

# A Quantitative Analysis of Regional Income Determinants in Remote Island Economies: Generation and Application of the Regional Input-Output Table

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This study models the income determination of a regional economy consisting of various types of industries, and decomposes the net regional product of remote islands in Japan into the income induced by central government expenditure, net income inflow, exports, and income-independent private expenditure. The result shows that 42–45% of the net regional product depends on central government expenditure. This study also proposed a non-survey approach to estimate the competitive import type of sub-prefectural regional input-output table from the corresponding prefectural table. This method assumes that: (A) Among the sub-prefectural regions, the share of regional output of sector  $i$ 's product exported to outside the prefecture is consistent, and the share of imports from outside the prefecture in the regional demand for sector  $i$ 's product is also consistent; (B) The share of cross-hauling in the trade volume of sector  $i$ 's product is equivalent in interregional trade and trade between the prefecture and outside the prefecture.

**Key words:** remote island, income determination model, regional IO table, cross-hauling, non-survey approach

## 1. Introduction

The Japanese remote islands provide services with public good characteristics, such as maintaining the country's Exclusive Economic Zone and preserving their nature and culture. Such services are provided by the inhabitants of the islands; therefore, sustaining remote island economies is a national issue. The central government has gradually allocated more spending to the remote islands. One can think that the growth of remote island economies has been mainly supported by the central government financial aid. Ando (1986) criticized the growth of local economies as an example of consumption-led growth without industrial development. The financial support received by local government service and construction sectors has been directed towards consumption, boosting the growth of local economies without a significant contribution to their industrial development.

After 2000, financial support has been cut, especially in the public works budget. The Remote

Islands Development Act was intended to remove economic backwardness and achieve a well-balanced national development. However, the act was amended in 2002, and the revised act requires remote islands to promote endogenous development with local creativity, exploiting their geographical and natural features (Sato, 2007: p. 145). Less favored areas in the mainland of Japan, such as mountainous regions, are also expected to foster endogenous development. However, they can rely on income from urban employment, while remote islands can only rely on the income generated in the region, because they are surrounded by sea and residents cannot commute to inland cities. Thus, the population supporting capacity of remote islands is exclusively determined by the income generated in the region. Such income is consistent with the definition of net regional product at factor prices, which can be defined as: Net regional product at factor prices (NRP) = Gross regional product (GRP, or value-added) – Consumption of fixed capital – Taxes on production and imports +

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Ordinary subsidies = Compensation of employees + Operation surplus + Consumption expenditure outside household. This study addresses the economic independence of remote islands through a quantitative analysis of the NRP determinants.

Regional income determinants have been analyzed using various regression techniques. According to previous studies, regional income is explained by capital, labor, and various macroeconomic factors (e.g., exports, government expenditure, and foreign aid). Among the most relevant studies focusing on remote islands in Japan, Ishikawa and Fukushima (2007) explained the regional income of Amami Oshima Island in terms of the number of tourists and fiscal expenditure, and concluded that one tourist and about 52,000 yen fiscal expenditure are substitutable. In their analysis of all remote islands in Japan, Ishikawa and Fukushima (2009) showed that both fiscal expenditure and population size have a positive impact on regional income, whereas the number of tourists does not have a significant impact. However, in their econometric analysis, it is hard to disentangle the intrinsic contribution of the each factor due to inter-correlations among factors.

This study proposes a Keynesian regional income determination model and shows that the NRP is determined by central government expenditure (including direct spending in the region and fiscal transfers to the region), net income inflows into the region (net production-factor income inflow and social transfers, as cash inflow), exports, and income-independent private expenditure (consumption and investment independent from income). This model describes a regional economy consisting of  $n$  types of industries, and the NRP of remote islands is decomposed into its determinants using an Input-Output (IO) analysis to evaluate each specific factor's impact. Among the studies focusing on remote islands, Tomikawa (2004) evaluated the impact of public works projects, while Sado City and Research Institute for Local Government (2007) and Fujimoto and Naitoh (2013) evaluated the impact of tourism. However, to the best of our knowledge, no previous study decomposed regional income into its fundamental determinants.

Since IO tables for the concerned regions are not released by the government, as a first step, we need to estimate regional IO tables. However, the estimation of regional exports and imports can be a particular issue. The survey approach is not feasible because it is very

costly. Thus, non-survey approaches have been used in the literature; however, they faced the challenge of capturing the extent of cross-hauling in trade. This study proposes a novel non-survey approach to overcome this challenge.

The remote islands in West Japan, designated under the Remote Islands Development Act, Special Measures for the Amami Islands Promotion and Development Act, and Okinawa Promotion and Development Special Treatment Act, are the object of this study. To be specific, 31 remote islands in Shimane, Nagasaki, Kagoshima, and Okinawa prefectures are analyzed (as reported in Table 3). Remote islands administrated by municipalities located in the mainland of Japan are excluded from the analysis, and remote islands located in the Seto Inland Sea are also excluded because their residents have easy access to the mainland, especially for employment. Mishima village and Toshima village are also excluded, because their residents are spread over three and seven isolated islands, respectively, and their village offices are located in Kagoshima city, on the Japanese mainland. The analysis is conducted using island-level geographic boundary unit data from 2005, and not municipal-level administrative boundary unit data.<sup>1)</sup>

## 2. Regional Income Determination Model

Regional output ( $X$ ) can be expressed as:

$$X = Z + C + I + G + E - M, \quad (1)$$

where  $Z$  denotes intermediate demand,  $C$  denotes private consumption,  $I$  denotes private investment,  $G$  denotes government expenditure by both regional and central governments, and  $E - M$  denotes net exports (= exports,  $E$  - imports,  $M$ ). Each of  $E$  and  $M$  consists of international and interregional trade. International trade is trade between region  $R$  and the rest of the world. Interregional trade is trade between region  $R$  and the rest of the nation. The regional government includes municipalities in the region, while the central government includes prefectural government, national government, and social security funds.

The private consumption ( $C$ ) can be assumed as:

$$C = c(1 - t^R - t^N)(Y + Y_i) + C^0. \quad (2)$$

$Y + Y_i$  denotes net regional income, where  $Y$  and  $Y_i$  denote NRP and net income inflow into the region, respectively.  $1 - t^R - t^N$  denotes disposable income

1) For example, Tokunoshima Island is administrated by three municipalities, and it is analyzed as a region by consolidating the three municipalities.

ratio, where  $t^R$  and  $t^N$  denote the tax rate applied by regional and central governments, respectively, and  $c$  denotes the marginal propensity to consume, which measures the share of additional disposable income that is spent on consumption.  $C^0$  denotes private consumption independent from income.

Within a regional framework the marginal propensity to investment in the local economy may be a function of local regional income (McCann, 2001: p. 152; Kuroda et al., 2008). Accordingly, private investment ( $I$ ) can be assumed as:

$$I = iV + I^0, \quad (3)$$

where  $V$  denotes GRP, and  $i$  denotes the marginal propensity to invest, which measures the share of additional value-added that is spent on investment.  $I^0$  denotes private investment independent from income.

The government expenditure ( $G$ ) can be assumed as:

$$G = t^R(Y + Y_i) + G_i, \quad (4)$$

where  $t^R(Y + Y_i)$  denotes regional government expenditure from own revenue sources, and  $G_i$  denotes central government expenditure, which includes intergovernmental fiscal transfer payments, direct consumption, investments in the region, and social transfers in kind (e.g., medical insurance and nursing-care insurance).

According to Kuroda et al. (2008), the import function can be assumed as:

$$M = m(Z + C + I + G), \quad (5)$$

where  $m$  denotes the share of imports in the regional demand. In the IO analysis, imports are assumed to behave as in Equation (5).

The relation between regional output ( $X$ ) and NRP ( $Y$ ) can be expressed as:

$$Y = yX, \quad (6)$$

where  $y$  denotes the ratio of NRP among the output, and is called income coefficient. The relation between regional output ( $X$ ) and GRP ( $V$ ) can be expressed as:

$$V = vX, \quad (7)$$

where  $v$  denotes the ratio of GRP among the output, and is called value-added coefficient. NRP ( $Y$ ) and GRP ( $V$ ) are endogenized in the model.

The difference between output ( $X$ ) and intermediate input ( $Z$ ) is the value-added ( $V$ ); namely  $V = X - Z$ . Substituting equation (7) into  $V = X - Z$  yields:

$$Z = (1 - v)X. \quad (8)$$

Substituting equations (1)–(8) simultaneously yields:

$$X = \frac{(1-m)G_i + (1-m)[c(1-t^R-t^N)Y_i + E + (1-m)(C^0 + I^0)]}{1 - (1-m)[(1-v) + c(1-t^R-t^N)y + iv + t^Ry]}, \quad (9)$$

where the numerator is the direct effect, which represents the effect directly produced by central government expenditure ( $G_i$ ), net income inflow ( $Y_i$ ), exports ( $E$ ), and income-independent private expenditure ( $C^0 + I^0$ ). The denominator,  $\{1 - (1-m)[(1-v) + c(1-t^R-t^N)y + iv + t^Ry]\}^{-1}$ , is the regional multiplier. The production, or direct effect, influences the regional intermediate demand needed for the production, and the income generated by the production influences the final regional demand. To meet these demands, the production process induces regional intermediate and final demand again. Through repetitions of the above mechanism, the direct effect result is amplified by a multiplier effect. Substituting equation (9) into equation (6) yields the proposed NRP determination model.

### 3. Multi-sector Model

The change in NRP caused by an exogenous impact depends on which sector of production is affected. Therefore, the model is multi-sectorized. Let us rewrite equation (1) and describe a regional economy consisting of  $n$  types of sectors, as:

$$X = AX + C + I + G + E - M, \quad (10)$$

where  $X$  denotes the column vector of output ( $X_i$ ;  $i=1...n$ ) of sector  $i$ 's product.  $A$  denotes the matrix of sector  $j$ 's intermediate input coefficients ( $a_{ij}$ ;  $i, j=1...n$ ) for sector  $i$ 's product, and, therefore,  $AX$  denotes the column vector of intermediate demand for sector  $i$ 's product.  $C$  denotes the column vector of private consumption ( $C_i$ ;  $i=1...n$ ) of sector  $i$ 's product; likewise,  $I$  denotes the column vector of private investment ( $I_i$ ), and  $G$  denotes the column vector of government expenditure ( $G_i$ ), while  $E$  denotes the column vector of exports ( $E_i$ ), and  $M$  denotes the column vector of imports ( $M_i$ ).

Multi-sectorizing equation (2), the private consumption function can be assumed as:

$$C = (1 - t^R - t^N)(Y + Y_i)c + C^0. \quad (11)$$

$1 - t^R - t^N$  denotes the scalar value of disposable income ratio.  $Y + Y_i$  denotes the scalar value of net regional income, where  $Y$  and  $Y_i$  denote NRP and net income inflow into the region, respectively.  $c$  denotes the column vector of marginal propensity to consume sector  $i$ 's product ( $c_i$ ).  $C^0$  denotes the column vector

of income-independent private consumption ( $C_i^0$ ) of sector  $i$ 's product.

Multi-sectorizing equation (3), the private investment function can be assumed as:

$$I = Vi + I^0, \quad (12)$$

where  $V (= \sum_j V_j)$  denotes the scalar value of GRP (=value-added).  $i$  denotes the column vector of marginal propensity to invest ( $i_i$ ) in sector  $i$ 's product.  $I^0$  denotes the column vector of income-independent private investment ( $I_i^0$ ) in sector  $i$ 's product.

Multi-sectorizing equation (4), the government expenditure function can be assumed as:

$$G = [t^R(Y + Y_i) + G_i](g^c + g^I), \quad (13)$$

where  $t^R(Y + Y_i)$  denotes the scalar value of regional government expenditure from own revenue sources, and  $G_i$  denotes the scalar value of central government expenditure. Both  $t^R(Y + Y_i)$  and  $G_i$  consist of consumption and investment.  $g^c$  and  $g^I$  denote column vectors of coefficient  $g_i^c$  and  $g_i^I$ , respectively, which measure the share of government expenditure that is spent on consumption and investment on sector  $i$ 's product, respectively.

Multi-sectorizing equation (5), the import function can be assumed as:

$$M = \hat{m}(AX + C + I + G), \quad (14)$$

where  $\hat{m}$  denotes the diagonal matrix of the import share in demand ( $m_i$ ) for sector  $i$ 's product.

Equation (6) can be multi-sectorized as:

$$Y = y'X. \quad (15)$$

$y'$  denotes the row vector of income coefficients ( $y_i = Y_i/X_i$ ) of sector  $i$ , where  $Y_i$  denotes NRP by sector  $i$ . Equation (7) can be multi-sectorized as:

$$V = v'X. \quad (16)$$

$v'$  denotes the row vector of value-added coefficients ( $v_i = V_i/X_i$ ) of sector  $i$ , where  $V_i$  denotes value-added by sector  $i$ .

Substituting equations (10) – (16) simultaneously yields:

$$X = K[G_i(I_n - \hat{m})g + Y(I_n - \hat{m})[(1 - t^R - t^N)c + t^Rg] + E + (I_n - \hat{m})(C^0 + I^0)], \quad (17)$$

$$\text{where: } K = [I_n - (I_n - \hat{m})[A + (1 - t^R - t^N)cy' + iv' + t^Rgy]]^{-1};$$

$$g = g^c + g^I.$$

$I_n$  denotes the identity matrix.  $K$  denotes the regional multiplier. The NRP ( $Y$ ) can be estimated using equation (15).  $Y$  can be decomposed into the income produced by central government expenditure ( $Y^{Gt}$ ), by the net income inflow ( $Y^{Yi}$ ), by exports ( $Y^E$ ), and by income-independent private expenditure ( $Y^0$ ). Each decomposed income component,  $Y^{Gt}$ ,  $Y^{Yi}$ ,  $Y^E$ , and  $Y^0$ , can be estimated as:

$$Y^{Gt} = G y' K (I_n - \hat{m})(g^c + g^I); \quad (18)$$

$$Y^{Yi} = Y y' K (I_n - \hat{m})[(1 - t^R - t^N)c + t^Rg]; \quad (19)$$

$$Y^E = y' K E; \quad (20)$$

$$Y^0 = y' K (I_n - \hat{m})(C^0 + I^0), \quad (21)$$

where  $Y = Y^{Gt} + Y^{Yi} + Y^E + Y^0$ .

#### 4. Estimating the Regional Input-Output Table

Regional IO tables are necessary to estimate equations (18)–(21). Let us estimate sub-prefectural regional IO tables using the prefectural IO tables: Okinawa prefectural IO table (404 rows and 350 columns), Kagoshima prefectural IO table (190 sectors), Shimane prefectural IO table (97 sectors), and Nagasaki prefectural IO table (108 sectors) are used. Hereafter, subscript  $R$  denotes a region, and  $P$  denotes a prefecture comprising sub-prefectural regions ( $Rs$ ).

##### 1) Estimating output

Regional sector  $i$ 's output ( $X_i^R$ ) is estimated in the following manner. First, a provisional estimate ( $\tilde{X}_i^R$ ) is obtained by dividing prefectural sector  $i$ 's output ( $X_i^P$ ) among sub-prefectural regions, according to the dividing indexes. Employment is principally used as the index.<sup>2)</sup> Using employment,  $\tilde{X}_i^R$  can be obtained as:

$$\tilde{X}_i^R = X_i^P \frac{L_i^R}{L_i^P},$$

where  $L_i^R$  and  $L_i^P (= \sum_R L_i^R)$  are employment in sector  $i$  in region  $R$  and in the corresponding prefecture, respectively. Second,  $X_i^R$  is estimated by adjusting  $\tilde{X}_i^R$  to reconcile it with official economic accounts. For example, let us assume provisional outputs of crop and livestock sectors as  $\tilde{X}_1^R$  and  $\tilde{X}_2^R$ , respectively. Using the value-added coefficient ( $v_i^P$ ) in the prefectural IO

2) The following indexes are used, except for the employment; agricultural sectors: production value; forestry, fishery, construction, and government services sectors: value-added; commerce sectors: value of commercial margin; house rent sectors: number of households; air transport sector: number of passengers.

table, the value-added of these sectors are  $v_1^P \tilde{X}_1^R$  and  $v_2^P \tilde{X}_2^R$ , respectively. Dividing the value-added of the agricultural sector, including crop and livestock sectors in the official economic accounts, according to the  $v_1^P \tilde{X}_1^R$  and  $v_2^P \tilde{X}_2^R$ ,  $v_1^P X_1^R$  and  $v_2^P X_2^R$  can be estimated. Dividing these expressions by  $v_1^P$  and  $v_2^P$ , outputs  $X_1^R$  and  $X_2^R$  can also be estimated.<sup>3)</sup>

### 2) Aggregating the IO table

The sectors of the prefectural IO table are aggregated to reconcile its sector classification with the sector classification of the estimated regional output. Okinawa, Kagoshima, Shimane, and Nagasaki prefectural IO tables are aggregated into 222, 146, 87, and 87 sectors, respectively.

### 3) Estimating value-added and intermediate inputs

The value-added by regional sector  $j$  ( $V_j^R$ ) can be estimated as:

$$V_j^R = v_j^P X_j^R,$$

where  $v_j^P$  denotes the value-added coefficient of prefectural sector  $j$ . Income by regional sector  $j$  ( $Y_j^R$ ) can be estimated as:

$$Y_j^R = y_j^P X_j^R,$$

where  $y_j^P$  denotes the income coefficient of prefectural sector  $j$ . The intermediate input of regional sector  $j$  ( $Z_{ij}^R$ ) for sector  $i$ 's product can be estimated as:

$$Z_{ij}^R = a_{ij}^P X_j^R,$$

where  $a_{ij}^P$  ( $=Z_{ij}^R/X_j^P$ ) denotes prefectural sector  $j$ 's intermediate input coefficient for sector  $i$ 's product.

The important assumption here is that the input coefficient ( $v_j$ ,  $y_j$ , or  $a_{ij}$ ) is consistent within a prefecture and the sub-prefectural regions.<sup>4)</sup> Input coefficients in official municipal IO tables are estimated using the input coefficients of the national or prefectural IO tables (Nakazawa, 2002). Can we

estimate input coefficients for small areas, such as remote islands, in the same way? Sector  $j$  produces a variety of products, which is known as a product mix. When a prefectural IO table is divided into sub-prefectural regional IO tables, the higher the number of divisions in the prefectural IO table, the more widely regional sector  $j$ 's product mix diverges from the prefectural one, and, the more widely the regional sector  $j$ 's input coefficients diverge from the prefectural ones. To address this issue, input coefficients are adjusted using the value-added/output ratio,  $v_j^R/x_j^R$  and  $v_j^P/x_j^P$ , (Miller and Blair, 2009). The value-added coefficients ( $v_j^R$ ) for sub-prefectural regions are not available; however, using IO tables with a more detailed sector classification, the product mix issue can be mitigated. Therefore, in this study, IO tables with more than 87 sectors are used. In addition, the product mix issue induced by sector aggregation is not significant, except for the manufacturing sectors,<sup>5)</sup> which contribute to only 4.7% of the GRP of remote islands. Consequently, the assumption that the input coefficient is consistent within a prefecture and the sub-prefectural regions does not pose significant issues.

### 4) Estimating final regional demand

The final regional demand ( $F_i^R$ ) for sector  $i$ 's product includes private consumption, private investment, government consumption, and government investment, and it is estimated as follows. i) The private consumption<sup>6)</sup> is estimated by dividing the prefectural total consumption by the net regional income ( $Y^R + Y_i^R$ ) by region, where ( $Y^R = \sum_j Y_j^R$ ) demotes NRP,  $Y_i^R$  denotes net income inflow into the region, including net production-factor income inflow<sup>7)</sup> and social transfers in cash inflow.<sup>8)</sup> ii) The private investment of sector  $i$ 's product is estimated by dividing the prefectural total investment by the GRP ( $V^R = \sum_j V_j^R$ ) by region. iii) The government con-

3) With regard to self-transport sectors, the outputs are estimated assuming exports and imports to be zero; accordingly, Regional output = Regional demand.

4) With regards to the livestock sector, the input coefficients are obtained from the survey on production cost of beef cow calf, as the output of the livestock sector in remote islands is consistent with the output of the beef cow calf.

5) Let us examine the error caused by the sector aggregation using the estimated IO tables of remote islands in Okinawa. A statistics  $|V_j^R - \tilde{V}_j^R|/V_j^R$  ( $j=1, \dots, 94$ ) is used to measure the extent of the error, where  $V_j^R$  is obtained by aggregating 222 sectorized value-added, as they appear in the IO table with 222 sectors, into 94 sectorized value-added,  $\tilde{V}_j^R$ , as they appear in the IO table with 94 sectors. Averaging  $|V_j^R - \tilde{V}_j^R|/V_j^R$  across all sectors and all remote islands, weighted by  $V_j^R$ ,  $\sum_R \sum_j |V_j^R - \tilde{V}_j^R|/\sum_R \sum_j V_j^R$  is obtained, and corresponds to 3.7% when  $j \in$  primary industry sectors, to 16.7% when  $j \in$  manufacturing sectors, and to 2.6% when  $j \in$  other sectors. One can find that the error is not significant except for the manufacturing sectors.

6) With regards to the house rent sector, the private consumption is estimated assuming the exports and imports to be zero, accordingly, Private consumption = Output - Government consumption.



sumption of sector  $i$ 's product is estimated in the following manner: The consumptions of government services (including water supply, waste management, public administration, education, and health and hygiene services) are estimated assuming the exports and imports to be zero<sup>9)</sup>; accordingly: Government consumption = Output – Private consumption. The government consumption through social transfers in kind (e.g., medical service and nursing care) are estimated by dividing the prefectural total consumption by the number of population by region. The other shares government consumption are estimated by dividing the prefectural total consumption by the government service sector's value-added by region. iv) The government investment is estimated by dividing the prefectural total investment by the contract amount for public works projects by region.

### 5) Estimating exports and imports

Using the estimates for the intermediate demand ( $Z_{ij}^R$ ) and final regional demand ( $F_i^R$ ), one can estimate the regional demand ( $D_i^R$ ) for sector  $i$ 's product as:

$$D_i^R = \sum_j Z_{ij}^R + F_i^R.$$

Using the estimates of  $X_i^R$  and  $D_i^R$ , one can estimate net exports ( $E_i^R - M_i^R$ ) by region  $R$  as:

$$E_i^R - M_i^R = X_i^R - D_i^R. \quad (22)$$

However, a region simultaneously exports and imports product  $i$ , a phenomenon referred to as cross-hauling. We cannot estimate  $E_i^R$  and  $M_i^R$  separately due to cross-hauling ( $Q_i$ ) defined as:

$$Q_i = E_i + M_i - |E_i - M_i|. \quad (23)$$

In generating official municipal IO tables, exports are estimated by conducting a commodity flow survey, and, then, imports are estimated by substituting the estimated exports into equation (22) (Nakazawa, 2002). If conducting a survey is not possible, one has no choice but to estimate  $E_i^R$  and  $M_i^R$  using non-survey approaches. Let us examine representative non-survey approaches.

#### (1) LQ approach

Location Quotient (LQ) and related techniques have been used in a great many regional studies

(Miller and Blair, 2009: p.349). LQ is the coefficient of regional specialization in sector  $i$ , which is defined as:

$$LQ_i^R = \frac{X_i^R}{\sum_i X_i^R} \bigg/ \frac{X_i^P}{\sum_i X_i^P}, \quad (24)$$

where the denominator corresponds to the proportion of prefectural sector  $i$ 's output ( $X_i^P$ ) to the total output ( $\sum_i X_i^P$ ) and the numerator is the corresponding proportion of regional sector  $i$ 's output. Equation (24) implies that, if  $LQ_i^R < 1$ , region  $R$  imports some of its needs for sector  $i$ 's product, and if  $LQ_i^R > 1$ , region  $R$  exports some of sector  $i$ 's output (Schaffer and Chu, 1969: p.85). The assumption underlying the LQ approach is "If there is a disparity in the regional specialization in sector  $i$  among the regions, and there is no disparity in the need for sector  $i$ 's product among the regions, sector  $i$ 's product moves from the regions with  $LQ_i^R > 1$  to the regions with  $LQ_i^R < 1$ ." A number of variants of the LQ approach have been proposed (Miller and Blair, 2009); hereafter, they are referred to as LQs.

The LQ approach has been used to regionalize non-competitive import type IO tables. In Japan, where competitive import type tables are released, there are few applications of it (e.g., Fujimoto, 2000; Asahi, 2004; Okubo and Ishizuka, 2009; Fujimoto and Naitoh, 2013). When competitive import type prefectural IO tables are regionalized, if  $LQ_i^R < 1$ , the regional average propensity to consume regional sector  $i$ 's product is estimated by multiplying the prefectural average propensity to consume prefectural sector  $i$ 's product by  $LQ_i^R$ , and if  $LQ_i^R \geq 1$ , the regional propensity to consume is regarded as consistent with the prefectural one (refer to equations (32a) and (32b)).<sup>10)</sup> Note that the average propensity to consume means the share of prefectural (or regional) output minus exports in the prefectural (or regional) demand. However, the reason why exports and imports by region  $R$  can be estimated by discounting the prefectural propensity to consume by LQ has not been addressed yet.<sup>11)</sup> In the next paragraphs, the reason is addressed, and a more feasible LQ approach is proposed.

The prefectural supply and demand equivalent

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- 7) Net production-factor income inflow (including compensation of employees, property income, and business income inflows) is estimated by subtracting net regional product from net regional income.
- 8) Social transfers in cash inflow (including social welfare spending, such as pension, and social assistance spending, such as livelihood protection) is estimated assuming that payment per capita is consistent between a prefecture and the sub-prefectural regions.
- 9) The imports and exports of government services are usually not accounted because most government services are public goods and are not traded on the market. Water supply and waste management services are traded, however, and are usually supplied monopolistically by the regional government for its residents.

condition of prefectural sector  $i$ 's product can be expressed as:

$$X_i^p(1-e_i^p)=D_i^p(1-m_i^p), \quad (25)$$

where  $e_i^p (=E_i^p/X_i^p)$  denotes the share of exports in the prefectural sector  $i$ 's output, and  $m_i^p (=M_i^p/D_i^p)$  denotes the share of imports in the prefectural demand for sector  $i$ 's product.  $X_i^p(1-e_i^p)$  denotes prefectural sector  $i$ 's output distributed within the prefecture, because the value of exports to areas outside the prefecture ( $e_i^p X_i^p$ ) is subtracted from the output ( $X_i^p$ ).  $D_i^p(1-m_i^p)$  denotes the prefectural demand for prefectural sector  $i$ 's product, as the value of imports from outside the prefecture ( $m_i^p D_i^p$ ) is subtracted from the demand ( $D_i^p$ ).

Assuming that the share of sub-prefectural regional sector  $i$ 's output exported to outside the prefecture is consistent with the share of prefectural sector  $i$ 's output exported to outside the prefecture, the following condition can be obtained:

$$\frac{X_i^R(1-e_i^R)}{X_i^R} = \frac{X_i^p(1-e_i^p)}{X_i^p}, \quad (26)$$

where the left-hand side denotes the share of regional sector  $i$ 's output distributed within the prefecture, and the right-hand side denotes the share of prefectural sector  $i$ 's output distributed within the prefecture. Assuming that the share of imports from outside the prefecture in the sub-prefectural regional demand for sector  $i$ 's product is consistent with the share of imports from outside the prefecture in the prefectural demand for sector  $i$ 's product, the following condition can be obtained:

$$\frac{D_i^R(1-m_i^R)}{D_i^R} = \frac{D_i^p(1-m_i^p)}{D_i^p}, \quad (27)$$

where the left-hand side denotes the share of product produced within the prefecture in the regional demand for sector  $i$ 's product, and the right-hand side denotes the share of product produced within the prefecture in the prefectural demand for sector  $i$ 's product. The above assumptions can be summarized as "Among the sub-prefectural regions, the share of regional output of

sector  $i$ 's product exported to outside the prefecture is consistent, and the share of imports from outside the prefecture in the regional demand for sector  $i$ 's product is also consistent."

Equation (26) and (27) can be re-arranged as  $X_i^p(1-e_i^p)=(X_i^p/X_i^R)X_i^R(1-e_i^R)$  and  $D_i^p(1-m_i^p)=(D_i^p/D_i^R)D_i^R(1-m_i^R)$ , respectively, and by substituting them into equation (25), the following expression can be obtained:

$$X_i^R(1-e_i^R)=D_i^R(1-m_i^R)DSLQ_i^R. \quad (28)$$

$DSLQ_i^R$  (Demand and Supply based LQ) in equation (28) corresponds to the LQ proposed in this study, and can be defined as:

$$DSLQ_i^R = \frac{X_i^R}{D_i^R} \bigg/ \frac{X_i^p}{D_i^p}, \quad (29)$$

where the denominator is the ratio of prefectural output ( $X_i^p$ ) to the prefectural demand ( $D_i^p$ ) for sector  $i$ 's product, and the numerator is the corresponding ratio in region  $R$ .  $DSLQ_i^R$  compares sector  $i$ 's production capacity relative to the demand for sector  $i$ 's product between the prefecture and region  $R$ .

Equation (28) can be expressed as:

$$X_i^R(1-e_i^R)-D_i^R(1-m_i^R)=D_i^R(1-m_i^R)(DSLQ_i^R-1), \quad (30)$$

where  $X_i^R(1-e_i^R)$  denotes regional sector  $i$ 's output distributed within the prefecture, including region  $R$ , since exports ( $e_i^R X_i^R$ ) to outside the prefecture are deducted from the regional output ( $X_i^R$ ).  $D_i^R(1-m_i^R)$  denotes regional demand for sector  $i$ 's product produced within the prefecture, including that produced in region  $R$ , since imports ( $m_i^R D_i^R$ ) from outside the prefecture are deducted from the regional demand ( $D_i^R$ ). Therefore, the left-hand side in equation (30) denotes net exports by region  $R$  in interregional trade within the prefecture. Assuming that "There is no cross-hauling in interregional trade," when  $DSLQ_i^R \geq 1$ ,  $D_i^R(1-m_i^R)(DSLQ_i^R-1)$  is the net or gross interregional exports, since  $X_i^R(1-e_i^R) \geq D_i^R(1-m_i^R)$  from equation (28); when  $DSLQ_i^R < 1$ ,  $D_i^R(1-m_i^R)(1-DSLQ_i^R)$  is the net or gross interregional imports, since  $X_i^R(1-e_i^R) < D_i^R(1-m_i^R)$  from equation (28). Under the above-mentioned assumption on cross-hauling, when

- 10) If non-competitive import type prefectural IO tables are available, information on the share of imports in sector  $j$ 's intermediate demand ( $m_{ij}^p$ ) for sector  $i$ 's product and the share of imports in final-demand sector  $f$ 's demand ( $m_{if}^p$ ) for sector  $i$ 's product are available. However, since only competitive import type tables are available, one needs to assume that the share of imports in demand ( $m_i^p$ ) is consistent among the demand sectors ( $m_{ij}^p=m_{if}^p=m_i^p$ ); therefore, the estimating accuracy is inferior compared to the case where non-competitive import type tables are available.
- 11) McCann (2001) shows that, if there is no interregional cross-hauling for any sectors, multiplying the national average propensity to consume of the domestically produced output of sector  $i$  by the appropriate LQ value, we can obtain an expression for the regional average propensity to consume of the regionally produced output of sector  $i$ .

$DSLQ_i^R \geq 1$ , interregional imports are assumed to be zero; when  $DSLQ_i^R < 1$ , interregional exports are assumed to be zero.

The LQ approach requires two assumptions, namely: (A) Among the sub-prefectural regions, the share of regional output of sector  $i$ 's product exported to outside the prefecture is consistent, the share of imports from outside the prefecture in the regional demand for sector  $i$ 's product is also consistent, and (B) There is no cross-hauling in interregional trade. Under assumptions (A) and (B),  $E_i^R$  and  $M_i^R$  can be shown as:

$$E_i^R = \begin{cases} e_i^p X_i^R + D_i^R(1-m_i^p)(DSLQ_i^R - 1) & \text{when } DSLQ_i^R \geq 1 \\ e_i^p X_i^R & \text{when } DSLQ_i^R < 1 \end{cases}; \quad (31a)$$

$$M_i^R = \begin{cases} m_i^p D_i^R & \text{when } DSLQ_i^R \geq 1 \\ m_i^p D_i^R + D_i^R(1-m_i^p)(1-DSLQ_i^R) & \text{when } DSLQ_i^R < 1 \end{cases}. \quad (31b)$$

The first terms in equations (31a) and (31b) denote trade flows between region  $R$  and outside the prefecture; the share of exports ( $e_i^p$ ) in the regional output and the share of imports ( $m_i^p$ ) in the regional demand are identical to those for the prefecture, respectively, under assumption (A). The second terms denote interregional trade flows within the prefecture; when  $DSLQ_i^R \geq 1$ , region  $R$  exports ( $D_i^R(1-m_i^p)(DSLQ_i^R - 1)$ ) but does not import, and when  $DSLQ_i^R < 1$ , region  $R$  imports ( $D_i^R(1-m_i^p)(1-DSLQ_i^R)$ ) but does not export under assumption (B).

Equations (31a) and (31b) can be deformed as:

$$E_i^R = X_i^R - D_i^R(1-m_i^p)DSLQ_i^R \\ \text{if } DSLQ_i^R \geq 1 \text{ then } DSLQ_i^R = 1; \quad (32a)$$

$$M_i^R = D_i^R - D_i^R(1-m_i^p)DSLQ_i^R \\ \text{if } DSLQ_i^R \geq 1 \text{ then } DSLQ_i^R = 1. \quad (32b)$$

Equation (28) can be deformed as  $e_i^p X_i^R = X_i^R - D_i^R(1-m_i^p)DSLQ_i^R$ ; if it is substituted into

equation (31a),  $E_i^R = X_i^R - D_i^R(1-m_i^p)$  when  $DSLQ_i^R \geq 1$ , and  $E_i^R = X_i^R - D_i^R(1-m_i^p)DSLQ_i^R$  when  $DSLQ_i^R < 1$ , which agree with equation (32a). Equation (31b) can be deformed as  $M_i^R = D_i^R - D_i^R(1-m_i^p)$  when  $DSLQ_i^R \geq 1$ , and  $M_i^R = D_i^R - D_i^R(1-m_i^p)DSLQ_i^R$  when  $DSLQ_i^R < 1$ , which agree with equation (32b). In equations (32a) and (32b),  $1-m_i^p$  denotes the prefectural average propensity to consume the prefectural sector  $i$ 's product. The term  $1-m_i^p$  is adjusted by  $DSLQ_i^R$ , and the regional propensity to consume is generated.<sup>12)</sup> The results show why exports and imports by region  $R$  can be estimated by discounting the prefectural propensity to consume by LQ. The results also show that LQ approach requires assumptions (A) and (B). Maegawa (2012) proposed an approach to estimate regional trade, which is not based on the LQ; however, the proposed approach is based on assumptions similar to the two assumptions discussed above.

In interregional trade within a prefecture, the sum of interregional net exports across all regions is consistent with the sum of interregional net imports across all regions, which can be proven as<sup>13)</sup>:

$$\sum_R D_i^R(1-m_i^p)(DSLQ_i^R - 1) = 0, \quad (33)$$

where the left-hand side denotes the sum of net exports across all regions. In regions where  $DSLQ_i^R \geq 1$ , net exports are positive; when  $DSLQ_i^R < 1$ , net exports are negative. Using LQs, except for DSLQ, interregional trade within the prefecture is not balanced, and the estimates for exports and imports are biased.<sup>14)</sup>

The LQ underestimates cross-hauling, as it assumes no cross-hauling in interregional trade. Industrial disaggregation helps relieve this problem, as the heterogeneity of sector  $i$ 's product is decreased; however, it does not entirely solve the issue (Richardson, 1985: p.613). To this end, let us consider alternative non-survey approaches, which take into account cross-hauling in interregional trade.

## (2) CHARM

The gravity model proposed by Leontief (1969)

12) The regional average propensity to consume regional sector  $i$ 's product is never higher than the prefectural one. However, if a region is specialized in sector  $i$ , the regional propensity to consume can be higher than the prefectural one. Therefore, Flegg and Webberb (2000) include a measure of regional specialization in the LQ; however, this does not seem to yield more accurate estimates, possibly because they allow upward adjustments of LQ depending on the regional specialization, even though LQ overestimates the regional propensity to consume.

13) The left-hand side in equation (33) can be re-arranged as  $(1-m_i^p)(\sum_R D_i^R DSLQ_i^R - \sum_R D_i^R)$ , where  $\sum_R D_i^R DSLQ_i^R = D_i^p$  and  $\sum_R D_i^R = D_i^p$ . Using equation (29),  $\sum_R D_i^R DSLQ_i^R$  can be expressed as  $\sum_R X_i^R(D_i^p/X_i^p)$ , where  $\sum_R X_i^R = X_i^p$ , and, therefore,  $\sum_R D_i^R DSLQ_i^R = D_i^p$ .

14) Sasaki and Shibata (1983) demonstrated that, using LQ as shown in equation (24), the exports of a region diverge vastly from the sum of the estimated exports of the sub-regions.



takes into account cross-hauling in interregional trade. Its basic idea is that the flow of sector  $i$ 's product from region  $R$  to region  $S$  can be considered a function of total output in  $R$ , total purchase in  $S$ , and distance between the regions (Miller and Blair, 2009: p. 365). In Japan, Nakano and Nishimura (2013) estimated the IO table of Nagoya city using a gravity model; they used interregional trade data in the multiregional IO table for eight divided regions of Japan, excluding Okinawa. However, when IO tables of remote islands are estimated, information on the relationship between distance and trade volume is not sufficient because remote islands are surrounded by the sea.<sup>15)</sup>

The FLQ proposed by Flegg and Webberb (1997) takes into account cross-hauling more significantly than LQs by multiplying LQs by  $\lambda$  ( $=\{\log_2 [1+(\sum_i X_i^R/\sum_i X_i^P)]\}^{\delta} \leq 1$ ). An advantage of the FLQ is that the size of region  $R$ ,  $\sum_i X_i^R/\sum_i X_i^P$ , can also be considered. However, the value of  $\delta$  is unknown and determined exogenously.<sup>16)</sup> In addition, LQs are multiplied by the fixed  $\lambda$  in all sectors; therefore, the obtained cross-hauling is not realistic at the individual sector level. The extent of cross-hauling varies depending on the product heterogeneity of sector  $i$ . For instance, cross-hauling may easily occur in the intra-industry trade of agricultural products because agricultural products are heterogeneous; however, it may hardly occur in the intra-industry trade of nursing-care services because they are homogeneous.

The Cross-Hauling Adjusted Regionalization Method (CHARM), proposed by Kronenberg (2009), considers cross-hauling based on product heterogeneity. The CHARM measures cross-hauling as:

$$Q_i = h_i(X_i + D_i) \quad \text{s.t. } Q_i/2 \leq X_i \text{ and } Q_i/2 \leq D_i, \quad (34)$$

where  $Q_i$  denotes cross-hauling in the trade of sector  $i$ 's product, which is assumed to be proportional to the sum of output and demand ( $X_i + D_i$ ) of sector  $i$ 's product.  $h_i$  denotes the ratio of cross-hauling to  $X_i + D_i$ , which is an index of product heterogeneity of sector  $i$ 's product. Substituting  $Q_i^P (=E_i^P + M_i^P - |E_i^P - M_i^P|)$ ,  $X_i^P$ , and  $D_i^P$  as obtained from the prefectural IO table into equation (34),  $h_i$  for the trade by prefecture can also be obtained. Assuming that  $h_i$  is equivalent in terms of trade by region  $R$  and by

prefecture, substituting  $h_i$ ,  $X_i^R$ , and  $D_i^R$  into equation (34), cross-hauling ( $Q_i^R$ ) in the trade by region  $R$  can be estimated. However, the CHARM underestimates cross-hauling. The sum of  $Q_i^R$  across all sub-prefectural regions is equal to the cross-hauling for the trade by prefecture ( $Q_i^P$ ), which can be proven as:

$$\begin{aligned} \sum_R Q_i^R &= \sum_R h_i(X_i^R + D_i^R) \\ &= h_i \sum_R (X_i^R + D_i^R) = h_i(X_i^P + D_i^P) = Q_i^P. \end{aligned}$$

The CHARM assigns  $Q_i^P$  among the sub-prefectural regions according to  $X_i^R + D_i^R$  and ignores cross-hauling in interregional trade.

### (3) Modified CHARM

Let us modify the CHARM to address this drawback. Assuming that "Among the sub-prefectural regions, the share of regional output of sector  $i$ 's product exported to outside the prefecture is consistent, and the share of imports from outside the prefecture in the regional demand for sector  $i$ 's product is also consistent," net exports of sector  $i$ 's product by region  $R$  in interregional trade within the prefecture ( $E_i^{RR} - M_i^{RR}$ ) can be derived as:

$$E_i^{RR} - M_i^{RR} = X_i^R(1 - e_i^P) - D_i^R(1 - m_i^P), \quad (35)$$

where  $E_i^{RR}$  and  $M_i^{RR}$  denote interregional exports and imports, respectively, of sector  $i$ 's product by region  $R$ .  $X_i^R(1 - e_i^P)$  denotes regional sector  $i$ 's output distributed within the prefecture, including region  $R$ .  $D_i^R(1 - m_i^P)$  denotes regional demand for the prefectural sector  $i$ 's product, including that produced in region  $R$ .

Assuming that cross-hauling ( $Q_i$ ) in the trade of sector  $i$ 's product is proportional to the sum of exports and imports ( $E_i + M_i$ ),  $Q_i$  can be expressed as:

$$Q_i = h'_i(E_i + M_i) \quad \text{s.t. } Q_i/2 \leq X_i \text{ and } Q_i/2 \leq D_i, \quad (36)$$

where  $h'_i$  denotes the ratio of cross-hauling to the trade volume ( $E_i + M_i$ ). Substituting equation (36) into equation (23),  $h'_i$  can be derived as:

$$h'_i = \frac{E_i + M_i - |E_i - M_i|}{E_i + M_i} \quad (37)$$

All variables on the right-hand side of equation (37) can be obtained from the prefectural IO table, and, accordingly,  $h'_i$  in the trade between the prefecture and outside the prefecture can also be obtained. Then,

15) One needs to rely on the information on the sea transport trade between Okinawa and the mainland of Japan. In that case, as Nakano and Nishimura (2013: p. 941) pointed out: i) information on the trade volume to estimate gravity parameter is not sufficient; ii) it is unreasonable to estimate short distance trade within a prefecture from the information on long distance trade between Okinawa and the mainland of Japan.

16) Flegg and Tohmo (2013) estimated regional IO tables through the regionalization of the national IO table and compared them with the survey based regional IO tables. From the comparison, they recommend empirically to use  $\delta = 0.25$ .

assuming that “ $h_i'$  is equivalent in interregional trade and trade between the prefecture and outside the prefecture,” cross-hauling,  $Q_i^{RR}$ , in interregional trade can be derived as:

$$Q_i^{RR} = h_i'(E_i^{RR} + M_i^{RR}), \quad (38)$$

whereas the definition of  $Q_i^{RR}$  is:

$$Q_i^{RR} = E_i^{RR} + M_i^{RR} - |E_i^{RR} - M_i^{RR}|. \quad (39)$$

Rearranging equation (38) as  $E_i^{RR} + M_i^{RR} = Q_i^{RR}/h_i'$  and substituting it into equation (39),  $Q_i^{RR}$  can be expressed as:

$$Q_i^{RR} = \frac{h_i'[E_i^{RR} - M_i^{RR}]}{1 - h_i'} \quad (40)$$

$$s.t. \quad Q_i^{RR}/2 \leq X_i^R(1 - e_i^p) \text{ and } Q_i^{RR}/2 \leq D_i^R(1 - m_i^p).$$

Substituting  $E_i^{RR} - M_i^{RR}$ , as estimated by equation (35), into equation (40),  $Q_i^{RR}$  can also be estimated. Substituting  $Q_i^{RR}$  and  $E_i^{RR} - M_i^{RR}$  into equation (39),  $E_i^{RR} + M_i^{RR}$  can be estimated. Substituting the estimates for  $E_i^{RR} + M_i^{RR}$  and  $E_i^{RR} - M_i^{RR}$  into  $E_i^{RR} = [E_i^{RR} + M_i^{RR} + (E_i^{RR} - M_i^{RR})]/2$  and  $M_i^{RR} = [E_i^{RR} + M_i^{RR} - (E_i^{RR} - M_i^{RR})]/2$ ,  $E_i^{RR}$  and  $M_i^{RR}$  can be estimated. Consequently, the imports and exports of sector  $i$ 's product by region  $R$  can be estimated as  $M_i^R = m_i^p D_i^R + M_i^{RR}$  and  $E_i^R = e_i^p X_i^R + E_i^{RR}$ , respectively.

The sum of  $Q_i^R$  across all sub-prefectural regions can be expressed as:

$$\begin{aligned} \sum_R Q_i^R &= \sum_R h_i'(E_i^R + M_i^R) \\ &= \sum_R h_i'[(e_i^p X_i^R + E_i^{RR}) + (m_i^p D_i^R + M_i^{RR})] \\ &= h_i' \sum_R (e_i^p X_i^R + m_i^p D_i^R) + h_i' \sum_R (E_i^{RR} + M_i^{RR}). \end{aligned}$$

The first term in the last equation denotes the sum of cross-hauling in the trade between region  $R$  and outside the prefecture across all region  $R$ s, and it can be expressed as  $h_i' \sum_R (e_i^p X_i^R + m_i^p D_i^R) = Q_i^p$ .<sup>17)</sup>  $Q_i^p$  is assigned among sub-prefectural regions according to the respective trade volumes ( $e_i^p X_i^R + m_i^p D_i^R$ ). The second term in the last equation denotes the sum of cross-hauling in the interregional trade by region  $R$

across all region  $R$ s.

#### (4) Estimation of exports and imports for remote island economies

Trade flows for remote islands can be estimated by the regionalization of prefectural IO tables using non-survey approaches. However, it may be difficult to obtain accurate estimates because the share of remote island economy in the prefectural economy is small. In Table 1, rows 1–5 show the results of previous works that compare output multipliers<sup>18)</sup> derived from survey- and non-survey-based regional IO tables, where the non-survey-based tables were estimated from the national IO table using the LQ or CHARM approach. Rows 6–11 show the results of experimental works conducted in this study, which compare output multipliers derived from survey- and non-survey-based prefectural IO tables of Okinawa, where the non-survey based tables are estimated from the national IO table.<sup>19)</sup> Okinawa prefecture can be considered as a remote island off the mainland of Japan, and contributes to merely 0.7% of the GDP of Japan.

In previous works (rows 1–5), output multipliers are overestimated, or import propensities are underestimated, meaning that cross-hauling is underestimated, probably because the LQ and CHARM approaches assume no cross-hauling in interregional domestic trade. This study derived output multipliers from IO tables estimated using the LQ and CHARM approaches, like in previous works. The results are shown in rows 6, 7, 9, and 10 of Table 1, where no significant overestimation is found. The accuracy of our estimates is likely to depend on the more detailed sector classification of IO tables used in this study. However, the main reason seems to be that the Okinawa prefecture is a remote island.

The extent of cross-hauling depends on two factors. The first is product heterogeneity: The higher product heterogeneity in the trade of sector  $i$ 's products, the larger the cross-hauling that trade allows. The second factor is the proximity to a border: If a firm is located close to the border, the closest supplier of a certain input may happen to be situated on the other side of the border (Kronenberg, 2009: p.49). In densely populated and highly urbanized countries, cross-hauling is the rule; this is the case even for commuting across

17)  $h_i' \sum_R (e_i^p X_i^R + m_i^p D_i^R) = h_i'(e_i^p \sum_R X_i^R + m_i^p \sum_R D_i^R) = h_i'(e_i^p X_i^p + m_i^p D_i^p) = h_i'(E_i^p + M_i^p) = Q_i^p$

18) The average of output multipliers for sector  $j$ s across all sectors. The output multiplier for sector  $j$  is the sum of the  $j^{\text{th}}$  column of the Leontief inverse matrix given by  $[I_n - (I_n - m^R)A^R]^{-1}$ .

19) In the estimation of the prefectural IO tables, true values of prefectural output ( $X_i^p$ ), prefectural intermediate input coefficient ( $a_{ij}^p$ ), and final prefectural demand ( $F_i^p$ ) are given by the values of the survey-based prefectural IO table, indicating the values that are assumed to be estimated accurately. The comparisons were conducted for IO tables with 85 and 200 sectors, corresponding to those of the Shimane and Nagasaki prefectural tables and that of the Okinawa prefectural table.

**Table 1. Comparison of output multipliers derived from survey and non-survey based regional IO tables**

	Origin of regionalization (Nation)	Destination of regionalization (Region)	GDP share of the region	Number of Sectors	Non-survey approach	Output multipliers		
						Survey ①	Non-survey ②	Percentage difference (②-①)/①
1 Tohmo (2004)	Finland	Keski-Pohjanmaa	1.1%	37	LQ	1.271	1.463	15.1%
2 Flegg and Tohmo (2013)	Finland	20 regions average	—	37	LQ	—	—	14.7%
3 Miller and Blair (2009)	China	North Cina <sup>1)</sup>	—	3	LQ	1.768	2.055	16.2%
4 Flegg and Tohmo (2012)	Finland	Uusimaa	31.6%	26	CHARM	1.482	1.542	4.0%
5 Flegg et al. (2014)	China	Hubei	4.0%	42	CHARM	1.919	2.078	8.3%
6 This study	Japan	Okinawa	0.7%	85	DSLQ	1.372	1.448	5.5%
7 "	"	"	"	"	CHARM	1.372	1.452	5.8%
8 "	"	"	"	"	Modified CHARM	1.372	1.367	-0.4%
9 This study	Japan	Okinawa	0.7%	222	DSLQ	1.345	1.391	3.4%
10 "	"	"	"	"	CHARM	1.345	1.403	4.3%
11 "	"	"	"	"	Modified CHARM	1.345	1.328	-1.3%

Note: 1) Heilongjiang, Jilin, Liaoning, Beijing, Tianjin, Hebei, Shandong.

regional boundaries (Boomsma and Oosterhaven, 1992: p. 272). However, isolated remote islands face extreme difficulties in trading and commuting across borders because they are surrounded by the sea. Therefore, the second determinant of cross-hauling, proximity to a border, can be ignored.<sup>20)</sup>

As shown in rows 6 and 9, the LQ approach seems to be reliable to estimate IO tables of remote islands. However, it seems clear that LQ underestimates cross-hauling, and the reason can be narrowed down to the first determinant of cross-hauling, product heterogeneity. Then, as shown in rows 8 and 11 of Table 1, the output multipliers are derived from the estimated IO tables using a modified CHARM. The output multipliers are slightly underestimated, translating in the overestimation of cross-hauling. The product heterogeneity in intra-prefectural trade is lower compared to trade between the prefecture and outside the prefecture.<sup>21)</sup> Therefore, the modified CHARM may overestimate cross-hauling.

#### (5) Characteristics of remote island economies

Table 2 shows the estimated IO table of Oki-Nishinoshima Island in Shimane prefecture. The GRP of Oki-Nishinoshima Island is equivalent to the median GRP among the 31 remote islands. Let us consider the characteristics of the economy. First, the center of gravity of the industrial structure is the primary

industry, construction, and public service sectors, and the share of value-added by each sector to GRP is 14%, 10%, and 33%, respectively. Second, the economy is highly import-dependent: It shows a trade deficit of 50 billion yen (about 5 hundred million dollars), equivalent to 1.4 million yen (about 14 thousand dollars) per capita. One can deduce that the deficit has been covered by the central government expenditure.

### 5. Quantitative Evaluation of Regional Income Determinants

#### 1) Setting variables and parameters

Most of the variables and parameters in equation (17) can be obtained from the estimated IO tables. However,  $G_i$ ,  $t^R$ ,  $(1-t^R-t^N)c$ ,  $C^0$ ,  $i$ , and  $I^0$  are unknown. The central government expenditure ( $G_i$ ) can be obtained by subtracting regional tax revenue from the government expenditure. Regional tax rates ( $t^R$ ) can be obtained by dividing regional tax revenue by the net regional income.

$(1-t^R-t^N)c$  and  $C^0$  can be estimated in the following manner. The private consumption ( $C_i$ ) of sector  $i$ 's product can be expressed as:

$$C_i = C_i^0 + c_i(1-t^R-t^N)(Y+Y_i), \quad (41)$$

where  $c_i$  denotes the marginal propensity to consume sector  $i$ 's product,  $1-t^R-t^N$  denotes the disposable

20) Let us consider as an example the interregional trade of waste management services. It is unlikely that waste produced in a remote island is treated in the mainland of Japan, and vice versa.

21) Let us consider the location of liquor industries. Various liquor industries, such as refined sake, malt liquors, and distilled spirits locate on a nation-wide basis; however, Kagoshima prefecture is an area where distilled spirits industries are concentrated.

Table 2. Regional IO table for Oki-Nishinoshima Island

(Unit: million yen)

	Primary industry	Manufacturing	Construction	Electricity, gas, and water supply	Commerce	Finance, insurance, and real estate	Transport, information, and communications	Public service	Other service	Final regional demand	Exports <sup>6)</sup>	Imports <sup>6)</sup>	Gross outputs
Primary industry <sup>1)</sup>	27	9	5	0	0	0	0	8	37	82	2,595	-139	2,624
Manufacturing <sup>2)</sup>	602	74	665	42	26	15	203	519	278	2,380	160	-4,774	189
Construction	1	0	5	10	4	73	7	82	6	2,717	0	-523	2,383
Electricity, gas, and water supply <sup>3)</sup>	4	3	18	58	21	3	14	244	91	368	128	-312	639
Commerce	124	13	145	13	13	4	53	164	121	1,273	780	-1,892	811
Finance, insurance, and real estate	45	5	45	7	54	160	112	45	60	2,369	216	-550	2,567
Transport, information, and communications	94	5	159	39	67	34	318	347	110	478	1,170	-1,054	1,766
Public service <sup>4)</sup>	7	4	6	4	3	2	10	30	7	6,114	387	-863	5,711
Other service <sup>5)</sup>	29	7	214	45	53	68	181	397	72	998	1,330	-1,669	1,727
Gross value added	1,691	69	1,122	421	570	2,208	869	3,874	945				
Gross inputs	2,624	189	2,383	639	811	2,567	1,766	5,711	1727	15,969	5,702	-10,712	18,416

Note: 1) Agriculture, forestry and fishery.

2) Including mining.

3) Including waste management.

4) Public administration, Education, research, medical service, health care, social welfare, and private non-profit service.

5) Business service and personal service.

6) Exports and imports are estimates by modified CHARM.

income ratio, and  $C_i^0$  denotes income-independent private consumption of sector  $i$ 's product.  $C_i^0$  and  $c_i(1-t^R-t^N)$  in equation (41) can be obtained from the estimates of the household consumption function, expressed as:

$$C_k = 112052 + 0.335Y_k \quad (\text{Unit: yen/month/household}), \quad (42)$$

(9.705) (15.668)

where t-statistics are given in parentheses and  $\text{Adj-R}^2 = 0.964$ , and where  $C_k$  ( $k=1\cdots 10$ ) and  $Y_k$  denote consumption expenditure and income per household of the  $k^{\text{th}}$  income decile group, respectively.<sup>22)</sup>  $C_k$  and  $Y_k$  can be obtained from the Family Income and Expenditure Survey. The marginal propensity to

consume multiplied by the disposable income ratio ( $\sum_i c_i(1-t^R-t^N)$ ) can be estimated as 0.335 from the regression model (42). Then,  $c_i(1-t^R-t^N)$  can be estimated by dividing  $\sum_i c_i(1-t^R-t^N)$  according to the private consumption ( $C_i$ ) of sector  $i$ 's product in the estimated IO table.  $C_i^0$  is estimated by substituting  $C_i$ ,  $Y+Y_i$ , and the estimated  $c_i(1-t^R-t^N)$  into equation (41).

However, it is not easy to estimate the marginal propensity to invest ( $i_i$ ) in sector  $i$ 's product. Therefore,  $i_i=0$  is assumed; consequently, the private investment in sector  $i$ 's product is assumed independent from income, namely,  $I_i=I_i^0$ .

22) The Keynesian absolute income hypothesis has had a large success in modeling consumption in short-term or cross-section analysis, but, less success in long-term time series analysis (Takagi et al., 2000). The hypothesis implies that the average propensity to consume declines as income increases; however, in long-term time series data, the average propensity to consume does not decline. Then, the consumption function is estimated: i) Using cross-section data, or ii) Using time series data, assuming that people make consumption decisions depending on their life stage. However, in the latter approach, the estimate varies depending on the period of analysis. Therefore, the former approach is used in this study.

**Table 3. NRP decomposed into its determinants<sup>1)</sup>**

(Unit: million yen)

	Central government expenditure on			Net income inflow as			Exports by			Income-independent expenditure	Total	(Population)
		Consumption	Investment		Production-factor income	Social transfers in cash		Primary industry sectors	Tourism industry sectors	Other industry sectors		
Oki-Nakanoshima	3,959	3,155	803	6	-208	214	1,459	270	601	588	1,295	6,718 (2,581)
Oki-Nishinoshima	4,540	3,837	703	-41	-319	278	3,414	1,618	1,055	742	1,602	9,515 (3,486)
Oki-Chiburi	990	862	127	24	-30	54	316	92	114	111	310	1,640 (725)
Oki -Okinoshima	23,254	17,277	5,977	754	-511	1,264	11,535	2,851	4,073	4,610	7,199	42,741 (16,904)
Tsushima	47,224	34,805	12,419	3,300	427	2,873	29,271	10,014	7,480	11,777	16,480	96,275 (38,481)
Iki	22,695	19,680	3,015	2,874	266	2,607	28,267	6,059	7,875	14,333	13,231	67,067 (31,414)
Shimogoto	41,379	34,600	6,779	3,488	-811	4,299	27,910	6,168	8,035	13,707	22,823	95,600 (44,765)
Ojika	2,373	2,102	271	310	91	219	1,847	750	457	640	1,068	5,597 (3,268)
Kamigoto	18,796	15,504	3,292	1,463	-595	2,058	27,146	8,280	7,819	11,046	10,293	57,698 (25,039)
Tanegashima	32,579	26,237	6,342	1,982	-652	2,634	26,740	6,026	5,407	15,307	12,802	74,103 (34,143)
Amami Oshima	68,740	58,804	9,935	4,440	-1,115	5,556	49,204	2,093	11,977	35,134	25,670	148,054 (70,462)
Yaku	13,018	9,075	3,943	524	-486	1,010	14,350	891	4,686	8,774	4,947	32,839 (13,761)
Kikai	8,197	5,717	2,479	341	-150	491	6,234	911	1,734	3,588	2,060	16,831 (8,572)
Tokunoshima	25,113	20,082	5,031	737	-1,339	2,076	19,408	3,880	3,317	12,211	7,889	53,148 (27,167)
Okinoerabu	15,511	11,991	3,520	360	-632	992	12,195	3,856	2,484	5,854	4,547	32,613 (14,551)
Yoron	4,391	3,879	511	207	-157	365	4,039	705	1,405	1,929	1,476	10,112 (5,731)
Ishigaki	33,382	27,615	5,768	3,431	769	2,662	35,150	4,668	15,295	15,187	18,349	90,312 (45,183)
Miyako	41,396	34,471	6,926	2,873	-198	3,071	38,181	8,654	11,904	17,622	19,390	101,840 (53,493)
Ie	2,550	1,783	767	445	130	314	3,805	2,290	816	699	1,276	8,075 (5,110)
Tokashiki	1,278	752	526	-16	-35	19	848	20	679	149	176	2,286 (790)
Zamami	1,259	916	343	-33	-67	34	1,447	34	1,249	164	277	2,950 (1,077)
Aguni	1,065	762	303	4	-26	30	633	72	204	358	198	1,900 (936)
Tonaki	867	535	333	15	4	11	210	68	50	92	97	1,189 (531)
Minamidaito	1,652	919	732	92	50	42	1,453	534	247	672	345	3,541 (1,448)
Kitadaito	1,150	551	598	17	4	13	458	181	109	168	129	1,754 (588)
Iheya	1,269	769	500	56	9	46	770	215	202	353	253	2,349 (1,547)
Izena	1,898	913	984	40	-13	53	1,258	429	259	570	371	3,567 (1,762)
Kume	7,436	5,921	1,515	403	26	377	6,981	1,955	2,314	2,712	2,235	17,055 (9,177)
Tarama	1,248	800	449	30	-4	33	1,238	666	111	461	248	2,764 (1,370)
Taketomi	4,058	2,082	1,976	-51	-191	140	6,405	1,035	3,551	1,819	1,201	11,613 (4,192)
Yonaguni	3,540	1,549	1,992	-19	-80	60	1,682	299	634	749	586	5,789 (1,796)

Note: 1) Average values obtained using IO tables estimated by LQ and modified CHARM.

## 2) Results

### (1) Regional income decomposed into its determinants

In Table 3, the estimates of equations (18)–(21) are shown as the average value of the estimates using the IO tables estimated by LQ and modified CHARM, where the NRP of each remote island is decomposed into its determinants. As shown in rows 6, 8, 9, and 11 of Table 1, LQ underestimates cross-hauling, while modified CHARM may overestimate cross-hauling. This is the reason why estimates obtained using alternative IO tables are averaged. Table 4 shows the

total of each decomposed NRP across all 31 remote islands, where the results using IO tables estimated by LQ and modified CHARM are shown, respectively. Let us compare the alternative estimates. The share of NRP explained by exports is 32% when using the LQ, and 40% when using the modified CHARM, whereas the share of NRP explained by factors other than imports is larger when using the LQ compared to the modified CHARM.

Table 4 shows that 42–45% of NRP is explained by central government expenditure, 3% by net income inflow, 32–40% by exports. The remaining 16–20%



**Table 4. Total decomposed NRP across all regions**

(Unit: million yen)

	Central government expenditure on			Net income inflow as			Exports by				Income-independent expenditure	Total
		Investment	Consumption		Production-factor income	Social transfers in cash		Primary industry sectors	Tourism industry sectors	Other industry sectors		
LQ (component ratio)	453,801 45.0%	360,280 35.8%	93,521 9.3%	31,002 3.1%	− 6,447 − 0.6%	37,449 3.7%	324,524 32.2%	77,141 7.7%	91,855 9.1%	155,528 15.4%	198,208 19.7%	1,007,535 100.0%
modified CHARM (component ratio)	419,813 41.7%	335,616 33.3%	84,197 8.4%	25,102 2.5%	− 5,243 − 0.5%	30,344 3.0%	403,185 40.0%	74,023 7.3%	120,438 12.0%	208,724 20.7%	159,435 15.8%	1,007,535 100.0%

**Table 5. Industrial structure based on sectorial NRP share and its determinants<sup>1)</sup>**

	Sectorial NRP share of		Sectorial share of income induced in remote island by			
	Nation	Remote Island	Central government expenditure	Net income inflow	Exports	Income-independent expenditure
Primary industry	1.4%	6.5%	0.1%	0.8%	17.5%	0.8%
Manufacturing	17.5%	4.3%	1.0%	2.0%	9.5%	2.3%
Construction	6.4%	10.2%	15.5%	2.8%	1.5%	16.4%
Electricity, gas, and water supply	2.0%	3.4%	3.1%	3.2%	4.3%	2.6%
Commerce	16.8%	8.6%	2.9%	14.5%	11.6%	15.4%
Finance, insurance, and real estate <sup>3)</sup>	14.0%	12.3%	5.1%	32.8%	10.7%	29.7%
Transport, information, and communications	10.1%	8.9%	1.9%	5.4%	19.4%	5.3%
Public service	18.4%	33.9%	65.9%	21.7%	7.2%	12.0%
Other service	13.4%	11.7%	4.5%	16.9%	18.2%	15.5%

Note: 1) Average values obtained using IO tables estimated by LQ and modified CHARM.

2) Regarding industrial classification, refer to the note to Table 2.

3) The reason why finance, insurance, and real estate sector's share of NRP are large in remote islands, as well as in the nation, is the following. Imputed rental income for the house accounts share large part of the finance, insurance, and real estate sector's NRP, which is large in the remote islands, as well as in the nation.

can be attributed to income-independent expenditure, whose determinants cannot be identified in this model. Decomposing the NRP induced by the central government expenditure, we found that approximately 80% is induced by government consumption, and the rest by government investment. Decomposing the NRP induced by exports, approximately 50% is induced by

the primary industry<sup>23)</sup> and tourism industry.<sup>24)</sup>

## (2) Determinants of the industrial structure of remote island

Table 5 shows the industrial structure based on sectorial NRP shares and its driving factors. Comparing sectorial NRP shares between the remote island and the nation, one can find that the industrial

structure of the remote islands is specialized in primary industry, construction, and public service sectors. What determines the industrial structure? Let us look at which sector's income is induced by each factor. Central government expenditure produces income mainly in the construction and public service sectors. Exports produce income mainly through the primary industry sector and tourism industry sectors (including commerce, transport, and other service sectors). One can deduce that the industrial structure has been mainly determined by the central government expenditure to support regional economies, where their comparative advantage is restricted to the primary industry.

### (3) Determinants of income variation among regions

The data used in this analysis are the average values of the estimates obtained using IO tables estimated by LQ and modified CHARM.

Let us begin the analysis by looking at the variation of income induced by the size of the regional economy. In Figure 1, the bars show per capita income induced by income-independent expenditure, the polylines show income multipliers of each income inducing factor, an additional income induced by a unit increase in each factor. In Figure 1, the regions are positioned in ascending order with respect to their GRPs. One can find that, the smaller the region, the smaller the income induced by income-independent expenditure, and the smaller the income multipliers. The results imply that, the smaller the region, the larger the regional spill over.

Next, let us analyze the relation between NRP and its components, decomposed into its determinants. In Figure 2, the NRP per capita is decomposed into its determinants. In Table 6, the second column reports the correlation coefficients between per capita NRP and each of its components, decomposed into its determinants, and the third-to-last column shows the correlation matrix for the components.

First, as shown in the second column of Table 6, a positive moderate correlation can be found between

income induced by exports and NRP. Examining the relation in detail, income induced by tourism industry's exports has a moderate positive correlation with NRP ( $r = 0.517$ , with  $p$ -value = 0.003); however, income induced by primary industry's or other industries' exports has no significant correlation with NRP ( $r = -0.027$ , with  $p$ -value = 0.886, or  $r = 0.036$ , with  $p$ -value = 0.849). Thus, exports by tourism industry can be seen as a determinant of the income variation among regions, while exports by primary industry or other industries does not.

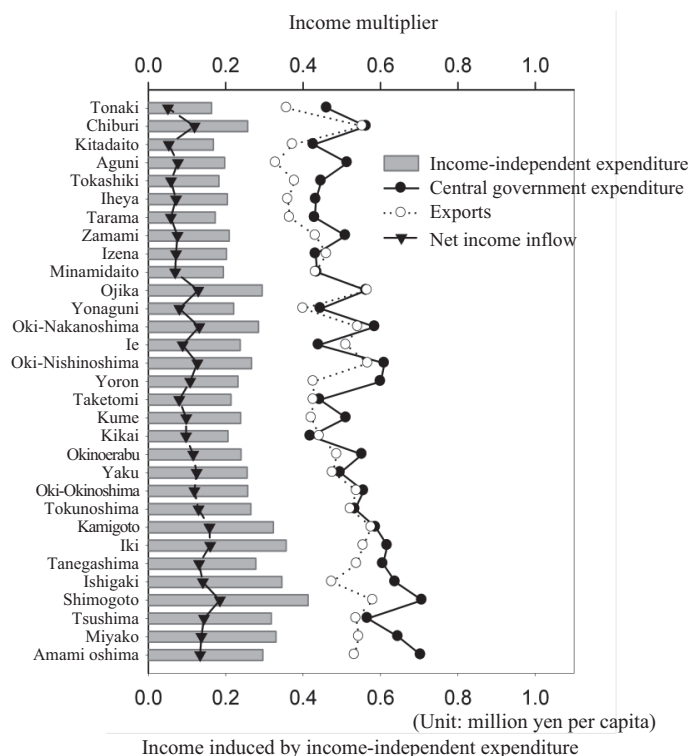
Second, a high positive correlation can be found between income induced by central government expenditure and NRP. It shows that central government expenditure is the most important income variation factor. Examining this relation in detail, it can be shown that a moderate positive correlation can be found between income induced by central government consumption and NRP ( $r = 0.563$ , with  $p$ -value = 0.001), and a stronger positive correlation can be found between income induced by central government investment and NRP ( $r = 0.684$ , with  $p$ -value = 0.000). Accordingly, central government investment is a more important determinant of the income variation among regions than central government consumption.

Third, a moderate negative correlation can be found between income induced by net income inflow and NRP. Let us consider the reasons by referring to the correlation matrix in Table 6. First, income induced by net income inflow has a moderate negative correlation with income induced by central government expenditure. Examining the relation in detail, it can be shown that income induced by net production-factor income inflow<sup>25)</sup> has a moderate negative correlation with income induced by central government consumption ( $r = -0.566$ , with  $p$ -value = 0.001). One can deduce that, the larger the central government consumption, the larger the production-factor inflows (such as employment inflows) into the region, and, accordingly, the larger the production-factor income spill over

23) The exports vector,  $E$ , in equation (20) is obtained in the following manner: Exports by primary industry sectors are allocated in the rows for each primary industry sector, and zeros are allocated in the remaining rows. The exports include primary industry products used as primary raw material by manufacturing sectors. Primary industry products produced in remote islands are often exported after being processed to save on transport costs. For example, sugarcane is exported after being processed into raw sugar. Therefore, exports of processed products can be attributed to the forward linkage effects of the production of the primary industry. Then, outputs of primary industry products used as primary raw material for exporting processed products are included.

24) The exports vector,  $E$ , in equation (20) is obtained in the following manner: Exports by tourism industry sectors are allocated in the rows for each tourism industry sector, and zeros are allocated in the remaining rows. The tourism industry sectors include retail trade, road passenger transport, coastal and inland water passenger transport, domestic air passenger transport, car rental and leasing, amusement and recreation, eating and drinking, and hotels.

25) Income induce by social transfers in cash inflow has no significant correlation with income induced by central government consumption ( $r = 0.195$ , with  $p$ -value = 0.292).



**Figure 1. Income induced by income-independent expenditure and income multipliers of each income inducing factor**

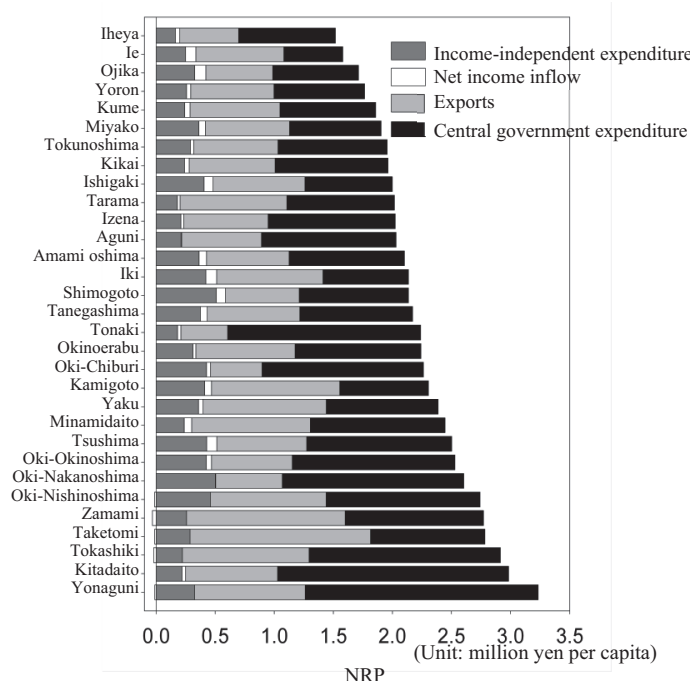
Note: Average values obtained using IO tables estimated by LQ and modified CHARM.

**Table 6. Correlation between NRP and its components decomposed into its determinants and correlation matrix of the components**

		NRP	Income induced by		
			Central government expenditure	Net income inflow	Exports
Income induced by	Central government expenditure	0.802**			
	Net income inflow	-0.573**	-0.561**		
	Exports	0.516**	-0.024	-0.406*	
	Income-independent expenditure	0.207	-0.027	0.287	-0.055

Note: 1) Average values obtained using IO tables estimated by LQ and modified CHARM.

2) The asterisks \*\* and \* indicate that the coefficients are statistically significant at the 1 and 5 percent level, respectively.



**Figure 2. NRP decomposed into its inducing factors**

Note: Average values obtained using IO tables estimated by LQ and modified CHARM.

from the region. Second, income induced by net income inflow has a moderate negative correlation with income induced by exports. Examining the relation in detail, it can be shown that income induced by net production-factor income inflow<sup>26)</sup> has a moderate negative correlation with income induced by tourism industry's exports ( $r = -0.428$ , with  $p$ -value = 0.016), while it has no significant correlation with income induced by primary industry's or other industries' exports ( $r = 0.231$ , with  $p$ -value = 0.210, or  $r = 0.015$ , with  $p$ -value = 0.935). One can deduce that, the larger the inbound tourism consumption, the larger the production-factor inflows (such as capital and labor inflow) into the region, and, accordingly, the larger the production-factor income spill over from the region. Regional income increases with additional central government consumption or inbound tourism consumption; however, not negligible share of the increased income outflows from the region, as it is balanced by the increase in production-factor inflows into the region.

## 6. Conclusion

This study constructed a Keynesian regional income determination model and showed that the net regional product (NRP, or income generated in the region) is determined by central government expenditure, net income inflow, exports, and income-independent private expenditure. This model is extended to an income determination model of a regional economy consisting of  $n$  types of industries, and this study proposed an approach to decompose NRP into its determinants using regional IO tables.

This model was applied to the analysis of remote island economies in Japan. The results are as follows. First, economic independence of the remote islands is difficult to achieve. The central government expenditure explains 42–45% of their NRP, and represents the most important income variation factor among regions, while the exports explain 32–40% of their NRP. Approximately 80% of the income produced by central government expenditure is induced by

26) Income induced by social transfers in cash inflow has no significant correlation with income induced by exports by primary industry, tourism industry, or other industries ( $r = -0.058$ , with  $p$ -value = 0.757;  $r = -0.278$ , with  $p$ -value = 0.131; or  $r = 0.206$ , with  $p$ -value = 0.267).

government consumption, suggesting that government consumption is the fundamental determinant of remote island economies. Government investment is more important than government consumption as an income variation factor among regions, which shows the effectiveness of public works projects as a measure to support regional economies. However, it is very likely that not negligible share of the income induced by central government expenditure would outflow from the region.

Second, export-based industries in remote islands are the primary industry and tourism industry, and account to approximately 50% of all exports induced income. Exports by the tourism industry can be seen as an income variation factor among regions, while exports by the primary industry cannot. Therefore, tourism has been deemed as a mean for the independence of remote island economies. However, it is very likely that not negligible share of the income induced by tourism would outflow from the region.

Third, the industrial structure of remote islands is specialized in primary industry, construction, and public service sectors, and has been mainly determined by the central government expenditure to support regional economies, since their comparative advantage is restricted to the primary industry.

This study proposed non-survey approaches to estimate competitive import type regional IO tables from prefectural tables. First, this study showed that the LQ approach requires two assumptions: (A) Among the sub-prefectural regions, the share of regional output of sector  $i$ 's product exported to outside the prefecture is consistent, and the share of imports from outside the prefecture in the regional demand for sector  $i$ 's product is also consistent; (B) There is no cross-hauling in interregional trade. Second, this study proposed a DSLQ, which compares the production capacity of sector  $i$ 's product relative to the demand for sector  $i$ 's product between a prefecture and the sub-prefectural regions, and showed that the estimates of exports and imports using LQs, except for the DSLQ, are biased. Third, this study also proposed a modified CHARM, which estimates trade flows under two assumptions: (A) Among the sub-prefectural regions, the share of regional output of sector  $i$ 's product exported to outside the prefecture is consistent, and the share of imports from outside the prefecture in the regional demand for sector  $i$ 's product is also consistent; (B) The share of cross-hauling in the trade volume of sector  $i$ 's product is equivalent in interregional trade and trade between the prefecture and outside the prefecture.

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