10.116	-6.126 *	3.752	7.285 .	-1.034
KI	15.908 *	-6.067 *	4.284	11.857 *	-4.209 .	10.984	20.047	11.239 *	-6.635	-15.631 *	-0.140
K^3	0.134	0.034	0.391 *	0.587 **	0.060	0.628	0.456	0.694 .	0.150	-0.476	0.053
I^3	-0.064 .	-0.178 .	-0.424 *	-0.489 **	-0.200 *	-0.586	-0.127	-0.687	-0.350	0.268	-0.047
K^2I	-0.486 *	-0.187	-1.215 *	-1.638 **	-0.272	-1.837	-1.070	-2.099 .	-0.615	1.219	-0.154
KI^2	0.233 .	0.350	1.250 *	1.546 **	0.392	1.809	0.742	2.090 .	0.813	-1.011	0.168
Adj R^2	0.777	0.885	0.928	0.915	0.927	0.930	0.926	0.893	0.930	0.936	0.929
					Semi-parameter (equation 7) - Two-way control						
ED	0.000 *	0.000	0.000	0.000	0.000	0.000	0.000	0.000 *	0.000	0.000	0.000 ***
L	0.181 .	0.040	0.151	0.173	0.262	-0.167	-0.029	0.372	-0.209	0.029	0.311 *
K	698.640	-9.644	-9.443	60.378	135.010	-135.050	-31.415	-8.077	27.424	-16.381	-26.108
I	47.016	27.267	15.746	-50.015	58.146	228.170	29.976	6.510	-60.619	-0.810	-37.626 .
K^2	-21.810	1.350	0.705	-8.517	1.820	40.481	1.558	-0.977	-0.319	2.296	-2.138
I^2	2.115	-0.104	-0.142	-5.508	6.045	34.098	-0.731	-1.952	3.201	2.155	-2.149 *
KI	-6.835	-1.970	-0.819	13.832	-15.145	-78.379	-0.838	3.073	-1.396	-3.769	6.604 **
K^3	0.185	-0.052	0.207	0.622	-0.254	-2.936	0.809	-0.114	-0.086	0.079	0.099 *
I^3	0.034	0.030	-0.284 *	-0.499	0.128	2.235	-1.055	0.218	0.065	-0.191	-0.024
K^2I	0.257	0.108	-0.704 .	-1.696	0.777	8.080	-2.696	0.415	0.295	-0.345	-0.242 *
KI^2	-0.161	-0.076	0.785 *	1.574	-0.561	-7.330	2.943	-0.522	-0.295	0.448	0.140 .
Adj R^2	0.005	0.485	0.253	0.125	0.114	0.017	0.372	0.070	0.163	0.426	0.191

Note: ***p<0.001; **p<0.01, and *<0.05.