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Poverty traps with Local Allocation Tax grants in Japan*

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Abstract

This paper investigates poverty traps with the Local Allocation Tax (LAT) grants in Japan. The LAT grants, which distributed to local governments by the central government, may be hesitated to make efforts for enhancing regional economic growth, due to the calculation of the LAT grants. We show that the LAT grants give a disincentive to increase their estimated tax revenue and lower regional income by a simple dynamic model. Based on implication of our model, the panel Granger (non-)causality tests are implemented. We find that there are poverty traps due to the LAT grants in Japan.

Keywords

Poverty trap, Local Allocation Tax grants, Regional economic growth, panel Granger (non-)causality tests

JEL classifications

H77, O43, R11

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1. Introduction

Economic and fiscal disparities among regions have received a lot of attention in Japan. The Gini coefficient of real prefectural GDP per capita is increasing since 1996, as shown in Figure 1. Also The Gini coefficient of local tax revenue¹ per capita by prefecture tends to rise since 1999. Though these inequalities cause concern about the difference of local governments' administrative services between rich and poor regions, Local Allocation Tax (LAT) grants from the central government have a function of interregional income redistribution. The system of the LAT grants is described further in section 2.

The central government distributes the LAT grants to local governments, financed by national taxes collected from people in both urban and rural regions. The LAT grants tends to be allocated more to local governments whose tax revenues are fewer than those whose tax revenues are more.

Local governments whose tax revenues are fewer, however, can receive more LAT grants for any reason. Hence, they may hesitate to make efforts to enlarge their tax base. If they make efforts to enlarge their tax base, their estimated tax revenue will increase. This will reduce their LAT grants receipt. As a result, their efforts to increase their tax revenues are offset by this reduction. In this way, the present system of the LAT grants gives a disincentive to increase their estimated tax revenue.

Many previous studies on the LAT grants pointed out defects of the system. Nagamine (1995) and Doi (1996, 2000) suggest that there are flypaper effects with the LAT grants and it distort resource allocation between private consumption and local expenditures, Hayashi (2000) and Doi and Bessho (2005) find subsidy effects with the LAT grants. It implies that the LAT grants, which are non-matching grants, enhance the specific local expenditures. Akai, Sato, and Yamashita (2005) investigates soft budget problems with the LAT grants. Hayashi (2006) provides a critical survey of previous studies on the LAT grants.

That disincentive may affect regional economic growth. If local governments do not make efforts to increase regional income due to such properties of the LAT grants, regional economic growth may be deteriorated. Though local governments may receive enough revenue sources including the LAT grants and manage public services, growth rate of regional income may continue to be low. The former governor of Tottori prefecture Yoshihiro Katayama intuitively phrased such situations as “poverty traps.”²

In this paper, we investigate poverty traps with the LAT grants. First, we explain the system of the LAT grants in section 2. Based on the actual scheme of the LAT grants, we show effects of the LAT grants on economic growth using a simple dynamic model in section 3. In section 4, we implement Granger (non-)causality test with panel data in Japan. We

¹ Including prefectural taxes and municipal taxes.

² It is based on his presentation at the Decentralization Reform Committee on September 18, 2007.

confirm poverty traps with the LAT grants based on estimation results. Finally concluding remarks follow in section 5.

2. System of Local Allocation Tax grants

The LAT grants are a certain proportion of national taxes that the central government transfers to local governments as a tax source whose purpose is not restricted to balancing local revenue sources between the central government and local governments without prejudicing the independence of local governments. As described in detail in Doi and Ihori (2009), the tax ensures smooth local administration. Local Allocation Tax grants have the following three functions. (a) To redistribute revenue sources between the central government and local governments (to transfer tax revenue from the central government to local governments so that both governments share the function and the gap is filled between public activities and allocation of revenue sources). (b) To ensure revenue sources of local governments (If local governments cannot ensure revenue sources, the central government ensures it instead so that local governments can provide smooth public services). (c) To equalize revenue sources among local governments (The central government adjusts financial resources so that the differences in the financial conditions of local governments are not reflected in the public services).

The central government decides how many LAT grants are allocated to which local governments. Upon allocating ordinary LAT grants, the Standard Financial Revenue (SFR) and the Standard Financial Need (SFN) are calculated for every local government. The SFR is the amount of tax collectable in the usual situation calculated by the central government according to a certain formula for every local government, based on region, size of population and other factors. The details are as shown in Figure 2. The SFN is the amount of expenses necessary for all local governments to carry out independently administrative work at an appropriate and rational level and that the central government calculates using a certain method for every local government, based on region, size of population and other factors. This amount is the aggregate of the amount calculated for every expense item according to the formula, that is, “unit cost” *times* the mount of “measuring units” *times* “adjustment coefficient.” These terms are explained below, and an outline of this calculation is shown in Table 1.

The unit cost is the amount of revenue sources per unit which is needed for local governments to supply standard public services. The unit cost is computed as the amount of general revenue sources per unit. Extra expenses for public services decided by local governments are excluded.

The measurement unit is used for measuring the estimated cost incurred in each item of public services. A unit that is closely interrelated with the costs concerned is used. Examples are the number of students versus education expenses and population versus social security expenses.

The adjustment coefficient is used for increasing or reducing a unit

cost to reflect the special environments of each local government. The adjustment coefficients reflect such matters as population density, climate, and geography. It also reflects the “investment mode factor”, which is the amount of local government debt incurred in public investments. For example, the more debt a local government has incurred in public investments, the larger the adjustment coefficient of its investment mode factor becomes.

If the SFR is less than the SFN, the difference is called the ‘shortfall in revenue source.’ The LAT grants are usually granted to local governments with revenue source shortfall (deficit-financed entity). A local government to which ordinary LAT grants is granted is called a “receiving body.” The majority of local governments are receiving bodies. The amount of ordinary LAT grants is calculated for every local government based on the difference between the SFN and the SFR. The LAT grants are distributed to each receiving body from the central government. Meanwhile, the ordinary LAT grants is not usually granted to local governments where the mount of the SFR exceeds that of the SFN (surplus-financed entity). A local government to which the ordinary LAT grant is not granted is called a “non receiving body.”

3. A simple model of poverty traps with the LAT grants

3.1 Basic framework

In order to investigate properties of the LAT grants, we focus on a local government in a small open economy. The local government in region i collects local taxes, receives fiscal transfer from the central government, $h_{i,t}$, and issues local government bonds, $b_{i,t}$, to finance its expenditure.

We presume that the local government levy only income taxes at a constant tax rate, τ_L . τ_L is assumed to be constant over time and the same among regions. That is, local tax revenue is equal to $\tau_L y_{i,t}$. $y_{i,t}$ denotes regional income of region i in period t . This assumption is valid under the current local tax system in Japan. Tax items and the local tax rates are specified in the Local Tax Law, which is a national law. Moreover, local governments impose local taxes at their own discretion and do not substantially exercise right to set local tax rates.

We assume that the local government has two kinds of expenditure. The one is welfare-improving (but unproductive) government consumption, $g_{i,t}$. The other is productive government investment, $x_{i,t}$. This investment can increase production in this region in the next period. Note that this government investment may not be equated with public fixed capital formation or public works in local budget, since inefficient investment and investment without increasing future regional production may be included in them. We assume the following intertemporal utility function of the local government

$$U_i = \sum_{t=1}^{\infty} \frac{u_i(g_{i,t})}{(1+\rho)^t} \quad \rho > 0 \quad (1)$$

where ρ is the subjective discount rate.³

The budget constraint of the local government is expressed as

$$b_{i,t} = g_{i,t} + x_{i,t} + (1+r)b_{i,t-1} - \tau_L y_{i,t} - h_{i,t} \quad (2)$$

where r is the interest rate, given exogenously, as the economy is small open. $b_{i,t}$ denotes the outstanding local government debt of region i at the end of period t . The initial level of local government debt sets $b_{i,0}$, given exogenously.

We employ a Solow-Swan growth model. Investment rate in region i is assumed to be given exogenously. It is a constant over time, $s_i > 0$. Production function in this region is expressed as

$$y_{i,t} = f_i(k_{i,t-1}, x_{i,t-1}) \quad (3)$$

$$\text{where } \frac{\partial y_{i,t}}{\partial k_{i,t-1}} > 0, \frac{\partial^2 y_{i,t}}{\partial k_{i,t-1}^2} < 0, \frac{\partial y_{i,t}}{\partial x_{i,t-1}} > 0, \frac{\partial^2 y_{i,t}}{\partial x_{i,t-1}^2} < 0, \frac{\partial^2 y_{i,t}}{\partial k_{i,t-1} \partial x_{i,t-1}} > 0.$$

$k_{i,t-1}$ is capital equipped by private firms in region i at the end of period $t-1$ (that is, at the beginning of period t). The initial level of private capital and government investment set $x_{i,0}$ and $k_{i,0}$, given exogenously, respectively. This production function is assumed to satisfy the Inada condition. The capital depreciates at the constant rate $\delta > 0$. On the other hand, the government investment fully depreciates in the next period. Thus

$$k_{i,t} = (1-\delta)k_{i,t-1} + s_i(1-\tau_L - \tau_C)y_{i,t} \quad (4)$$

where τ_C denotes national tax rate for fiscal transfer from the central government. That is,

$$\sum_{i=1}^N \tau_C y_{i,t} = \sum_{i=1}^N h_{i,t}. \quad (5)$$

In order to focus on behaviors of local government, we do not investigate behaviors (or the objective function) of the central government in this paper. Policies of the central government are assumed to be exogenously given. Now, $\tau \equiv \tau_L + \tau_C$.

We suppose the local government is myopic in the sense that it does not take into account interregional migration of residents and interregional capital flows.⁴

First, we examine effects of lump-sum transfer from the central government as the benchmark case. Lump-sum transfer has no substitution effects. The local government i maximizes the utility function (1) subject to the budget constraint (2) and (3). First order conditions of this optimization problem are as follows.

³ We can interpret this function as the objective function of the local government. Or else, we can interpret it as the utility function of the representative resident in region i . In this case, this function is assumed to be additively separable with respect to his/her utilities from welfare-improving government consumption and private goods.

⁴ Perfectly free migration of residents makes the utility of residents be equalized among regions. Also perfectly free interregional capital flows makes return of capital be equalized among regions. However, we presume the local government cannot take into account these conditions in maximizing its utility.

$$\begin{aligned}
\frac{u'_i(g_{i,t})}{(1+\rho)^t} - \lambda_{i,t} &= 0 \\
-\lambda_{i,t} + \lambda_{i,t+1} \tau_L \frac{\partial y_{i,t+1}}{\partial x_{i,t}} &= 0 \\
-\lambda_{i,t-1}(1+r) + \lambda_{i,t} &= 0
\end{aligned}$$

And the following transversality condition is satisfied.

$$\lim_{t \rightarrow \infty} \lambda_{i,t} \frac{b_{i,t}}{(1+\rho)^t} = 0 \quad (6)$$

Hence,

$$\frac{u'_i(g_{i,t})}{u'_i(g_{i,t-1})} = \frac{1+\rho}{1+r} \quad (7)$$

$$\frac{\partial y_{i,t}}{\partial x_{i,t-1}} = \frac{1+r}{\tau_L} \quad (8)$$

The above optimality conditions (7), (8), the budget constraint of local government (2) and the law of motion for capital (4) determine resource allocation as the benchmark case. Condition (7) governs intertemporal allocation of government consumption. Condition (8) is the efficiency criterion of government investment.

3.2 Effects of the Standard Financial Revenue in the LAT grants

Second, we investigate effects of the Standard Financial Revenue (SFR) in the LAT grants. As explained in section 2, the amount of the (ordinary) LAT grant is calculated for each local government based on the difference between the SFN and the SFR. Thus, we can express as follows

$$h_{i,t} = \eta_i g_{i,t} - \theta \tau_L y_{i,t} \quad 1 > \eta_i > 0, 1 > \theta > 0 \quad (9)$$

This $h_{i,t}$ is determined to satisfy the budget constraint (5) through adjusting the coefficient of government consumption, η_i . η_i may vary over time. $\eta_i g_{i,t}$ implies the SFN in this case. According to the current system of LAT grants, the SFN for government investment should be included. In this section, however, it is excluded for simplicity. We include it in the SFN in the next section. Moreover, $\theta \tau_L y_{i,t}$ means the SFR. As mentioned above, θ is 75% in the current system. θ is assumed to be constant over time, since it is actually unchanged over time under the current system.

Substituting (9) into (2),

$$b_{i,t} = (1-\eta_i)g_{i,t} + x_{i,t} + (1+r)b_{i,t-1} - (1-\theta)\tau_L y_{i,t} \quad (2')$$

The local government i maximizes the utility function (1) subject to the budget constraint (2') and (3). First order conditions of this optimization problem are as follows.

$$\begin{aligned}
\frac{u'_i(g_{i,t})}{(1+\rho)^t} - (1-\eta_i)\lambda_{i,t} &= 0 \\
-\lambda_{i,t} + \lambda_{i,t+1}(1-\theta)\tau_L \frac{\partial y_{i,t+1}}{\partial x_{i,t}} &= 0
\end{aligned}$$

$$\lambda_{i,t} - \lambda_{i,t+1}(1+r) = 0$$

And the transversality condition (6) is satisfied. Hence,

$$\frac{u'_i(g_{i,t})}{u'_i(g_{i,t-1})} = \frac{(1+\rho)(1-\eta_t)}{(1+r)(1-\eta_{t-1})} \quad (10)$$

$$\frac{\partial y_{i,t}}{\partial x_{i,t-1}} = \frac{1+r}{(1-\theta)\tau_L} > \frac{1+r}{\tau_L} > 0 \quad (11)$$

The condition for government investment is distorted by the LAT grants. In particular, this distortion is due to the SFR. From the property of the production function, condition (11) implies the government investment x_i decreases compared with the benchmark case. It means a decrease in regional production.

Furthermore, we can explain poverty traps due to the LAT grants. The production function is assumed to be the following AK function. That is,

$$y_{i,t} = A_i(x_{i,t-1})k_{i,t-1}$$

where $A_i(x_{i,t-1})$ is a function of $x_{i,t-1}$ with $A_i'(x_{i,t-1}) > 0$, and $A_i''(x_{i,t-1}) < 0$.⁵ Thus,

$$k_{i,t} = (1-\delta)k_{i,t-1} + s_i(1-\tau)A_i(x_{i,t-1})k_{i,t-1} \quad (4')$$

From (4'), the growth rate of capital is represented as

$$\frac{k_{i,t}}{k_{i,t-1}} = 1 - \delta + s_i(1-\tau)A_i(x_{i,t-1})$$

Under such a formula of the LAT grants, the government investment in this case decreases compared with the benchmark case. That is, $A_i(x_{i,t-1})$ decreases. The growth rate of $k_{i,t}$ may decrease due to the LAT grants. If $1 - \delta + s_i(1-\tau)A_i(x_{i,t-1}) < 1$, $k_{i,t} < k_{i,t-1}$. For example, when $\delta = 0.05$, $s_i = 0.1$, $\tau = 0.3$, $A_i(x_{i,t-1}) = 0.6$, $1 - \delta + s_i(1-\tau)A_i(x_{i,t-1}) < 1$.

Also under this specification, (11) is replaced by

$$\frac{\partial y_{i,t}}{\partial x_{i,t-1}} = A'_i(x_{i,t-1})k_{i,t-1} = \frac{1+r}{(1-\theta)\tau_L} \quad (11')$$

If $k_{i,t} < k_{i,t-1}$, $A'_i(x_{i,t}) > A'_i(x_{i,t-1})$ from (11'), because $A'_i(x_{i,t})k_{i,t} = A'_i(x_{i,t-1})k_{i,t-1}$. Hence $x_{i,t} < x_{i,t-1}$ under this specification.⁶ It implies $y_{i,t} < y_{i,t-1}$.

In this situation, the steady state of regional income is zero, as shown in Figure 3. That is a kind of poverty traps. It is similar to the kleptocratic poverty trap, introduced by Azariadis (2006). Azariadis and Stachurski (2005) define a poverty trap as any self-reinforcing mechanism which causes poverty to persist. Poverty traps defined above are consistent with this definition.

⁵ As shown in Appendix, the analytical results would be qualitatively the same even if we consider more general form of the production function.

⁶ Incidentally, from (4') and (11'), the series of $\{x_{i,t}\}$ is determined by

$$A'(x_{i,1}) = \frac{1+r}{(1+\theta)\tau_L k_{i,0} \{1 - \delta + s_i(1-\tau)A_i(x_{i,0})\}}, \dots, A'(x_{i,t}) = \frac{1+r}{(1+\theta)\tau_L k_{i,0} \prod_{j=1}^{t-1} \{1 - \delta + s_i(1-\tau)A_i(x_{i,j})\}}.$$

Consequently, the LAT grants may decrease productive government investment and lower growth rates of capital and regional income. It is a cause of poverty traps.

3.3 Effects of the Standard Financial Need in the LAT grants

Finally, we investigate effects of the Standard Financial Need (SFN) in the LAT grants. In addition to (9), compensation for government investment is included in the SFN. Thus, we can express as follows

$$h_{i,t} = \eta_t g_{i,t} + \omega_t \alpha_{i,t-1} x_{i,t-1} - \theta \tau_L y_t \quad (9')$$

where $1 > \eta_t > 0$, $1 > \theta > 0$, $1 > \omega_t > 0$, $1 < \alpha_{i,t-1}$

$\omega_t \alpha_{i,t-1} x_{i,t-1}$ reflects the “investment mode factor,” as described in section 2. ω_t denotes the coefficient of the investment mode factor. $\alpha_{i,t-1}$ means a coefficient which implies gap between productive public investment and unproductive one. More specifically, $\alpha_{i,t-1} x_{i,t-1}$ is the actual expenditure for public investment, but just $x_{i,t-1}$ is productive public investment, which increases regional production, and $(\alpha_{i,t-1} - 1)x_{i,t-1}$ is unproductive public investment, which does not increase regional production, in region i in period $t-1$. The bigger $\alpha_{i,t-1}$ is, the larger the fraction of unproductive public investment is. Such situation that $\alpha_{i,t}$ in the entire period equals one is the same as one in section 3.1 and 3.2.

This $h_{i,t}$ in (9) satisfies the budget constraint (5). η_t and ω_t may vary over time through decision-making process of the LAT grants. Also $\alpha_{i,t}$ may vary over time and across regions. We suppose that $\alpha_{i,t}$ is exogenously given for the local governments.

Substituting (9') into (2),

$$b_{i,t} = (1 - \eta_t) g_{i,t} + \alpha_{i,t} x_{i,t} - \omega_t \alpha_{i,t-1} x_{i,t-1} + (1 + r) b_{i,t-1} - (1 - \theta) \tau_L y_{i,t} \quad (2'')$$

The local government maximizes the utility function (1) subject to the budget constraint (2'') and (3). First order conditions of this optimization problem are as follows.

$$\begin{aligned} \frac{u'_i(g_{i,t})}{(1 + \rho)^t} - (1 - \eta_t) \lambda_{i,t} &= 0 \\ -\lambda_{i,t} \alpha_{i,t} + \lambda_{i,t+1} \left\{ (1 - \theta) \tau_L \frac{\partial y_{i,t+1}}{\partial x_{i,t}} + \omega_{t+1} \alpha_{i,t+1} \right\} &= 0 \\ \lambda_{i,t} - \lambda_{i,t+1} (1 + r) &= 0 \end{aligned}$$

And the transversality condition (6) is satisfied. Hence,

$$\frac{u'_i(g_{i,t})}{u'_i(g_{i,t-1})} = \frac{(1 + \rho)(1 - \eta_t)}{(1 + r)(1 - \eta_{t-1})} \quad (10)$$

$$\frac{\partial y_{i,t}}{\partial x_{i,t-1}} = \frac{(1 + r) \alpha_{i,t-1} - \omega_t \alpha_{i,t}}{(1 - \theta) \tau_L} \quad (12)$$

Whether the above partial differential coefficient in (12) is more than $(1+r)/\tau_L$ is not trivial. The parameter ω_t has a subsidy effect for productive

government investment. If $\omega_t \alpha_{i,t} > (1+r)(\theta + \alpha_{i,t-1} - 1)$, $\frac{(1+r)\alpha_{i,t-1} - \omega_t \alpha_{i,t}}{(1-\theta)\tau_L} < \frac{1+r}{\tau_L}$.

It implies that productive government investment is enhanced by the LAT grants under this condition. In this case, growth rate of capital and regional income is higher than that in the benchmark case. For example, when $\theta = 0.75$, $r = 0.02$, $\omega_t = 0.8$, $\tau_L = 0.1$, and $\alpha_{i,t-1} = \alpha_{i,t} = 1.1$ in any period t , $\omega_t \alpha_{i,t} > (1+r)(\theta + \alpha_{i,t-1} - 1)$. On the other hand, when all parameters are the same value excluding $\alpha_{i,j} > 1.16$ in any period $j \geq t - 1$, $\omega_t \alpha_{i,t} < (1+r)(\theta + \alpha_{i,t-1} - 1)$. That is, when unproductive public investment increases, growth rate of capital and regional income cannot be higher by the LAT grants than that in the benchmark case. In such situation, the LAT grants may induce poverty traps though investment mode factor is reflected.

In the next section, we confirm whether the LAT grants enhance or deteriorate regional economic growth by using panel data on the Japanese regional economy and local public finance.

4. Empirical analyses of poverty traps

4.1 Panel Granger (non-)causality test

We can recognize poverty traps described in section 3 as causality from receipt of the LAT grants to regional economic growth. However, prefectural GDP data is continuously available only from 1990. It is too short time span to estimate vector autoregression or vector error correction models by prefecture. So we employ panel Granger (non-)causality tests.

In an early stage, Holtz-Eakin, Newey and Rosen (1988) proposed the following linear model for a panel causality test

$$Y_{i,t} = \sum_{j=1}^J \gamma^j Y_{i,t-j} + \sum_{j=1}^J \beta^j X_{i,t-j} + \mu_i + \varepsilon_{i,t}$$

where $i = 1, 2, \dots, N$. $t = 1, 2, \dots, T$. $\varepsilon_{i,t}$ are i.i.d. with $E(\varepsilon_{i,t}) = 0$
 $E(\varepsilon_{i,t}^2) = \sigma_{\varepsilon,t}^2$

This specification is assumed to be the same parameters, β^j and γ^j , among individuals.

More generally, we can make these parameters different among individuals. Thus

$$Y_{i,t} = \sum_{j=1}^J \gamma_i^j Y_{i,t-j} + \sum_{j=1}^J \beta_i^j X_{i,t-j} + \mu_i + \varepsilon_{i,t} \quad (13)$$

Hurlin and Venet (2004), and Hurlin (2005, 2008) adopted the above linear model with fixed coefficients and a Wald test for the Granger (non-)causality hypothesis in heterogeneous panel data. Methodology of these tests is used by Im, Pesaran, and Shin (2003) to test the unit root hypothesis. Also these causality tests are applied in Peltrault and Venet (2005), Bhaduri and Durai (2006), and Suliman (2008).⁷

⁷ Hurlin and Venet (2001) proposed an F test for panel causality test, though it is similar to Hurlin and Venet (2004), and Hurlin (2005, 2008). This test is applied in

Hurlin and Venet (2004), and Hurlin (2005, 2008) set the following null hypothesis in (13),

$$H_0: \beta_i = 0 \quad \forall i = 1, 2, \dots, N$$

$$\text{where } \beta_i = (\beta_i^1, \beta_i^2, \dots, \beta_i^J)'$$

This is the homogenous non-causality (HNC) hypothesis. The alternative hypothesis is

$$H_1: \begin{aligned} \beta_i &= 0 & \forall i = 1, 2, \dots, N_1 & \quad (N_1 < N) \\ \beta_i &\neq 0 & \forall i = N_1+1, N_1+2, \dots, N \end{aligned}$$

where N_1 is unknown but satisfies the condition $0 \leq N_1/N < 1$: The fraction N_1/N is necessarily inferior to one, since if $N_1 = N$ there is no causality for all the individual of the panel, and then we get the null hypothesis HNC. Hurlin and Venet (2004), and Hurlin (2005, 2008) proposed using the average of individual Wald statistics to test the HNC hypothesis for individuals, such that

$$W_{N,T}^{Hnc} = \frac{1}{N} \sum_{i=1}^N W_{i,T}$$

where $W_{i,T}$ denotes the individual Wald statistics for the i th cross section unit associated to the individual test $H_0: \beta_i = 0$.

In a large T sample,

$$\sqrt{\frac{N}{2J}}(W_{N,T}^{Hnc} - J) \xrightarrow[T, N \rightarrow \infty]{d} N(0,1)$$

However, we have a small T sample. For a fixed $T > 5 + 2J$, Hurlin and Venet (2004), and Hurlin (2005, 2008) proposed to compute the following approximated standardized statistic

$$\tilde{Z}_{N,T}^{Hnc} = \sqrt{\frac{N}{2J} \times \frac{(T-2J-5)}{(T-J-3)}} \times \left[\frac{(T-2J-3)}{(T-2J-1)} W_{N,T}^{Hnc} - J \right]$$

This standardized average statistic $\tilde{Z}_{N,T}^{Hnc}$ converges in distribution as follows

$$\tilde{Z}_{N,T}^{Hnc} \xrightarrow[N \rightarrow \infty]{d} N(0,1)$$

Hurlin (2008) shows power of this panel Granger non-causality test based on Monte Carlo simulations. It implies that the above statistics provide very good small sample properties.

Therefore, we use equation (13) and statistic $\tilde{Z}_{N,T}^{Hnc}$ to implement panel non-causality test on regional economic growth and the LAT grants.

4.2 Prefectural data

Prefectural GDP data based on System of National Accounts 1993 (93SNA) is available from 1990. This data is taken from Cabinet Office “Annual Report on Prefectural Accounts.” Also GDP deflator is taken from it as a price index. Data of the LAT grants is taken from Ministry of Internal Affairs and Communications “Annual Statistical Report on Local

Hansen and Rand (2006), Hood, Kidd, and Morris (2008), Erdila and Yetkiner (2009), and He and Zhang (2010).

Government Finance.” Population by prefecture is taken from Ministry of Internal Affairs and Communications “Basic Resident Registers.” We set sample period is from fiscal 1990 to 2006.

All variables are expressed in per capita real term basis because there is a significant difference in population among prefectures. We use real GDP per capita (GDP), per capita real LAT grants received by just prefecture (LATGP), and per capita real LAT grants received by prefecture and municipalities (LATGT).

Tokyo, Kanagawa, Aichi, and Osaka prefectures have been non-receiving bodies of the LAT grants. Since we focus on receiving bodies of the LAT grants, we exclude these four prefectures. Thus we have 43 prefectures in our sample.

4.3 Test results

First, we implement a unit root test proposed by Im, Pesaran, and Shin (2003). The result is reported in Table 2. This test concludes to the rejection of the non stationarity hypothesis for all three variables.

Before the Granger non-causality tests, we estimate equations based on (13) and identify their lag length.

$$GDP_{i,t} = \sum_{j=1}^J \alpha_i^j GDP_{i,t-j} + \sum_{j=1}^J \beta_i^j LATGX_{i,t-j} + \mu_i^{GDP} + \varepsilon_{i,t}^{GDP} \quad (14)$$

$$LATGX_{i,t} = \sum_{j=1}^J \gamma_i^j GDP_{i,t-j} + \sum_{j=1}^J \zeta_i^j LATGX_{i,t-j} + \mu_i^{LATGX} + \varepsilon_{i,t}^{LATGX} \quad (15)$$

where $LATGX$ means $LATGP$ or $LATGT$

As determined by the Schwarz criterion, shown in Table 3, lag length equals one.

Based on these equations with $J=1$, the panel Granger non-causality test proposed by Hurlin and Venet (2004), and Hurlin (2005, 2008) is implemented. The test statistics and their p-values are reported in Table 4. From these results, the null hypothesis in all regressions is rejected at a 5 percent significant level. We find Granger causality from real prefectural GDP per capita to per capita real LAT grants, and vice versa, in some prefectures.

Moreover, we show estimation results in Table 5.⁸ In (14), the LAT grants in last year (LATGP) are negatively correlated with prefectural GDP in most prefectures. Also these estimated coefficients (β_i^1) are significant at a 5 percent significant level in some prefectures in Tables 5-1 (the LATGP case) and 5-3 (the LATGT case). Especially, prefectures in urban area and their neighborhood have significantly negative coefficients (β_i^1); For example, Miyagi ($i = 5$), Saitama (11), Chiba (12), Kyoto (26), Hyogo (28), Nara (29), Okayama (33), Hiroshima (34), Fukuoka (40), Saga (41), and Nagasaki (42) in both cases. In these prefectures, Miyagi, Saitama, Chiba, Kyoto, Hyogo, Hiroshima, and Fukuoka have government-designated cities, which are the

⁸ In Table 5, estimated coefficients of fixed effect (i.e. prefecture dummies) are omitted to report.

largest cities in Japan.⁹ In such prefectures, it seems that an increase in the LAT grants significantly reduces real prefectural GDP.

Incidentally, we also estimate equations (14) and (15) in all prefectures including Tokyo, Kanagawa, Aichi, and Osaka. In these four prefectures, there are municipalities which receive the LAT grants, though prefectural governments do not receive the LAT grants. These results are shown in Tables 5-5 and 5-6. These are almost the same as results in Tables 5-3 and 5-4.

Based on estimation results in Tables 5-3 and 5-4, we estimate impulse response functions in 43 prefectures. We investigate the estimated impulse responses to a one-standard-deviation shock of LATGT (0.01158, shown in Table 5-4). Accumulated impulse responses of prefectural GDP and LATGT to one standard deviation shocks of LATGT are shown in Figure 4. Each gray line in this figure implies accumulated impulse response of each prefecture. The results suggest that the shock caused by an increase in the LAT grants (per capita in real term) leads to a decrease in real GDP per capita in almost all prefectures. In other words, an increase in the LAT grants (per capita in real term) reduces real prefectural GDP per capita in almost all prefectures. In Figure 4, in just 3 prefectures, which have positive but insignificant estimated β_i^1 , their prefectural GDPs increase in this situation.

These means that an increase in the LAT grants cause a decrease in prefectural GDP. That indicates phenomenon of poverty traps due to the LAT grants.

5. Concluding remarks

We have examined poverty traps with the LAT grants in Japan. As mentioned above, the LAT grants may be hesitated to make efforts for enhancing regional economic growth. We show that the LAT grants give a disincentive to increase their estimated tax revenue and lower regional income by a theoretical model.

Based on implication of our dynamic model, the panel Granger (non-)causality tests are implemented. The heterogeneous autoregressive model with fixed coefficients and a Wald test for the Granger (non-)causality hypothesis proposed by Hurlin and Venet (2004), and Hurlin (2005, 2008) is employed as causality tests in this paper. As our results, we find that there are poverty traps due to the LAT grants.

On the other hand, Nishikawa and Yokoyama (2004) examine another poverty trap with the LAT grants. They describe that this trap causes negligence for tax collection of local governments. If local governments that receive lots of LAT grants slack their efforts to collect local taxes, their Standard Financial Revenue in calculation of the LAT grants

⁹ Four eliminated prefectures in these estimation, Tokyo, Kanagawa, Aichi, and Osaka, also have government-designated cities or special wards, which are administrative divisions in the central area of Tokyo.

becomes lower and their receipt of the LAT grants becomes more. However, they find no evidence of this type of poverty traps.

Despite this, results in this paper are not inconsistent with their study. Nishikawa and Yokoyama (2004) focuses on incentives for tax collection of local government, but does not define poverty traps as being related to regional income. Poverty traps defined in this paper disincentive effects with the LAT grants to regional income or regional economic growth, though we do not deal with such incentives. Poverty traps defined in this paper is conceptually close to the definition of Azariadis and Stachurski (2005)

Poverty traps shown in this paper cause the formula of the LAT grants. In particular, the amount of the ordinary LAT grant is calculated for each local government based on the difference between the SFN and the SFR. This calculation is a significant fault of the LAT grants in this sense. In future decentralization reform in Japan, the calculation of the LAT grants should be revised. For example, the central government should reorganize the current intergovernmental transfers, the LAT grants and national government disbursement, as Doi and Ihori (2009) proposed. To ensure revenue sources of local governments, the central government should grant specific fixed-amount subsidies to national-minimum service providers (such as local governments). If subsidies are granted in this manner, there is no need to employ the gap-filling approach seen in the current LAT grant scheme. Moreover, the fiscal equalization system may be established to equalize revenue sources among local governments, if needed. These are one way of break out of poverty traps in the Japanese rural regions.

Appendix

In the case of a more general form of production function, we can describe an analysis in section 3.2 as follows. Using the more general form of production function (3), equation (4') is rewritten as

$$k_{i,t} = (1 - \delta)k_{i,t-1} + s_i(1 - \tau)f_i(k_{i,t-1}, x_{i,t-1}) \quad (4'')$$

From (4''), the growth rate of capital is represented as

$$\frac{k_{i,t}}{k_{i,t-1}} = 1 - \delta + s_i(1 - \tau) \frac{f_i(k_{i,t-1}, x_{i,t-1})}{k_{i,t-1}}$$

If $1 - \delta + s_i(1 - \tau) \frac{f_i(k_{i,t-1}, x_{i,t-1})}{k_{i,t-1}} < 1$, $k_{i,t} < k_{i,t-1}$. Under such a formula of the LAT

grants, (11') is replaced by

$$\frac{\partial y_{i,t}}{\partial x_{i,t-1}} = \frac{\partial f_i(k_{i,t-1}, x_{i,t-1})}{\partial x_{i,t-1}} = \frac{1 + r}{(1 - \theta)\tau_L} \quad (11'')$$

It implies that $\frac{\partial f_i(k_{i,t-1}, x_{i,t-1})}{\partial x_{i,t-1}}$ is constant over time in more general setting.

In (3), we have assumed that $\frac{\partial^2 y_{i,t}}{\partial k_{i,t-1} \partial x_{i,t-1}} > 0$. Therefore, if $k_{i,t} < k_{i,t-1}$, $\frac{\partial f_i(k_{i,t}, x)}{\partial x} < \frac{\partial f_i(k_{i,t-1}, x)}{\partial x}$ in the same value of x . Since $\frac{\partial f_i(k_{i,t-1}, x_{i,t-1})}{\partial x_{i,t-1}}$ is constant over time, however, $x_{i,t}$ satisfies $x_{i,t} < x_{i,t-1}$. Such situation that $k_{i,t} < k_{i,t-1}$ and $x_{i,t} < x_{i,t-1}$ implies $y_{i,t} < y_{i,t-1}$.

As a result, the analytical results in section 3.2 would be qualitatively the same in a more general form of the production function.

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Figure 1

Note: From 1990, prefectural GDP is based on System of National Accounts 1993 (93SNA). From 1980 to 1989, it is taken from data based on the old standard of SNA (68SNA).

Source: Cabinet Office “Annual Report on Prefectural Accounts,” Ministry of Internal Affairs and Communications “Annual Statistical Report on Local Government Finance,” and “Basic Resident Registers.”

Figure 2

Micro-Allocation Rule of the LAT Grants

Source: Doi and Ihori (2009)

Figure 3
Poverty Traps

Figure 4
Accumulated Impulse Responses of GDP and LATGT to One Standard
Deviation Shock of LATGT

Table 1

Calculation of the Standard Financial Need (Outline)

Police expenses =
unit cost of police officer * number of police officers * adjustment coefficient
Education expenses =
unit cost of teacher * number of teachers * adjustment coefficient
Public works expenses = ...
Agriculture, forestry, and fishery expenses = ...
Commerce and industry expenses = ...
Debt-service expenses = ...
...
Sum of the above amount = the Standard Financial Need of this local government

Note: * means 'multiplied by'.

Source: Doi and Ihori (2009)

Table 2
Unit Root Tests

	Statistic	P-value
GDP	-3.852	0.000
LATGP	-4.048	0.000
LATGT	-3.076	0.001

Table 3
Schwarz Information Criterion for Identification

Lag order		
J=1	J=2	J=3
Dependent var.: GDP, Independent var.: GDP LATGP		
-1.389	-0.770	-0.137
Dependent var.: LATGP, Independent var.: GDP LATGP		
-5.944	-5.569	-4.908
Dependent var.: GDP, Independent var.: GDP LATGT		
-1.419	-0.796	-0.137
Dependent var.: LATGT, Independent var.: GDP LATGT		
-5.102	-4.687	-3.896

Table 4
Granger Non-causality Tests

	Statistic	P-value
LATGP to GDP		
$\tilde{W}_{N,T}^{Hnc}$	4.403	—
$\tilde{Z}_{N,T}^{Hnc}$	11.282	0.000
GDP to LATGP		
$\tilde{W}_{N,T}^{Hnc}$	4.488	—
$\tilde{Z}_{N,T}^{Hnc}$	11.578	0.000
LATGT to GDP		
$\tilde{W}_{N,T}^{Hnc}$	5.332	—
$\tilde{Z}_{N,T}^{Hnc}$	14.521	0.000
GDP to LATGT		
$\tilde{W}_{N,T}^{Hnc}$	1.795	—
$\tilde{Z}_{N,T}^{Hnc}$	2.191	0.014

Table 5-1
Estimation Results

Dependent var.: GDP, Independent var.: GDP LATGP

Prefecture		Coefficient	t-Statistic	P-value		Coefficient	t-Statistic	P-value
Hokkaido	α_1^1	0.0242	0.2456	0.8061	β_1^1	-1.7196	-1.1880	0.2353
Aomori	α_2^1	0.4353	5.7745	0.0000	β_2^1	-1.5271	-1.5834	0.1139
Iwate	α_3^1	0.5399	11.6317	0.0000	β_3^1	-2.2328	-2.1288	0.0337
Miyagi	α_4^1	0.1480	2.9881	0.0029	β_4^1	-1.5085	-1.5849	0.1135
Akita	α_5^1	0.4953	6.8520	0.0000	β_5^1	-1.5819	-3.0924	0.0021
Yamagata	α_6^1	0.6386	5.9145	0.0000	β_6^1	-1.0639	-0.5998	0.5489
Fukushima	α_7^1	0.6446	7.7492	0.0000	β_7^1	-1.2679	-0.6344	0.5261
Ibaraki	α_8^1	0.2556	1.9931	0.0467	β_8^1	-1.8748	-1.0241	0.3062
Tochigi	α_9^1	0.6585	7.3510	0.0000	β_9^1	-0.9013	-0.6018	0.5475
Gunma	α_{10}^1	0.4047	2.4032	0.0166	β_{10}^1	-2.0215	-1.2683	0.2052
Saitama	α_{11}^1	0.4289	3.2241	0.0013	β_{11}^1	-7.1130	-4.7876	0.0000
Chiba	α_{12}^1	0.2700	0.9154	0.3604	β_{12}^1	-12.9219	-4.3602	0.0000
Niigata	α_{15}^1	0.3854	6.5632	0.0000	β_{15}^1	-1.1926	-1.2687	0.2050
Toyama	α_{16}^1	0.3473	5.2948	0.0000	β_{16}^1	-1.1413	-0.9227	0.3565
Ishikawa	α_{17}^1	0.5450	4.4957	0.0000	β_{17}^1	-0.5936	-0.3757	0.7073
Fukui	α_{18}^1	0.5651	6.1678	0.0000	β_{18}^1	-0.1989	-0.2017	0.8402
Yamanashi	α_{19}^1	0.8036	10.3052	0.0000	β_{19}^1	-2.3301	-1.5865	0.1132
Nagano	α_{20}^1	0.7730	7.6188	0.0000	β_{20}^1	-2.4121	-0.9083	0.3641
Gifu	α_{21}^1	0.4933	4.0338	0.0001	β_{21}^1	-1.6221	-1.1450	0.2527
Shizuoka	α_{22}^1	0.6380	3.4718	0.0006	β_{22}^1	0.9465	0.2717	0.7860
Mie	α_{24}^1	0.9997	19.3369	0.0000	β_{24}^1	-3.8880	-1.4570	0.1456
Shiga	α_{25}^1	0.6106	4.0845	0.0001	β_{25}^1	-3.4847	-1.5768	0.1154
Kyoto	α_{26}^1	0.4262	2.3837	0.0174	β_{26}^1	-2.9183	-2.0236	0.0435
Hyogo	α_{28}^1	0.3980	2.2414	0.0254	β_{28}^1	-6.7377	-5.7448	0.0000
Nara	α_{29}^1	0.2640	2.8595	0.0044	β_{29}^1	-2.1104	-3.2823	0.0011
Wakayama	α_{30}^1	0.2349	2.9625	0.0032	β_{30}^1	-0.6805	-1.1181	0.2640
Tottori	α_{31}^1	0.4194	3.5837	0.0004	β_{31}^1	-1.1049	-1.5904	0.1123
Shimane	α_{32}^1	0.5468	11.7059	0.0000	β_{32}^1	0.7481	1.3254	0.1856
Okayama	α_{33}^1	0.1864	1.8572	0.0638	β_{33}^1	-5.8094	-4.5463	0.0000
Hiroshima	α_{34}^1	0.3943	1.6743	0.0946	β_{34}^1	-3.5505	-2.1975	0.0284
Yamaguchi	α_{35}^1	0.4324	6.0527	0.0000	β_{35}^1	-0.3495	-0.2583	0.7962
Tokushima	α_{36}^1	0.6483	14.9340	0.0000	β_{36}^1	0.6427	0.8777	0.3804
Kagawa	α_{37}^1	0.4520	6.5559	0.0000	β_{37}^1	-0.4427	-0.4970	0.6194
Ehime	α_{38}^1	0.4866	6.7555	0.0000	β_{38}^1	-1.4711	-0.9065	0.3650
Kochi	α_{39}^1	0.3116	2.3763	0.0178	β_{39}^1	-0.0423	-0.0354	0.9718
Fukuoka	α_{40}^1	0.3337	5.7401	0.0000	β_{40}^1	-3.9411	-2.6574	0.0081
Saga	α_{41}^1	0.5271	13.9542	0.0000	β_{41}^1	-2.2678	-3.6464	0.0003
Nagasaki	α_{42}^1	0.2988	6.3770	0.0000	β_{42}^1	-1.5640	-3.1211	0.0019
Kumamoto	α_{43}^1	0.2951	2.8491	0.0045	β_{43}^1	0.3343	0.2718	0.7859
Oita	α_{44}^1	0.6598	10.7745	0.0000	β_{44}^1	0.0889	0.0448	0.9643
Miyazaki	α_{45}^1	0.2601	3.3938	0.0007	β_{45}^1	-0.1410	-0.1510	0.8800
Kagoshima	α_{46}^1	0.1751	1.0932	0.2747	β_{46}^1	0.6953	0.3002	0.7641
Okinawa	α_{47}^1	0.2265	3.0815	0.0022	β_{47}^1	-0.0758	-0.1644	0.8695

Adjusted R-squared 0.9767
Standard error of regression 0.0741

Log likelihood 936.1615
Schwarz criterion -1.3886

Table 5-2
Estimation Results

Dependent var.: LATGP, Independent var.: GDP LATGP

	Coefficient	t-Statistic	P-value		Coefficient	t-Statistic	P-value
γ_1^1	-0.0108	-1.2414	0.2149	ζ_1^1	0.6629	5.5914	0.0000
γ_2^1	-0.0116	-1.0977	0.2728	ζ_2^1	0.6974	4.9947	0.0000
γ_3^1	-0.0031	-0.4474	0.6548	ζ_3^1	0.7288	6.2097	0.0000
γ_4^1	-0.0048	-1.1001	0.2717	ζ_4^1	0.6796	6.0846	0.0000
γ_5^1	-0.0066	-0.7382	0.4607	ζ_5^1	0.7780	6.7431	0.0000
γ_6^1	-0.0024	-0.4675	0.6403	ζ_6^1	0.7639	6.6438	0.0000
γ_7^1	-0.0048	-0.9793	0.3278	ζ_7^1	0.7747	6.3772	0.0000
γ_8^1	-0.0324	-3.1788	0.0016	ζ_8^1	0.8530	7.4145	0.0000
γ_9^1	-0.0159	-3.5183	0.0005	ζ_9^1	0.8922	11.1018	0.0000
γ_{10}^1	-0.0086	-1.1092	0.2678	ζ_{10}^1	0.7491	5.8438	0.0000
γ_{11}^1	-0.0291	-3.8095	0.0002	ζ_{11}^1	0.6810	6.3047	0.0000
γ_{12}^1	-0.0170	-1.0828	0.2794	ζ_{12}^1	0.4555	3.0319	0.0025
γ_{15}^1	-0.0085	-1.5789	0.1149	ζ_{15}^1	0.7891	7.6147	0.0000
γ_{16}^1	-0.0203	-3.2882	0.0011	ζ_{16}^1	0.8350	7.8779	0.0000
γ_{17}^1	-0.0003	-0.0472	0.9624	ζ_{17}^1	0.7571	6.2603	0.0000
γ_{18}^1	-0.0107	-1.4783	0.1399	ζ_{18}^1	0.8249	5.7209	0.0000
γ_{19}^1	-0.0198	-2.1934	0.0287	ζ_{19}^1	0.8861	6.0225	0.0000
γ_{20}^1	-0.0007	-0.1076	0.9143	ζ_{20}^1	0.7449	5.1125	0.0000
γ_{21}^1	-0.0142	-1.3903	0.1650	ζ_{21}^1	0.8294	6.4291	0.0000
γ_{22}^1	-0.0119	-2.6281	0.0088	ζ_{22}^1	0.8914	10.6931	0.0000
γ_{24}^1	-0.0117	-4.0176	0.0001	ζ_{24}^1	0.7438	6.4484	0.0000
γ_{25}^1	-0.0224	-2.6588	0.0081	ζ_{25}^1	0.7287	6.9106	0.0000
γ_{26}^1	-0.0118	-0.8107	0.4178	ζ_{26}^1	0.7504	9.1427	0.0000
γ_{28}^1	-0.0131	-1.3635	0.1732	ζ_{28}^1	0.6994	8.6214	0.0000
γ_{29}^1	-0.0255	-2.1314	0.0335	ζ_{29}^1	0.8329	8.2262	0.0000
γ_{30}^1	-0.0262	-3.2131	0.0014	ζ_{30}^1	0.8719	7.4471	0.0000
γ_{31}^1	-0.0217	-1.6954	0.0905	ζ_{31}^1	0.7511	4.0904	0.0000
γ_{32}^1	-0.0021	-0.2046	0.8380	ζ_{32}^1	0.7672	4.3711	0.0000
γ_{33}^1	-0.0150	-1.1322	0.2580	ζ_{33}^1	0.7234	5.7486	0.0000
γ_{34}^1	-0.0241	-1.8491	0.0649	ζ_{34}^1	0.7742	9.6688	0.0000
γ_{35}^1	-0.0228	-4.2515	0.0000	ζ_{35}^1	0.8788	8.1942	0.0000
γ_{36}^1	-0.0091	-2.1109	0.0352	ζ_{36}^1	0.7374	3.9215	0.0001
γ_{37}^1	-0.0146	-1.4093	0.1593	ζ_{37}^1	0.8296	4.7023	0.0000
γ_{38}^1	-0.0033	-0.4503	0.6527	ζ_{38}^1	0.6830	4.0501	0.0001
γ_{39}^1	-0.0128	-1.2500	0.2118	ζ_{39}^1	0.7908	4.8706	0.0000
γ_{40}^1	-0.0071	-1.0781	0.2814	ζ_{40}^1	0.5970	3.7324	0.0002
γ_{41}^1	-0.0064	-1.1837	0.2370	ζ_{41}^1	0.7482	5.8660	0.0000
γ_{42}^1	-0.0074	-1.2860	0.1989	ζ_{42}^1	0.7557	6.2441	0.0000
γ_{43}^1	-0.0230	-3.1788	0.0016	ζ_{43}^1	0.8226	7.5205	0.0000
γ_{44}^1	-0.0096	-2.1597	0.0312	ζ_{44}^1	0.8824	6.6202	0.0000
γ_{45}^1	-0.0256	-1.8422	0.0659	ζ_{45}^1	0.6977	5.1146	0.0000
γ_{46}^1	-0.0240	-3.8154	0.0002	ζ_{46}^1	0.8655	9.2345	0.0000
γ_{47}^1	-0.0314	-2.6688	0.0078	ζ_{47}^1	0.7389	6.2911	0.0000

Adjusted R-squared 0.9817
Standard error of regression 0.0076

Log likelihood 2601.198
Schwarz criterion -5.9441

Table 5-3
Estimation Results

Dependent var.: GDP, Independent var.: GDP LATGT							
	Coefficient	t-Statistic	P-value		Coefficient	t-Statistic	P-value
α_1^1	0.0018	0.0142	0.9887	β_1^1	-0.2838	-0.3247	0.7455
α_2^1	0.4304	4.2938	0.0000	β_2^1	-0.7312	-0.8634	0.3883
α_3^1	0.5275	9.2355	0.0000	β_3^1	-1.2395	-1.4042	0.1608
α_4^1	0.1401	3.0311	0.0025	β_4^1	-1.0869	-1.6982	0.0900
α_5^1	0.4901	6.3226	0.0000	β_5^1	-0.8836	-2.5908	0.0098
α_6^1	0.6638	4.9862	0.0000	β_6^1	-1.0395	-0.8304	0.4067
α_7^1	0.7073	8.0925	0.0000	β_7^1	-2.1136	-1.7910	0.0738
α_8^1	0.2247	1.9922	0.0468	β_8^1	-1.6756	-1.7744	0.0765
α_9^1	0.6588	8.4315	0.0000	β_9^1	-1.3211	-1.3958	0.1633
α_{10}^1	0.3999	2.9147	0.0037	β_{10}^1	-1.9201	-2.4547	0.0144
α_{11}^1	0.2760	2.3648	0.0184	β_{11}^1	-4.9036	-5.1046	0.0000
α_{12}^1	0.1909	0.7145	0.4752	β_{12}^1	-9.4853	-4.6861	0.0000
α_{15}^1	0.4146	6.8428	0.0000	β_{15}^1	-1.1863	-2.1537	0.0317
α_{16}^1	0.3428	4.6749	0.0000	β_{16}^1	-0.6970	-1.0094	0.3132
α_{17}^1	0.4859	3.6314	0.0003	β_{17}^1	0.1030	0.0978	0.9221
α_{18}^1	0.5621	5.8513	0.0000	β_{18}^1	-0.4097	-0.5242	0.6003
α_{19}^1	0.7887	10.0230	0.0000	β_{19}^1	-1.7247	-1.7099	0.0878
α_{20}^1	0.8013	4.9982	0.0000	β_{20}^1	-1.6532	-0.8324	0.4055
α_{21}^1	0.4813	4.4036	0.0000	β_{21}^1	-1.2652	-1.7837	0.0750
α_{22}^1	0.6755	4.0242	0.0001	β_{22}^1	-0.5740	-0.2311	0.8173
α_{24}^1	0.9861	20.1826	0.0000	β_{24}^1	-3.0300	-1.7370	0.0829
α_{25}^1	0.6168	4.3089	0.0000	β_{25}^1	-2.7138	-2.1199	0.0344
α_{26}^1	0.4359	2.5492	0.0110	β_{26}^1	-2.2564	-2.6572	0.0081
α_{28}^1	0.4255	2.4903	0.0130	β_{28}^1	-4.0070	-5.7796	0.0000
α_{29}^1	0.2424	2.5679	0.0105	β_{29}^1	-1.3231	-3.4529	0.0006
α_{30}^1	0.2039	2.7269	0.0066	β_{30}^1	-0.4890	-1.2866	0.1987
α_{31}^1	0.4292	3.3634	0.0008	β_{31}^1	-0.8412	-1.8520	0.0645
α_{32}^1	0.4919	8.4621	0.0000	β_{32}^1	0.6288	1.4596	0.1449
α_{33}^1	0.2383	2.1769	0.0299	β_{33}^1	-3.2365	-5.0986	0.0000
α_{34}^1	0.4075	1.9141	0.0561	β_{34}^1	-2.6035	-2.8816	0.0041
α_{35}^1	0.4433	5.7558	0.0000	β_{35}^1	-0.7244	-0.9116	0.3624
α_{36}^1	0.6312	14.3197	0.0000	β_{36}^1	0.3726	0.9473	0.3438
α_{37}^1	0.4345	6.0890	0.0000	β_{37}^1	-0.3966	-0.6428	0.5206
α_{38}^1	0.4433	5.5946	0.0000	β_{38}^1	-0.5041	-0.4479	0.6544
α_{39}^1	0.3094	1.7595	0.0790	β_{39}^1	-0.2507	-0.2730	0.7850
α_{40}^1	0.2829	5.5520	0.0000	β_{40}^1	-2.4125	-3.3743	0.0008
α_{41}^1	0.5322	14.2703	0.0000	β_{41}^1	-1.6075	-3.6522	0.0003
α_{42}^1	0.2901	6.5524	0.0000	β_{42}^1	-1.0072	-3.0871	0.0021
α_{43}^1	0.3037	3.4695	0.0006	β_{43}^1	-0.8108	-1.2490	0.2122
α_{44}^1	0.6496	9.3584	0.0000	β_{44}^1	-0.1138	-0.0829	0.9339
α_{45}^1	0.2332	3.2651	0.0012	β_{45}^1	-0.3551	-0.7124	0.4765
α_{46}^1	0.2309	1.5165	0.1299	β_{46}^1	-0.6183	-0.5520	0.5812
α_{47}^1	0.1797	2.5845	0.0100	β_{47}^1	-0.1749	-0.7626	0.4460
Adjusted R-squared		0.9774		Log likelihood		947.1883	
Standard error of regression		0.0730		Schwarz criterion		-1.4187	

Table 5-4
Estimation Results

Dependent var.: LATGT, Independent var.: GDP LATGT

	Coefficient	t-Statistic	P-value		Coefficient	t-Statistic	P-value
γ_1^1	0.0074	0.5424	0.5878	ζ_1^1	0.7115	5.3886	0.0000
γ_2^1	-0.0026	-0.2006	0.8411	ζ_2^1	0.7171	5.2358	0.0000
γ_3^1	0.0065	0.6637	0.5071	ζ_3^1	0.7146	5.8037	0.0000
γ_4^1	0.0044	0.6821	0.4954	ζ_4^1	0.7506	6.3978	0.0000
γ_5^1	0.0114	0.8562	0.3922	ζ_5^1	0.7534	6.1770	0.0000
γ_6^1	0.0073	0.7733	0.4396	ζ_6^1	0.7733	6.0383	0.0000
γ_7^1	0.0009	0.1240	0.9013	ζ_7^1	0.7759	6.0933	0.0000
γ_8^1	-0.0332	-2.0377	0.0420	ζ_8^1	0.8962	8.4649	0.0000
γ_9^1	-0.0150	-2.6426	0.0084	ζ_9^1	0.9106	9.3126	0.0000
γ_{10}^1	-0.0054	-0.4669	0.6407	ζ_{10}^1	0.8165	6.5559	0.0000
γ_{11}^1	-0.0428	-3.1485	0.0017	ζ_{11}^1	0.8219	8.3503	0.0000
γ_{12}^1	-0.0207	-0.9473	0.3439	ζ_{12}^1	0.6703	4.7520	0.0000
γ_{15}^1	-0.0013	-0.1327	0.8945	ζ_{15}^1	0.8247	7.4166	0.0000
γ_{16}^1	-0.0179	-1.6179	0.1062	ζ_{16}^1	0.8956	9.7129	0.0000
γ_{17}^1	0.0116	0.8655	0.3871	ζ_{17}^1	0.7657	5.8215	0.0000
γ_{18}^1	-0.0097	-0.8709	0.3841	ζ_{18}^1	0.8604	5.5828	0.0000
γ_{19}^1	-0.0205	-1.6191	0.1059	ζ_{19}^1	0.9173	6.5022	0.0000
γ_{20}^1	0.0043	0.2909	0.7713	ζ_{20}^1	0.8127	4.5485	0.0000
γ_{21}^1	-0.0141	-0.8762	0.3813	ζ_{21}^1	0.8747	6.1912	0.0000
γ_{22}^1	-0.0131	-1.9886	0.0472	ζ_{22}^1	0.9424	11.7514	0.0000
γ_{24}^1	-0.0109	-2.2125	0.0273	ζ_{24}^1	0.7898	7.1714	0.0000
γ_{25}^1	-0.0268	-1.9524	0.0513	ζ_{25}^1	0.8423	7.9764	0.0000
γ_{26}^1	-0.0115	-0.5054	0.6134	ζ_{26}^1	0.8414	9.4169	0.0000
γ_{28}^1	-0.0123	-0.6545	0.5131	ζ_{28}^1	0.8418	11.4081	0.0000
γ_{29}^1	-0.0163	-0.7475	0.4551	ζ_{29}^1	0.8736	8.1420	0.0000
γ_{30}^1	-0.0219	-1.6751	0.0944	ζ_{30}^1	0.8816	7.2079	0.0000
γ_{31}^1	-0.0078	-0.2794	0.7800	ζ_{31}^1	0.7971	4.2751	0.0000
γ_{32}^1	0.0258	1.0251	0.3057	ζ_{32}^1	0.6914	3.2807	0.0011
γ_{33}^1	-0.0124	-0.6840	0.4942	ζ_{33}^1	0.8110	9.4376	0.0000
γ_{34}^1	-0.0343	-1.8462	0.0654	ζ_{34}^1	0.8922	11.1276	0.0000
γ_{35}^1	-0.0242	-2.5255	0.0118	ζ_{35}^1	0.9175	7.7239	0.0000
γ_{36}^1	-0.0056	-0.8345	0.4043	ζ_{36}^1	0.7407	3.6183	0.0003
γ_{37}^1	-0.0056	-0.3770	0.7063	ζ_{37}^1	0.8058	4.8053	0.0000
γ_{38}^1	0.0059	0.4267	0.6698	ζ_{38}^1	0.6868	3.7887	0.0002
γ_{39}^1	0.0062	0.2796	0.7799	ζ_{39}^1	0.7843	4.7679	0.0000
γ_{40}^1	-0.0071	-0.6842	0.4941	ζ_{40}^1	0.7830	5.1509	0.0000
γ_{41}^1	0.0005	0.0774	0.9383	ζ_{41}^1	0.7545	5.6022	0.0000
γ_{42}^1	0.0033	0.4039	0.6864	ζ_{42}^1	0.7852	6.6077	0.0000
γ_{43}^1	-0.0258	-2.1739	0.0301	ζ_{43}^1	0.8394	6.9166	0.0000
γ_{44}^1	-0.0058	-0.6806	0.4964	ζ_{44}^1	0.8646	5.9651	0.0000
γ_{45}^1	-0.0244	-1.3361	0.1820	ζ_{45}^1	0.8119	6.4634	0.0000
γ_{46}^1	-0.0249	-1.7787	0.0758	ζ_{46}^1	0.8719	7.0104	0.0000
γ_{47}^1	-0.0387	-2.2055	0.0278	ζ_{47}^1	0.8113	7.5950	0.0000

Adjusted R-squared 0.9844
Standard error of regression 0.0116

Log likelihood 2293.596
Schwarz criterion -5.1025

Table 5-5
Estimation Results

Dependent var.: GDP, Independent var.: GDP LATGT

Prefecture	Coefficient	t-Statistic	P-value	Coefficient	t-Statistic	P-value		
Hokkaido	α_1^1	0.0369	0.3127	0.7546	β_1^1	-0.2438	-0.2896	0.7722
Aomori	α_2^1	0.4583	4.5717	0.0000	β_2^1	-0.7144	-0.8534	0.3938
Iwate	α_3^1	0.5472	9.6821	0.0000	β_3^1	-1.2080	-1.3590	0.1746
Miyagi	α_4^1	0.1651	3.5204	0.0005	β_4^1	-0.9722	-1.5358	0.1251
Akita	α_5^1	0.5144	6.5270	0.0000	β_5^1	-0.8561	-2.5355	0.0115
Yamagata	α_6^1	0.6814	5.0726	0.0000	β_6^1	-1.0101	-0.7983	0.4250
Fukushima	α_7^1	0.7234	8.2058	0.0000	β_7^1	-2.0481	-1.7158	0.0867
Ibaraki	α_8^1	0.2618	2.3018	0.0217	β_8^1	-1.5624	-1.6075	0.1084
Tochigi	α_9^1	0.6766	8.6309	0.0000	β_9^1	-1.2263	-1.2815	0.2005
Gunma	α_{10}^1	0.4272	3.0564	0.0023	β_{10}^1	-1.8329	-2.2822	0.0228
Saitama	α_{11}^1	0.3124	2.6914	0.0073	β_{11}^1	-4.6325	-4.9091	0.0000
Chiba	α_{12}^1	0.2091	0.8016	0.4231	β_{12}^1	-9.0698	-4.6670	0.0000
Tokyo	α_{13}^1	0.6399	9.2714	0.0000	β_{13}^1	-6.4161	-0.3035	0.7616
Kanagawa	α_{14}^1	-0.2394	-1.5334	0.1257	β_{14}^1	-7.5046	-4.3906	0.0000
Niigata	α_{15}^1	0.4339	7.2739	0.0000	β_{15}^1	-1.0743	-1.9413	0.0527
Toyama	α_{16}^1	0.3574	4.6868	0.0000	β_{16}^1	-0.6041	-0.8616	0.3892
Ishikawa	α_{17}^1	0.5024	3.6877	0.0002	β_{17}^1	0.1386	0.1293	0.8971
Fukui	α_{18}^1	0.5781	5.9539	0.0000	β_{18}^1	-0.3433	-0.4333	0.6649
Yamanashi	α_{19}^1	0.8080	10.2942	0.0000	β_{19}^1	-1.6560	-1.6292	0.1037
Nagano	α_{20}^1	0.8150	5.0533	0.0000	β_{20}^1	-1.5887	-0.7951	0.4268
Gifu	α_{21}^1	0.5103	4.6354	0.0000	β_{21}^1	-1.2045	-1.6622	0.0969
Shizuoka	α_{22}^1	0.6900	4.1073	0.0000	β_{22}^1	-0.4623	-0.1849	0.8533
Aichi	α_{23}^1	0.7702	8.1217	0.0000	β_{23}^1	-3.6666	-2.9160	0.0037
Mie	α_{24}^1	0.9989	20.5617	0.0000	β_{24}^1	-2.9169	-1.6581	0.0978
Shiga	α_{25}^1	0.6285	4.3655	0.0000	β_{25}^1	-2.5181	-1.9582	0.0506
Kyoto	α_{26}^1	0.4469	2.5773	0.0102	β_{26}^1	-2.0898	-2.4476	0.0146
Osaka	α_{27}^1	0.0537	1.3000	0.1941	β_{27}^1	-2.8392	-4.6082	0.0000
Hyogo	α_{28}^1	0.4298	2.5533	0.0109	β_{28}^1	-3.8048	-5.5234	0.0000
Nara	α_{29}^1	0.2749	2.9929	0.0029	β_{29}^1	-1.2334	-3.2575	0.0012
Wakayama	α_{30}^1	0.2319	2.9821	0.0030	β_{30}^1	-0.4490	-1.1636	0.2450
Tottori	α_{31}^1	0.4580	3.5772	0.0004	β_{31}^1	-0.7810	-1.7168	0.0865
Shimane	α_{32}^1	0.5152	8.8422	0.0000	β_{32}^1	0.6089	1.3950	0.1635
Okayama	α_{33}^1	0.2494	2.2047	0.0278	β_{33}^1	-3.0626	-4.9453	0.0000
Hiroshima	α_{34}^1	0.4264	1.9833	0.0477	β_{34}^1	-2.4252	-2.6905	0.0073
Yamaguchi	α_{35}^1	0.4620	5.9630	0.0000	β_{35}^1	-0.6416	-0.7949	0.4270
Tokushima	α_{36}^1	0.6474	14.8594	0.0000	β_{36}^1	0.3779	0.9604	0.3372
Kagawa	α_{37}^1	0.4552	6.5152	0.0000	β_{37}^1	-0.3581	-0.5848	0.5589
Ehime	α_{38}^1	0.4641	5.8687	0.0000	β_{38}^1	-0.4574	-0.4057	0.6851
Kochi	α_{39}^1	0.3349	1.9595	0.0505	β_{39}^1	-0.2211	-0.2474	0.8047
Fukuoka	α_{40}^1	0.3145	6.3873	0.0000	β_{40}^1	-2.3001	-3.1747	0.0016
Saga	α_{41}^1	0.5535	15.2296	0.0000	β_{41}^1	-1.5774	-3.5816	0.0004
Nagasaki	α_{42}^1	0.3087	6.8681	0.0000	β_{42}^1	-0.9147	-2.8658	0.0043
Kumamoto	α_{43}^1	0.3356	3.8072	0.0002	β_{43}^1	-0.7528	-1.1430	0.2535
Oita	α_{44}^1	0.6662	9.5517	0.0000	β_{44}^1	-0.1050	-0.0758	0.9396
Miyazaki	α_{45}^1	0.2712	3.8662	0.0001	β_{45}^1	-0.2738	-0.5292	0.5969
Kagoshima	α_{46}^1	0.2524	1.6447	0.1005	β_{46}^1	-0.5178	-0.4594	0.6461
Okinawa	α_{47}^1	0.2232	3.2949	0.0010	β_{47}^1	-0.1472	-0.6350	0.5257

Adjusted R-squared 0.9907
Standard error of regression 0.0755

Log likelihood 1008.395
Schwarz criterion -1.3364

Table 5-6
Estimation Results

Dependent var.: LATGT, Independent var.: GDP LATGT

	Coefficient	t-Statistic	P-value		Coefficient	t-Statistic	P-value
γ_1^1	0.0068	0.5033	0.6149	ζ_1^1	0.7109	5.3842	0.0000
γ_2^1	-0.0031	-0.2366	0.8130	ζ_2^1	0.7168	5.2351	0.0000
γ_3^1	0.0062	0.6386	0.5233	ζ_3^1	0.7141	5.7988	0.0000
γ_4^1	0.0041	0.6320	0.5276	ζ_4^1	0.7488	6.3943	0.0000
γ_5^1	0.0110	0.8320	0.4057	ζ_5^1	0.7529	6.1722	0.0000
γ_6^1	0.0070	0.7483	0.4545	ζ_6^1	0.7728	6.0362	0.0000
γ_7^1	0.0007	0.0912	0.9274	ζ_7^1	0.7748	6.0904	0.0000
γ_8^1	-0.0338	-2.1000	0.0361	ζ_8^1	0.8944	8.4684	0.0000
γ_9^1	-0.0153	-2.7420	0.0063	ζ_9^1	0.9091	9.3269	0.0000
γ_{10}^1	-0.0059	-0.5074	0.6121	ζ_{10}^1	0.8151	6.5498	0.0000
γ_{11}^1	-0.0434	-3.2521	0.0012	ζ_{11}^1	0.8176	8.3965	0.0000
γ_{12}^1	-0.0210	-0.9613	0.3368	ζ_{12}^1	0.6637	4.7788	0.0000
γ_{13}^1	-0.0058	-2.3765	0.0178	ζ_{13}^1	0.6169	2.7586	0.0060
γ_{14}^1	-0.0063	-0.6898	0.4905	ζ_{14}^1	0.7210	5.3719	0.0000
γ_{15}^1	-0.0016	-0.1654	0.8687	ζ_{15}^1	0.8229	7.4197	0.0000
γ_{16}^1	-0.0181	-1.6375	0.1020	ζ_{16}^1	0.8941	9.7208	0.0000
γ_{17}^1	0.0114	0.8486	0.3964	ζ_{17}^1	0.7652	5.8206	0.0000
γ_{18}^1	-0.0100	-0.8961	0.3705	ζ_{18}^1	0.8593	5.5887	0.0000
γ_{19}^1	-0.0208	-1.6550	0.0984	ζ_{19}^1	0.9162	6.5050	0.0000
γ_{20}^1	0.0041	0.2765	0.7822	ζ_{20}^1	0.8117	4.5497	0.0000
γ_{21}^1	-0.0145	-0.9105	0.3629	ζ_{21}^1	0.8737	6.1900	0.0000
γ_{22}^1	-0.0134	-2.0481	0.0409	ζ_{22}^1	0.9406	11.7914	0.0000
γ_{23}^1	-0.0177	-2.7189	0.0067	ζ_{23}^1	0.8450	7.5270	0.0000
γ_{24}^1	-0.0111	-2.2871	0.0225	ζ_{24}^1	0.7880	7.1729	0.0000
γ_{25}^1	-0.0269	-1.9762	0.0485	ζ_{25}^1	0.8392	8.0222	0.0000
γ_{26}^1	-0.0117	-0.5124	0.6085	ζ_{26}^1	0.8387	9.4564	0.0000
γ_{27}^1	0.0007	0.1118	0.9110	ζ_{27}^1	0.8553	14.6508	0.0000
γ_{28}^1	-0.0124	-0.6601	0.5094	ζ_{28}^1	0.8386	11.4942	0.0000
γ_{29}^1	-0.0168	-0.7737	0.4394	ζ_{29}^1	0.8722	8.1423	0.0000
γ_{30}^1	-0.0223	-1.7190	0.0861	ζ_{30}^1	0.8810	7.2060	0.0000
γ_{31}^1	-0.0083	-0.2970	0.7666	ζ_{31}^1	0.7961	4.2720	0.0000
γ_{32}^1	0.0255	1.0123	0.3118	ζ_{32}^1	0.6917	3.2832	0.0011
γ_{33}^1	-0.0125	-0.6898	0.4905	ζ_{33}^1	0.8083	9.4996	0.0000
γ_{34}^1	-0.0346	-1.8678	0.0622	ζ_{34}^1	0.8894	11.1853	0.0000
γ_{35}^1	-0.0245	-2.5727	0.0103	ζ_{35}^1	0.9162	7.7331	0.0000
γ_{36}^1	-0.0058	-0.8830	0.3776	ζ_{36}^1	0.7406	3.6184	0.0003
γ_{37}^1	-0.0060	-0.4000	0.6893	ζ_{37}^1	0.8052	4.8020	0.0000
γ_{38}^1	0.0055	0.4044	0.6861	ζ_{38}^1	0.6861	3.7837	0.0002
γ_{39}^1	0.0058	0.2612	0.7940	ζ_{39}^1	0.7839	4.7644	0.0000
γ_{40}^1	-0.0076	-0.7430	0.4578	ζ_{40}^1	0.7812	5.1399	0.0000
γ_{41}^1	0.0002	0.0279	0.9778	ζ_{41}^1	0.7540	5.5947	0.0000
γ_{42}^1	0.0030	0.3713	0.7105	ζ_{42}^1	0.7837	6.6040	0.0000
γ_{43}^1	-0.0263	-2.2566	0.0244	ζ_{43}^1	0.8385	6.9170	0.0000
γ_{44}^1	-0.0060	-0.7180	0.4730	ζ_{44}^1	0.8644	5.9672	0.0000
γ_{45}^1	-0.0250	-1.3810	0.1677	ζ_{45}^1	0.8107	6.4626	0.0000
γ_{46}^1	-0.0253	-1.8144	0.0701	ζ_{46}^1	0.8703	7.0120	0.0000
γ_{47}^1	-0.0394	-2.2721	0.0234	ζ_{47}^1	0.8108	7.5980	0.0000

Adjusted R-squared 0.9886
Standard error of regression 0.0113

Log likelihood 2527.284
Schwarz criterion -5.1383