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The Role of Public Intangibles on Externalities of Social Infrastructure in Japan: Empirical Studies Using the Japanese Regional KLEMS Type Database

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Abstract

Using the updated datasets on social infrastructure and regional productivity, we reexamine the contributions of social infrastructure on productivity improvements. Our study adds two new ideas to the previous studies on social infrastructure: 1) we consider the complementary role of intangibles to externalities of social infrastructure, and 2) we include a new measure -the spillover effects considering transaction volumes between two prefectures -—in our analysis.

To conduct our study, we use three datasets: 1) the updated dataset of social infrastructure published by the Cabinet Office, Government of Japan, 2) the 2021 version of the Regional Japan Industrial Productivity Database, which measures intangibles at the prefectural level, and 3) the inter-regional Input-Output Tables, which are used for the measurement of our unique spillover effects.

Using these datasets, we find that the ratio of intangibles to tangibles in the public sector in rural areas has not increased compared to those in the private sector and the public sector in the urban areas.

In the estimation results based on the production function including social infrastructure and public intangibles, we do not find positive and significant externalities of social infrastructure. However, the coordination of social infrastructure with intangibles by industry contributes to the productivity improvements. In addition, we find positive and significant effects of social infrastructure in rural areas. We also find positive and significant contributions of social infrastructure for restorations from large earthquakes such as Great East-Japan Earthquake and Kumamoto Earthquake.

Our results on intangibles and social infrastructure are consistent with our experiences during the COVID-19 pandemic, when the responses of the government to this pandemic were slow due to the lack of digitalization. Our study shows that we need to accumulate intangibles not only in the private sector but also in the public sector.

JEL Classification Codes：E22, O34, R53

Keywords：Externalities, Intangibles, Social Infrastructure Spillover Measure

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1. Introduction: Social Infrastructure and Intangibles

For a long time, economists have recognized that social infrastructure have externality effects on the whole economy. For example, roads, ports and airports play a role to promote distributions between regions through network effects. These externality effects are important for policymakers, because the construction of social infrastructure is justified as a policy tool to improve the productivity of whole economy. For example, presidents elected from the Democratic Party in the US, such as Obama and Biden, emphasized the redevelopment of social infrastructure. Then, many economists have examined the externality effects of social infrastructure by estimating the production function where TFP depends on the amount of social infrastructure.

However, after many studies on social infrastructure showed positive externality effects in the 20th century, economists have lost their concerns on social infrastructure in the 21st century. Especially in Japan, people have begun to think that new social infrastructure is not necessary, because large capital formation in social infrastructure in the 1990s generated huge budget deficits. They also argue that social infrastructure in the area with small populations should be reviewed.

In our study, we reexamine the role of social infrastructure in Japan, because the new category of social infrastructure has been added to the traditional category in the 21st century. Although traditional studies on tangible social infrastructure such as bridges, ports and roads, public intangibles such as knowledge in technology and software provided by public sectors may play the same role in the tangible public infrastructure in the 21st century. Our study examines the role of these public intangibles on productivity growth as well as the traditional infrastructure. For example, in Japan, we usually pay highway fares when we use express highways. The electronic toll collection system makes this payment of highway fares easy and contributes to productivity improvement in the highway services. If the MaaS system developed in Europe where several transportation systems are integrated is also developed in Japan, it will contribute not only to further productivity improvements through more efficient transportation but also to better environments.

Although there are many studies that examine externalities of public infrastructure or spillover effects of intangibles, studies that combine the public intangibles with public infrastructure are, to the best of our knowledge, not found. To conduct this study, we use two unique databases. First, we use the regional-level KLEMS database (it is called as R-JIP 2021 database) in Japan. We have already obtained the data on intangibles at the industry-level from the Japanese KLEMS database. However, it has been difficult for us to match the data on intangibles at the industry-level to the data on public infrastructure at the prefectural level published by the Cabinet Office. Thanks to the R-JIP 2021 database, we are able to overcome these difficulties. Because this database follows the 2008 SNA, we are able to obtain the data on intangibles at the industry and prefectural level and to match this data to the data on public infrastructure at the prefectural level.

Second, we construct a unique spillover measure using the inter-regional Input-Output Tables. In the previous studies that examine the effects of public infrastructure, a spillover effect was measured by the distance between regional capitals. However, our measure using the inter-regional I-O tables is more economically reasonable than the previous measure because it is measured by the trade volume between two prefectures.

In the next section, we review the related literature of our study. We introduce articles in the two related research fields: the effects of social infrastructure on productivity and the spillover effects of intangibles. In the third section, we explain the analytical framework of our paper. We also explain the data used in our study. Using these datasets, we overview the accumulation of social infrastructure and public intangibles in Japan. In the fourth section, we estimate production functions including public infrastructure and public intangibles. Estimation results show that we do not find the positive and significant effects of social infrastructure alone on productivity. However, social infrastructure associated with intangibles such as R&D and software shows positive and significant effects on productivity. We also find the positive and significant effects of social infrastructure in the rural area on productivity improvements. In addition, social infrastructure contributes to restoration from earthquake. In the last section, we summarize our results and policy implications.

2. Related Literature

In this section, we introduce articles in the two fields related to our paper: the effects of social infrastructure on productivity, and the spillover effects of intangibles.

In the first research field, Mera (1973) and Asako and Wakasugi (1984) are pioneers. They examined the effects of public infrastructure on productivity using the data of public infrastructure at the prefectural level published by Cabinet Office, Government of Japan. Aschauer (1989) conducts a similar study to the previous studies. These studies considered simple spillover effects of public infrastructure. The simple spillover effects mean that the social infrastructure in a specific region affects the productivity generated by the activities of private firms within the region. They showed the positive and significant effects of social infrastructure on the regional productivity.

In the 1990s, a lot of studies developed the spillover effects of public infrastructure by considering its effects from the other regions. Mitsui, Takezawa and Kawachi (1995) examine the effects of two types of social infrastructure: one is infrastructure which covers within 100kms from the regional capital of each prefecture and the other is infrastructure which covers prefectures in which regional capital exists between 100kms and 300kms from the specific regional capital. They found the spillover effects that consider social infrastructure within not only its own prefecture but also other prefectures.

Tsukai et al (2002) consider not only spillover effects from social infrastructure in other regions but also from the amount of production in other regions, as they assume that production volume represents amount of knowledge like Arrow (1962) and this knowledge is transmitted from one region to other regions. In addition, they show that marginal productivities of social infrastructure in the urban areas such as Tokyo, Osaka, and Aichi are very high.

Miyara and Fukushige (2008) consider several combinations of social infrastructures and estimated a production function including combined social infrastructures by prefecture. They also consider utilization rates of private and public capitals at their estimations. Their estimation results show that the contributions of all types of public capital to productivity are found in only Osaka.

Miyagawa, Kawasaki and Edamura (2013) examine spillover effects of social infrastructure using a similarity index of industrial structure between two prefectures. They found the effects of social infrastructure after the 1990s, and spillover effects were found in the non-manufacturing sector.

Although the above studies examined the effects of social infrastructure from the estimations of production functions including social infrastructure, Pereira and Roca-Sagalés (2003) and Bronzini and Paolo Piselli (2009) examined the spillover effects of social infrastructure using the time-series technique. In the former article, using the VAR model, the authors find that most spillover effects of social infrastructure are dominated by spillover effects from other regions in Spain. In the latter article, using panel cointegration analysis, they find positive spillover effects of social infrastructure, R&D and human capital on productivity in Italy. Among three components, the effects of social infrastructure and human capital are larger than those of R&D.

In the second field of related literature, we introduce articles on spillover effects of intangibles. Corrado, Haskel and Jona-Lasinio (2017) examine the spillover effects of intangibles categorized by Corrado, Hulten and Sichel (2009). They estimate a production function including intangibles using the productivity database (it is called INTAN-Invest database) which covers the EU countries, the UK and the US. Their estimation results showed that the intangibles in the whole country have positive and significant effects on output at the industry-level in this country.

Nonnis, Bounfour and Kim (2023) also examine the spillover effects of intangibles. They construct principal components of intangibles as each intangible asset correlates with each other. Using EUKLEMS and WIOD databases, they examine the two types of spillover effects of intangibles: domestic spillover effects and foreign spillover effects. Estimation results show that the former spillover effects are more effective than the latter on productivity growth.

3. An Analytical Framework and Datasets

3-1. A Production Function with Social Infrastructure and Intangibles

A typical production function in the previous studies, which examined the effects of social infrastructure on output, is expressed as follows:

(1) $Y_t^r = A(V_{t-1}^r)F(K_{t-1}^r,\ L_{t-1}^r)$.

In Equation (1), Y_t^r is a value added in the market sector in prefecture r at time t, V_t^r is social infrastructure in prefecture r, and K_t^r and L_t^r are capital input and labor input in prefecture r, respectively.

To study complementary effects of intangibles with social infrastructure, we modify Equation (1).

(2) $Y_t^{rj} = A\left(V_{t-1}^r, Z_{t-1}^{pr},\ S_{t-1}^{pr}\right)F(K_{t-1}^{rj},\ L_{t-1}^{rj})$.

Equation (2) is a production function of a value added in prefecture r and industry j. Z_t^{pr} is R&D stock in the public sector in prefecture r and S_t^{pr} is software stock in the public sector in prefecture r. We specify a production function (F) and TFP function (A) as follows

(3-1) $F(K_{t-1}^{rj},\ L_{t-1}^{rj}) = (K_{t-1}^{rj})^{\alpha}(L_{t-1}^{rj})^{1-\alpha}$,
(3-2) $A\left(V_{t-1}^r, Z_{t-1}^{pr},\ S_{t-1}^{pr}\right) = (V_{t-1}^r)^{\beta}(Z_{t-1}^{pr})^{\gamma_1}(S_{t-1}^{pr})^{\gamma_2}$.

Taking log of Equations (2), (3-1) and (3-2), we obtain the following equation for our estimations.

(4) $ln\left(y_t^{r,j}\right) = const. + \alpha\, ln\left(k_{t-1}^{r,j}\right) + \beta\, ln(v_{t-1}^r) + \gamma_1\, ln\left(z_{t-1}^{pr}\right) + \gamma_2\, ln\left(s_{t-1}^{pr}\right) + \varepsilon_t + \varepsilon_{rj} + \varepsilon_{tj}$,

where $x_t^{r,j} = \frac{X_t^{r,j}}{L_t^{r,j}}$ $(X = Y, K, V, Z \text{ and } S)$.

When we examine complementary effects of intangibles to social infrastructure, we add cross terms between social infrastructure and intangibles to Equation (4).

(5) $ln\left(y_t^{r,j}\right) = const. + \alpha\, ln\left(k_{t-1}^{r,j}\right) + \beta\, ln(v_{t-1}^r) + \gamma_1\, ln\left(z_{t-1}^{pr}\right) + \gamma_2\, ln\left(s_{t-1}^{pr}\right) +$

$\gamma_3 \, ln(v_{t-1}^{r} * z_{t-1}^{pr}) + \gamma_4 \, ln(v_{t-1}^{r} * S_{t-1}^{pr}) + \varepsilon_t + \varepsilon_{rj} + + \varepsilon_{tj}$

3-2. The Definition of Public Sector and the Concept of Spillover Effects

In Equations (4) and (5), we assume that social infrastructure and public intangibles affect the value added in the private sector in a specific prefecture through spillover effects. Public intangibles mean intangibles that are held in the public sector. As for the definition of public sector, we follow the classification suggested by Corrado, Jäger and Jona-Lassinio (2016). They define seven industries shown in Table 1 as a public sector. These industries correspond to industries from 27 to 30 in the R-JIP classification. Although scientific research and development are conducted in the private firms, we classify this industry in a public sector as the knowledge generated from the R&D activities that are typically utilized publicly. Similarly, when we construct the data on public software assets, we include the information services industry in the public sector because software generated from this industry is often publicly available.

(Insert Table 1 around here)

In our estimations, we assume two types of spillover effects. One is the spillover effects within a prefecture, which means that the social infrastructure and public intangibles in a prefecture affect a value added in the same prefecture. The other is the spillover effects that the social infrastructure and public intangibles in not only the concerned prefecture, but also other prefectures affect the value added in the concerned prefecture. The second spillover effects in the case of R&D are expressed in the following way.

(6) $Z_t^{p,r} = \sum_{j=27}^{j=30} Z_t^{r,j} + \sum_{k \neq r} w_r^k \sum_{j=27}^{j=30} Z_t^{k,j}$

The first term of the right-hand side of Equation (6) represents the spillover effects within a prefecture. The first definition of spillover effects focuses only this first term. The second term of Equation (6) represents the spillover effects from other prefectures. The term expressing the spillover weight in a prefecture r (w_r^k) is expressed as $\frac{\boldsymbol{TR_r^k}}{\sum_{h \neq r} \boldsymbol{TR_r^h}}$. TR_r^k and is the trading volume between a prefecture r and a prefecture k. The data for trading volume among prefectures is obtained from the inter-regional Input-Output Table 2011 published in the website of Research Institute of Economy, Trade and Industry.

3-3. The Data

For our estimations, we use two kinds of datasets. One is the dataset of the social infrastructure in Japan published by Cabinet Office, Government of Japan. This dataset consists of 18 types of social infrastructure at the prefectural level. We obtain the aggregate data for capital formation and capital stock of social infrastructure by prefecture from the latest version released in 2022.

The other is the dataset of R-JIP database released in 2021. The R-JIP database consists of value added, capital, and labor to measure productivity at the industry and prefectural level. The data is classified into 31 industries. Because it satisfies the criterion of 2008 SNA, its capital stock includes not only tangible assets but also intangibles such as R&D and software. The construction of these intangibles follows the guidelines of the prefectural-level SNA distributed by the Cabinet Office. The prefectural level R&D stock is allocated based on the share of workers who engage in R&D activities at the prefectural level. The prefectural level software stock is constructed from the software stock/ value added ratio at the aggregate level and the value added at the industry and prefectural level.

3-4. An Overview of Social Infrastructure and Intangibles in the Japanese Economy

Using the above datasets, we overview the roles of social infrastructure and intangibles in the Japanese economy. Figure 1 shows the movements of social infrastructure in Japan. Social infrastructure increased rapidly until the 1990s. Its amount in 2000 was 19 times of that in 1953. However, since 2000, it has not grown. The amount of productive social infrastructure was 793 trillion yen in 2019. The Cabinet Office classifies social infrastructure into 18 categories such as roads, ports, and all kinds of infrastructure except flood control and postal services, none of which has increased in the 21st century.

(Insert Figure 1 around here)

In addition to the slow growth of the social infrastructure in the 21st century, the share of replacement investment in the total investment in the social infrastructure has increased. In Figure 2, the share of replacement in the total capital formation in social infrastructure has increased from 25% in 2000 to 95% in 2019. This means that almost all capital formations in social infrastructure are used of the replacement recently.

(Insert Figure 2 around here)

Generally speaking, social infrastructure is allocated heavily for the economic revitalization in rural areas of Japan. Certainly, Figure 3 shows that the social infrastructure per capita in the rural area has been higher than that in urban areas since 1980.[1] In addition, the gap in social infrastructure per capita between two areas has become wider. The social infrastructure per capita in the rural areas was 1.6 times of that in urban areas in 2019.

(Insert Figure 3 around here)

In Figure 4, we compare the ratio of intangibles to tangibles between the market sector and public sector. The ratio in the public sector is much lower than that in the private sector. Especially, the share of intangibles has not increased in the public sector in the rural areas in Japan. This low weight of intangibles in the public sector led to the slow responses of the public sector to the COVID-19 pandemic.

(Insert Figure 4 around here)

Finally, we examine the simple relationship between the social infrastructure per capita and labor productivity growth in Figure 5. In Figure 5, we take the social infrastructure per capita on the horizontal axis and labor productivity growth rate on the vertical axis. Although we make two figures in 1995 and 2018, we are not able to find any positive relationships between the social infrastructure and labor productivity growth rate in either case.[2] However, in these figures, we simply check the direct relationship between the social infrastructure and labor productivity growth. In recent days, we may not find the positive effects of social infrastructure without the complementary effects of intangibles. Hence, we reexamine the effects of social infrastructure on productivity growth considering several complementary factors with intangibles.

(Insert Figure 5 around here)

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[1] We divide the whole Japan into urban areas and rural areas based on the trading volumes between central prefectures in the Tokyo metropolitan area, the Chukyo area and the Kansai area and adjacent prefectures. Following this criterion, the Tokyo metropolitan area consists of Saitama, Chiba, Tokyo, and Kanagawa prefectures, the Chukyo area consists of Aichi, Shizuoka, and Mie prefectures and the Kansai area consists of Kyoto, Osaka, Hyogo, and Shiga prefectures. Other prefectures are recognized as the regional areas See Appendix 1.

[2] Although we check the relationship between the level of labor productivity and social infrastructure per capita in 1995 and 2018, we do not find any positive relationships between two variables.

4. Estimation Results

4-1. Basic Estimation Results

We estimate Equations (4) and (5) by the fixed estimations. The estimation periods are from 1995 to 2018, because the R-JIP database covers this period. The basic statistics of the variables used for the estimations are summarized in Table 2.

(Insert Table 2 around here)

In Table 2, Zave and Save represent the average R&D stock and the software stock at the industry-level in the whole Japan. Because capital formations in R&D activities are zero in real estate and hotels and restaurants industries in the whole Japan and we do not measure the log of R&D stock, we do exclude Zave in these industries from its observations.

The basic estimation results assuming a simple measure of spillover effects are shown from (1) to (3) in Table 3. As shown in Equations (4) and (5), we conduct pooled estimations with a year fixed effect and industry*prefecture fixed effects. We do not find any positive and significant effects of public infrastructure on productivity in the market sector, although the capital/labor ratio in the market sector has positive and significant impacts on productivity, as the standard theory expects. Similarly, we do not find any positive and significant effects of intangibles in the local public sector on productivity. However, when we add the cross term between social infrastructure and industry-level averaged intangible terms (Zave and Save) to Equation (5) and estimate it, we find that these cross terms show the positive and significant effects on productivity at the prefectural level. These results imply that as the averaged industry-level knowledge and software in the whole country have strong network effects, the localized or customized knowledge and software are useless for productivity improvements at the prefectural level.

(Insert Table 3 around here)

The basic estimation results with spillover effects through the transactions with other prefectures are shown from (4) to (6) in Table 3. The results are similar to those using the simple spillover measure. Although we do not find any evidence of positive and significant effects of social infrastructure on productivity improvements, the cross terms between the social infrastructure and averaged industry-level intangibles show positive and significant effects on productivity.

In Table 4, we show estimation results by instrumental variable method. Instruments are lagged variables of explanatory variables, the capital formation in ICT hardware/GDP ratio, the capital formation in R&D/GDP ratio, the capital formation in software/GDP ratio, TFP growth rate at the industry-level in the US and products of exports by industry in Japan,.[3] As from (1) to (3) in Table 3, we show the estimation results with the simple measure of spillover effects. In the other estimation results, we use the spillover measure through transactions with other prefectures.

(Insert Table 4 around here)

The estimation results in Table 4 are similar to Tables 3. The positive and significant effects of the cross terms between the social infrastructure and industry-level averaged intangible terms are robust. In addition, we find positive and the significant effects of social infrastructure and local software stock in Column (2) and (4) respectively, though these coefficients are not significant in the other estimations.[4]

4-2. Estimation Results by Area

In Tables 3 and 4, we do not find robust results for the positive effects of social infrastructure on productivity. However, as seen in Figure 3, there is a huge gap in allocation of social infrastructure between urban and rural areas in Japan.[5] Then we examine the effects of social infrastructure on productivity by area. Table 5 shows estimation results by area. Although we show estimation results with spillover measures thorough transactions with other prefectures in Table 5, estimation results with simple spillover measure are similar to those shown in Table 5. As in Tables 3 and 4, we find that the cross term between the social infrastructure and averaged industry-level intangibles are positive and significant. Although we find a positive and significant coefficient on social infrastructure in the IV estimation in the rural area, we do not find the same results in the other estimation methods such as fixed estimations and GMM estimations.

(Insert Table 5 around here)

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[3] We obtain the data on exports by industry from the Input-Output Table in the 2021 version of JIP database. As this table consists of 100 industries, we summarize these industries into 31 industries which are consistent with the industries in the 2018 version of R-JIP database.

[4] We also conduct GMM estimations. However, as these estimation results are similar those in fixed estimations and IV estimations and they do not pass exogeneity tests.

[5] The prefectures in the urban area and the rural follow the definition shown in Note 1. Although we add Fukuoka prefecture to the urban area defined in Note 1, the estimation results do not change.

4-3. The Role of Social Infrastructure in the Restoration from Large Earthquakes

Although our estimations do not show that social infrastructure without assistance of intangibles play a role in productivity improvements at the prefectural level, it may contribute to productivity in the case of disaster such as an earthquake which we suffered from many times in the estimation period.[6] To make dummy variables of earthquakes, we select prefectures and years which was damaged from the following earthquakes: Hanshin-Awaji Earthquake in 1995, Niigata Chuetsu Earthquake in 2004, Great East-Japan Earthquake in 2011, Kumamoto Earthquake in 2016 and Hokkaido Iburi East Earthquake in 2018. [7]Then, we add the cross terms between the social infrastructure and these dummy variables to Equations (5).

The Estimation results with earthquake dummy variables are shown in Table 6. In this table, we show the results of IV estimations in the other columns. In all estimations, we assume the spillover measures through transactions with other prefectures. As we expect, we find the positive and significant effects of cross terms between social infrastructure and earthquake dummies on productivity. These results imply the restoration of social infrastructure damaged by earthquakes contributes to productivity in the damaged areas. In addition, we almost find positive and significant effects of social infrastructure without earthquake dummies on productivity growth in the rural area. However, we do not find positive and significant effects of social infrastructure on productivity in the rural area in the case of fixed estimations and GMM estimations.

(Insert Table 6 around here)

5. Conclusions and Policy Implications

Using the updated datasets on social infrastructure and regional productivity, we reexamine the contributions of social infrastructure on productivity improvements. Our study adds the two new ideas to the previous studies on social infrastructure: one is that we consider the complementary role of intangibles to externalities of social infrastructure, and the other is that we include new measure of spillover effects considering transaction volumes between two prefectures in our analysis.

To conduct our study, we use three data sets: 1) the updated dataset of social infrastructure published by Cabinet Office, Government of Japan, 2) the 2021 version of Regional Japan Industrial Productivity Database which measures intangibles at the prefectural level, and 3) the

[6] For example, many public ports for fisheries in the Tohoku area, which suffered from Great East-Japan Earthquake, have improved productivity by advancing digitalization after the earthquake.

[7] Years and prefectures of earthquake dummies are shown in Appendix 2. Reconstruction projects from earthquakes take a long time. In the case of the Hanshin-Awaji Earthquake, it took 25 years from the earthquake. We recognize all estimation years from the earthquake as reconstruction periods. Even if we assume that the reconstruction period is five years, our estimation results do not change.

inter-regional Input-Output database in 2011 published by Research Institute of Economy, Trade and Industry. From these datasets, we find that the ratio of intangibles to tangibles in the public sector is too low compared to that in the private sector. This overview is consistent with our experiences during the COVID-19 when the responses of the Japanese government to the pandemic were slow due to the lack of intangibles.

In the basic estimation results based on the production function including social infrastructure and intangibles, we do not find the positive and significant externalities of social infrastructure. However, the cross terms between social infrastructure and averaged industry-level intangibles show positive and significant effects on productivity improvements. These results imply that social infrastructure, with the help of intangibles such as R&D and software, gives positive impacts on productivity at the regional level, though social infrastructure alone has no impacts on productivity. Although accumulation of intangibles at the local level does not contribute to the productivity improvements, these results are consistent with the network effects of intangibles.

We also examine the role of social infrastructure on restorations from large earthquakes. When we estimate Equation (5) with earthquake dummies, we find the positive and significant contributions of social infrastructure to the restoration from earthquakes.

Our estimation results imply that the averaged industry-level intangibles support the externality effects of social infrastructure. However, these results do not mean that local governments need not advance digitalization. The digitalization means not only accumulation of ICT equipment and software but also effective usage of ICT equipment and software. The local government should advance the latter sense of digitalization. If the local government and branches in the central government construct the digital system by which firms can make documents which are submitted to the local public sector more easily made, it will contribute to the productivity improvements for the private sector.

Now, we recognize software as accumulation of capital formation in software. However, firms and governments do not accumulate software assets but use the cloud, online meeting tools, and generative AI by paying its usage fees. These payments are not recognized as expenditures for assets but counted as period costs which are not captured in our datasets, If we can obtain the data which cover these costs, the effects of collaborations between social infrastructure and intangibles on productivity will be captured more accurately.

Appendix 1 -- Classification of Urban and Rural Areas

Name of Urban Area	Name of Prefecture
Kanto Area	Tokyo
	Chiba
	Saitama
	Kanagawa
Chukyo Area	Aichi
	Shizuoka
	Mie
Kansai Area	Osaka
	Hyogo
	Kyoto
	Shiga

Appendix 2 -- Years and Prefectures in Dummy Variables in Each Earthquake

Name of earthquale	Dummy variables
Hanshin-Awaji Earthquake	1995-2018 in Hyogo
Niigata Chuetsu Earthquake	2004-2018 in Niigata
Great East-Japan Earthquake	2011-2018 in Aomori
	2011-2018 in Iwate
	2011-2018 in Miyagi
	2011-2018 in Fukushima
	2011-2018 in Ibaraki
Kumamoto Earthquake	2016-2018 in Kumamoto
Hokkaido Iburi-East Earthquake	2018 in Hokkaido

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Table 1 -- The Definition of Public Sector

Public sector	**Industry classification number in SPINTAN project**	**Industry classification number in the Japanese National Census**	**Industry Classification in R-JIP Database**
Scientific research and development	**72**	**L(71)**	**27**
Public administration and defence; compulsory social security	**84**	**S**	**28**
Education	**85**	**Q**	**29**
Human health and social work activities	**86**	**N(56~57)**	**30**
Residential care activities and social work activities without accommodation	**87-88**	**N(58)**	**30**
Creative arts and entertainment service	**90-91**	**Q(67)**	**n.a.**
Gambling and betting activities	**92-93**	**Q(67)**	**n.a.**

Table 2 -- Summary of Statistics for the Basic Estimations

	ln(Yrj/Lrj)	ln(Krj/Lrj)	ln(Vr/Lr)	ln(Zpr/Lr)	ln(Spr/Lr)	ln(Vr/Lr) * ln(Zpr/Lr)	ln(Vr/Lr) * ln(Spr/Lr)	ln(Vr/Lr) * ln(Zave/Lr)	ln(Vr/Lr) * ln(Save/Lr)
Mean	**1.286**	**2.131**	**2.429**	**-1.027**	**-2.343**	**-2.475**	**-5.667**	**-11.058**	**-12.572**
Median	**1.216**	**1.822**	**2.453**	**-1.044**	**-2.347**	**-2.527**	**-5.702**	**-10.230**	**-12.184**
Standard deviation	**0.740**	**1.267**	**0.176**	**0.255**	**0.314**	**0.561**	**0.650**	**5.447**	**3.465**
Max	**4.574**	**5.741**	**2.903**	**-0.357**	**-1.461**	**-0.852**	**-2.939**	**-1.023**	**-4.184**
Min	**-11.769**	**-0.490**	**1.786**	**-1.634**	**-3.143**	**-3.669**	**-7.116**	**-32.474**	**-27.280**
Number of observations	**36425**	**36425**	**36425**	**36425**	**36425**	**36425**	**36425**	**34028**	**36425**

Table 3 -- Basic Estimation Results (fixed estimations)

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable = ln(Yrj/Lrj) (t)	Simple Spillover Measure			The Spillover Measure Using Inter-regional IO Tables		
ln(Krj/Lrj) (t-1)	0.5253***	0.5252***	0.4715***	0.5255***	0.5256***	0.4719***
	(0.0339)	(0.0339)	(0.0347)	(0.0340)	(0.0340)	(0.0348)
ln(Vr/Lr) (t-1)	0.1001	-0.0615	-0.1620	0.2006	0.1461	0.1032
	(0.1287)	(0.3507)	(0.3648)	(0.2121)	(0.3907)	(0.4132)
ln(Zpr/Lr) (t-1)	-0.0273	0.1191	0.1058	-0.0296	-0.0576	-0.1746
	(0.0558)	(0.3751)	(0.3938)	(0.1179)	(0.7879)	(0.8378)
ln(Spr/Lr) (t-1)	-0.0248	-0.0163	0.348	-0.1231	-0.0562	0.3632
	(0.1241)	(0.2685)	(0.2828)	(0.2404)	(0.6418)	(0.6781)
ln(Vr/Lr) * ln(Zpr/Lr) (t-1)		-0.0772	-0.0598		0.0113	0.0738
		(0.1921)	(0.2015)		(0.3095)	(0.3291)
ln(Vr/Lr) * ln(Spr/Lr) (t-1)		-0.0099	-0.2286		-0.0269	-0.1873
		(0.1460)	(0.1542)		(0.2515)	(0.2663)
ln(Vr/Lr) * ln(Zave/Lr) (t-1)			0.0570***			0.0402***
			(0.0074)			(0.0056)
ln(Vr/Lr) * ln(Save/Lr) (t-1)			0.1148***			0.0934***
			(0.0180)			(0.0155)
Const.	-0.2404	0.0409	1.8316**	-0.7597	-0.7322	1.3722
	(0.5758)	(0.7703)	(0.8131)	(1.0563)	(1.3057)	(1.3742)
year dummy	yes	yes	yes	yes	yes	yes
industry x region	yes	yes	yes	yes	yes	yes
R-squared						
within	0.1967	0.1968	0.2242	0.1968	0.1968	0.2211
between	0.4761	0.4763	0.3330	0.4738	0.4740	0.3125
orverall	0.4236	0.4239	0.3029	0.4217	0.4219	0.2850
No. of Obs.	30,456	30,456	28,200	30,456	30,456	26,200
No. of Groups	1,269	1,269	1,175	1,269	1,269	1,175

The lower cell in each estimation result shows standard error.

*, **, and *** show significance at 10%, 5%, and 1% levels, respectively.

Table 4 -- Basic Estimation Results (IV estimations)

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable = ln(Yrj/Lrj) (t)	Simple Spillover Measure			The Spillover Measure Using Inter-regional IO Tables		
ln(Krj/Lrj) (t-1)	0.5614***	0.5614***	0.5014***	0.5619***	0.5620***	0.5024***
	(0.0209)	(0.0209)	(0.0233)	(0.0210)	(0.0210)	(0.0236)
ln(Vr/Lr) (t-1)	0.0558	-0.2114	-0.3415*	0.1518*	0.0748	0.0787
	(0.0553)	(0.1690)	(0.1777)	(0.0775)	(0.1570)	(0.1664)
ln(Zpr/Lr) (t-1)	-0.0273	0.2871	0.2655	-0.0165	0.0668	-0.0966
	(0.0274)	(0.2067)	(0.2186)	(0.0633)	(0.5571)	(0.5960)
ln(Spr/Lr) (t-1)	-0.0069	-0.0325	0.4530***	-0.1043	-0.0657	0.4177
	(0.0471)	(0.1245)	(0.1335)	(0.0959)	(0.3149)	(0.3379)
ln(Vr/Lr) * ln(Zpr/Lr) (t-1)		-0.1637	-0.1384		-0.0334	0.0501
		(0.1091)	(0.1155)		(0.2142)	(0.2290)
ln(Vr/Lr) * ln(Spr/Lr) (t-1)		0.0068	-0.2877***		-0.0151	-0.2178
		(0.0730)	(0.0779)		(0.1236)	(0.1326)
ln(Vr/Lr) * ln(Zave/Lr) (t-1)			0.0614***			0.0438***
			(0.0028)			(0.0020)
ln(Vr/Lr) * ln(Save/Lr) (t-1)			0.1521***			0.1189***
			(0.0085)			(0.0070)
year dummy	yes	yes	yes	yes	yes	yes
industry x region	yes	yes	yes	yes	yes	yes
R-squared						
Centred	0.1591	0.1592	0.1833	0.1592	0.1591	0.1814
Uncentred	0.1591	0.1592	0.1833	0.1592	0.1591	0.1814
Hansen-J	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
No. of Obs.	27,918	27,918	25,850	27,918	27,918	25,850
No. of Groups	1,269	1,269	1,175	1,269	1,269	1,175

The lower cell in each estimation result shows standard error.

*, **, and *** show significance at 10%, 5%, and 1% levels, respectively.

Table 5 -- Estimation Results by Area

	(1)	(2)	(3)	(4)
Dependent variable = ln(Yrj/Lrj) (t)	Urban area		Rural area	
	Fixed Estimations	IV Estimations	Fixed Estimations	IV Estimations
ln(Krj/Lrj) (t-1)	0.5848***	0.5806***	0.4519***	0.4898***
	(0.0720)	(0.0377)	(0.0384)	(0.0273)
ln(Vr/Lr) (t-1)	-0.3452	-0.3726	0.5000	0.5374*
	(0.7025)	(0.2660)	(0.6120)	(0.2928)
ln(Zpr/Lr) (t-1)	0.5238	0.7158	0.0406	0.3567
	(1.2594)	(0.9452)	(1.1060)	(0.7808)
ln(Spr/Lr) (t-1)	0.5290	0.6393	-0.2632	-0.4774
	(0.9760)	(0.4476)	(0.9687)	(0.5699)
ln(Vr/Lr) * ln(Zpr/Lr) (t-1)	-0.2355	-0.2902	-0.0012	-0.1197
	(0.4925)	(0.3752)	(0.4362)	(0.3016)
ln(Vr/Lr) * ln(Spr/Lr) (t-1)	-0.0363	-0.0216	-0.0452	0.0098
	(0.3992)	(0.2010)	(0.3594)	(0.2017)
ln(Vr/Lr) * ln(Zave/Lr) (t-1)	0.0267**	0.0319***	0.0440***	0.0472***
	(0.0117)	(0.0041)	(0.0064)	(0.0023)
ln(Vr/Lr) * ln(Save/Lr) (t-1)	0.0624*	0.0845***	0.1016***	0.1286***
	(0.0366)	(0.0144)	(0.0173)	(0.0079)
Const.	3.2046		-0.2752	
	(2.3807)		(2.0859)	
year dummy	yes	yes	yes	yes
industry x region	yes	yes	yes	yes
R-squared				
Centred	0.2958	0.2517	0.2085	0.1703
Uncentred	0.4652	0.2517	0.3152	0.1703
Overall	0.4314		0.2830	
Hansen-J		0.0000		0.0000
No. of Obs.	6,600	6,050	21,600	19,800
No. of Groups	275	275	900	900

The lower cell in each estimation result shows standard error.

*, **, and *** show significance at 10%, 5%, and 1% levels, respectively.

Table 6 -- Estimation Results with Earthquake Dummies

	(1)	(2)	(3)
Dependent variable = ln(Yrj/Lrj) (t)	**All Japan**	**Urban area**	**Rural area**
ln(Krj/Lrj) (t-1)	**0.5048*****	**0.5806*****	**0.4914*****
	(0.0237)	**(0.0377)**	**(0.0274)**
ln(Vr/Lr) (t-1)	**0.0705**	**-0.3690**	**0.5609***
	(0.1663)	**(0.2769)**	**(0.2925)**
ln(Vr/Lr)*Earth(t-1)	**0.0353*****	**(0.0123)**	**0.0316*****
	(0.0050)	**(0.2104)**	**(0.0053)**
ln(Zpr/Lr) (t-1)	**-0.327**	**0.7114**	**-0.0595**
	(0.5981)	**(0.9456)**	**(0.7925)**
ln(Spr/Lr) (t-1)	**0.5770***	**0.6391**	**-0.2283**
	(0.3400)	**(0.4478)**	**(0.5766)**
ln(Vr/Lr) * ln(Zpr/Lr) (t-1)	**0.1432**	**-0.2886**	**0.0459**
	(0.2297)	**(0.3752)**	**(0.3059)**
ln(Vr/Lr) * ln(Spr/Lr) (t-1)	**-0.2607***	**-0.0216**	**-0.0806**
	(0.1329)	**(0.2010)**	**(0.2037)**
ln(Vr/Lr) * ln(Zave/Lr) (t-1)	**0.0437*****	**0.0319*****	**0.0472*****
	(0.0020)	**(0.0041)**	**(0.0023)**
ln(Vr/Lr) * ln(Save/Lr) (t-1)	**0.1186*****	**0.0845*****	**0.1282*****
	(0.0070)	**(0.0144)**	**(0.0079)**
year dummy	**yes**	**yes**	**yes**
industry x region	**yes**	**yes**	**yes**
R-squared			
within	**0.1828**	**0.2517**	**0.1718**
between	**0.1828**	**0.2517**	**0.1718**
orverall	**0.0000**	**0.0000**	**0.0000**
No. of Obs.	**25,850**	**6,050**	**19,800**
No. of Groups	**1,175**	**275**	**900**

The lower cell in each estimation result shows standard error.
*, **, and *** show significance at 10%, 5%, and 1% levels, respectively.

Figure 1 -- The Amount of Social Infrastructure in Japan

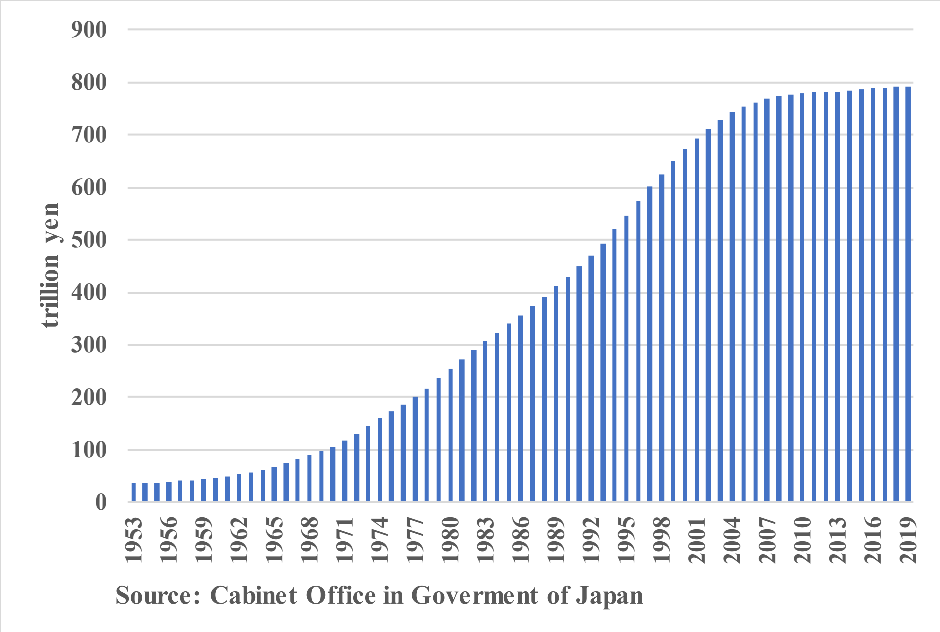


Figure 2 -- The Share of Replacement Investment in Social Infrastructure

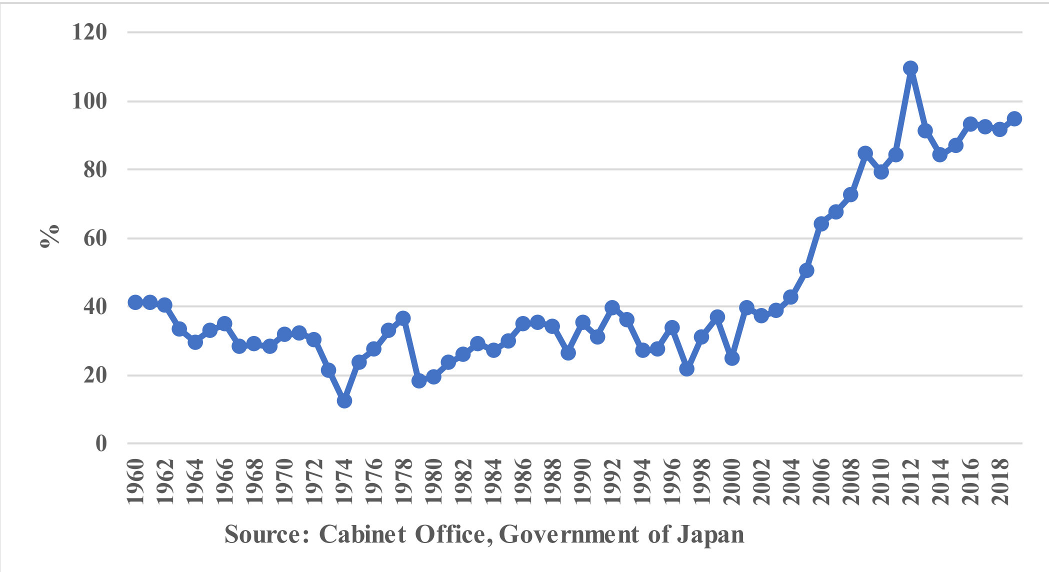


Figure 3 -- The Gap in Social Infrastructure Between Urban Areas and Rural Areas in Japan

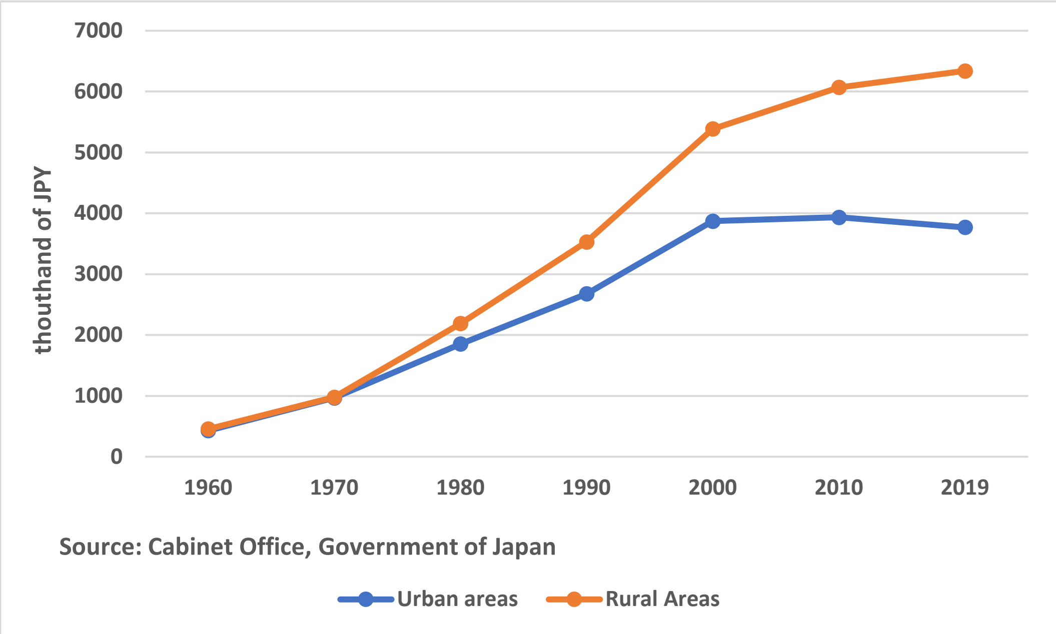


Figure 4 -- The Ratio of Intangibles to Tangibles in the Market and Public Sectors

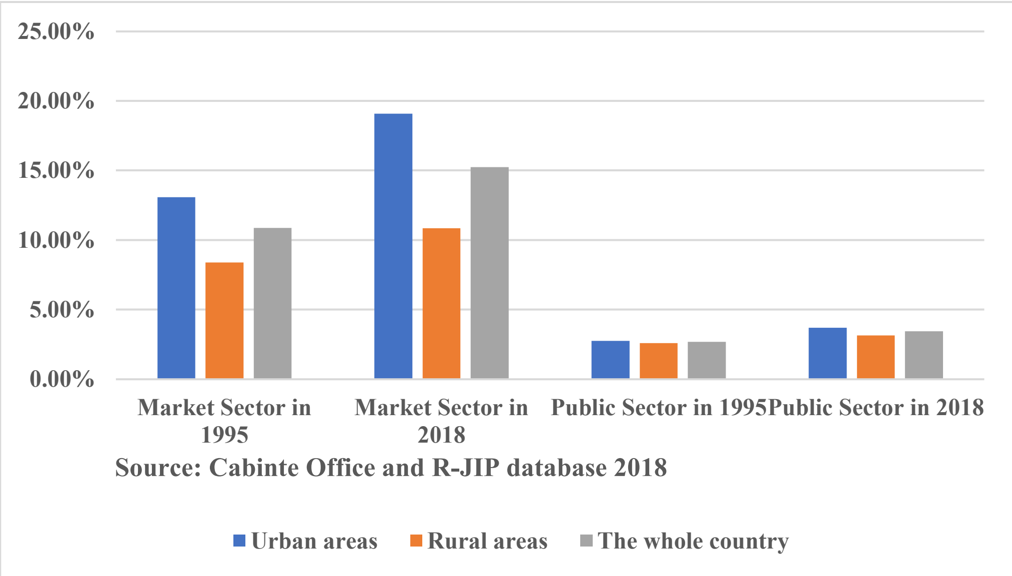
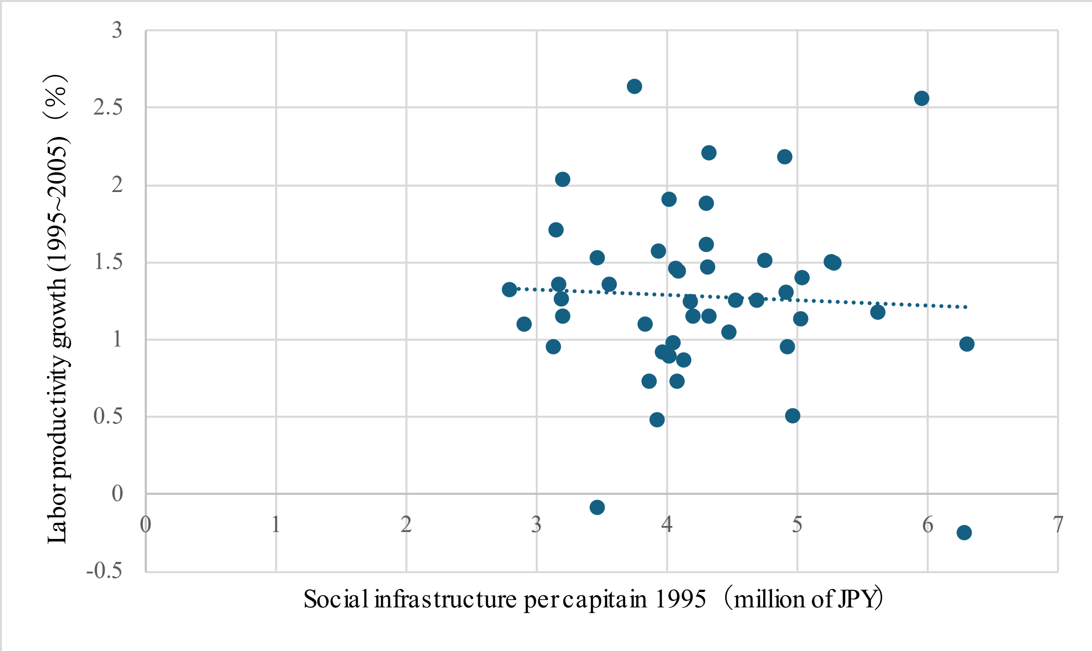


Figure 5 The Relationship between Labor Productivity Growth and Social Infrastructure per Capita

(1) 1995 -2005



(2) 2010-2018