Construction of a Multi-region Waste Input-Output Table

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Abstract - We constructed a multi-region waste input-output (WIO) table for the 47 prefectures in Japan using a multi-region IO table of goods and services (Hasegawa et al., 2011) and interregional waste-shipment data provided by the Ministry of the Environment of Japan (2006, 2008). Internal disparities in are a crucial issue in most countries, particularly when they affect the economy and environment, such as CO_2 emissions and waste production, treatment, transportation and disposal. Unfortunately, the number of regions considered in most IO analyses has sometimes been insufficient for investigating emissions-related problems in sufficient detail. For example, in a case study conducted in Tokyo, Japan, Tsukui et al. (2011) showed that the positive economic effect associated with consumption by the metropolitan region was outweighed by the negative effect in terms of emissions produced by the corresponding regions in other regions. Interestingly, using a two-region interregional waste IO table, these authors were unable to accurately quantify the extent to which the consumption in Tokyo impacted upon the corresponding regions. The purpose of this study was therefore to clarify the relationship between different domestic regions. Not only is the method used to construct the WIO table explained, but the interregional dependency between the production of commodities and treatment of waste is empirically examined using the table.

Keywords: Interregional waste input-output, Regional waste input-output

1. Introduction

The total land area of the Japanese archipelago is 377,950 km^2. The islands, which extend along a 3,200 km northwest-southeast arc from 20 to 45°N and 122 to 153°E, are climatically, topographically, and economically diverse. As a consequence of this diversity, the circumstances surrounding the treatment and transportation of waste differ markedly between different regions. In Japan, the functional unit of these regions is the prefecture. Each prefecture has a local government, which is responsible for developing, promulgating and administering and waste treatment policy in a given jurisdiction.

The aim of this study was to compile a multi-region waste input-output (WIO) table for the 47 prefectures in Japan and to estimate the impacts that regional changes in final consumption have on the waste treatment and recycling activities of other regions. However, with a population of approximately 128 million people in 2010, compiling a 47-area WIO table for Japan would require a considerably detailed regional analysis. What, therefore, would be the advantage of compiling such a detailed table?

Kagawa et al. (2007) investigated the spatial repercussion effects of regional waste management using a nine-region WIO table, where each of the nine regions was defined by the Ministry of the Economy, Trade and Industry (METI) of Japan; essentially, these regions consisted of prefectures that shared a close relationship, either with respect to economic activity or geographical proximity. However, Tsukui (2009) found that some of the prefectures within these regions differed markedly from other prefectures in the same group, although diversity within an group is not negligible. For example, the “Kyushu” region, which is one of the nine regions defined by the METI classification, accepts large amounts of waste from other regions. However, detailed analysis by Tsukui (2009) found that, of the prefectures in the region, Fukuoka Prefecture accepts approximately 74.5% of all the waste imported into the region from other regions in the country; the other six prefectures constituting the Kyushu region accept relatively little waste from other regions. Hasegawa et al. (2011) also found that the extent of carbon leakage (i.e., an increase in carbon emissions in one region as an indirect or unintended consequence of emission reduction measures implemented in another region") is not the same in prefectures that are in close proximity to each other. We are concerned that the resolution of the nine-region WIO table is not sufficient for investigating the various environmental issues that exist between regions; specifically, waste transportation, waste treatment, and the emission of carbon dioxide. We therefore sought to extend the utility of existing WIO tables by compiling a multi-region WIO table for 47 prefectures.

2. Model

Table 1 shows the basic structure of the interregional waste input–output (IR-WIO) table for the 47 prefectures in Japan that was compiled in this study. The table is essentially an expansion of a conventional multi-region model (Isard, 1951) and a WIO model (Nakamura et al., 2002). For simplicity, only three regions are depicted in Table 1.

The superscripts denote the region, $r, s \in \{1, 2, \cdots, 47\}$, $x_{\mathrm{I,I}}^{\mathrm{rs}}$ denotes the transaction value between industries, $w_{\mathrm{I}}^{\mathrm{rs}}$ denotes the amount of waste produced by industrial sectors, $\mathrm{F_I}^{\mathrm{rs}}$ and $\mathrm{F_w}^{\mathrm{rs}}$ denote vectors for the sum of the final demand across industrial sectors and the amount of waste derived from final demand sectors, respectively. V is a vector denoting the value-added sector, E and M are vectors denoting the sum of exports and imports, respectively. $\mathrm{X_I}^{\mathrm{r}}$ denotes the vector for the production value, and W^{r} denotes a vector for the amount of treatment.

			Inputs: Region A (1 … n_x)	Inputs: Region B (1 … n_x)	Inputs: Region C (1 … n_x)	Final demand: Region A	Final demand: Region B	Final demand: Region C	Exports	Production value or amount of treatment
Inputs	Region A	1 … n_x	$\boldsymbol{x}_{I,I}^{11}$	$\boldsymbol{x}_{I,I}^{12}$	$\boldsymbol{x}_{I,I}^{13}$	$\boldsymbol{F}_{I}^{11}$	$\boldsymbol{F}_{I}^{12}$	$\boldsymbol{F}_{I}^{13}$	$\boldsymbol{E}_{I}^{11}$	$\boldsymbol{X}_{I}^{1}$
	Region B	1 … n_x	$\boldsymbol{x}_{I,I}^{21}$	$\boldsymbol{x}_{I,I}^{22}$	$\boldsymbol{x}_{I,I}^{23}$	$\boldsymbol{F}_{I}^{21}$	$\boldsymbol{F}_{I}^{22}$	$\boldsymbol{F}_{I}^{23}$	$\boldsymbol{E}_{I}^{21}$	$\boldsymbol{X}_{I}^{2}$
	Region C	1 … n_x	$\boldsymbol{x}_{I,I}^{31}$	$\boldsymbol{x}_{I,I}^{32}$	$\boldsymbol{x}_{I,I}^{33}$	$\boldsymbol{F}_{I}^{31}$	$\boldsymbol{F}_{I}^{32}$	$\boldsymbol{F}_{I}^{33}$	$\boldsymbol{E}_{I}^{31}$	$\boldsymbol{X}_{I}^{3}$
Waste emissions	Region A	1 … n_w	$\boldsymbol{w}_{I}^{11}$	$\boldsymbol{w}_{I}^{12}$	$\boldsymbol{w}_{I}^{13}$	$\boldsymbol{F}_{w}^{11}$	$\boldsymbol{F}_{w}^{12}$	$\boldsymbol{F}_{w}^{13}$	$-\boldsymbol{E}_{w}^{1}$	$\boldsymbol{W}^{1}$
	Region B	1 … n_w	$\boldsymbol{w}_{I}^{21}$	$\boldsymbol{w}_{I}^{22}$	$\boldsymbol{w}_{I}^{23}$	$\boldsymbol{F}_{w}^{21}$	$\boldsymbol{F}_{w}^{22}$	$\boldsymbol{F}_{w}^{23}$	$-\boldsymbol{E}_{w}^{2}$	$\boldsymbol{W}^{2}$
	Region C	1 … n_w	$\boldsymbol{w}_{I}^{31}$	$\boldsymbol{w}_{I}^{32}$	$\boldsymbol{w}_{I}^{33}$	$\boldsymbol{F}_{w}^{31}$	$\boldsymbol{F}_{w}^{32}$	$\boldsymbol{F}_{w}^{33}$	$-\boldsymbol{E}_{w}^{3}$	$\boldsymbol{W}^{3}$
Imports			$\boldsymbol{M}_{I}^{1}$	$\boldsymbol{M}_{I}^{2}$	$\boldsymbol{M}_{I3}$	$\boldsymbol{M}_{F}^{1}$	$\boldsymbol{M}_{F}^{2}$	$\boldsymbol{M}_{F}^{3}$		
Value added			$\boldsymbol{V}_{I}^{1}$	$\boldsymbol{V}_{I}^{2}$	$\boldsymbol{V}_{I3}$					
Production value or amount of treatment			$\boldsymbol{X}_{I}^{1}$	$\boldsymbol{X}_{I}^{2}$	$\boldsymbol{X}_{I}^{3}$					

Table 1. Generalized framework of the multi-region waste input-output table employed in this study

3 Data and system characteristics of waste treatment in Japan

3.1 The waste treatment system in Japan

The waste treatment policies employed in Japan are strongly connected to the local governments of prefectures. In Japan, waste is essentially classified into ‘industrial waste’ and ‘general waste’. The amount of industrial waste produced in Japan in 2007 was 419.4 million tons per year, which is approximately nine times larger than the 48.1 million tons of general waste produced in the same year (MOE, 2008). The disposal of industrial waste is thus a very important policy issue in Japan.

In this study, the industrial waste produced by the industrial sector was categorized into the 19 categories shown in Table 2; these categories are based on the related laws for waste treatment. In Japan, while most industrial wastes are treated by private companies, the activities of these companies are supervised by the local governments of corresponding prefecture. The outlook of industrial waste treatment is planned by the prefectural government and the private waste treatment companies then follow these plans. Companies that wish to undertake the treatment or transportation of industrial waste need to attend a lecture offered by prefectural governments, apply for a waste treatment license, and receive authorization from the local government of each prefecture. This authorization must be renewed periodically after a specified period and the waste treatment companies are required to report their activities to the relevant local government authorities. Indeed, most of the statistical data published on industrial waste in Japan is based on these reports, which are collected by local government before being edited and published by the Ministry of the Environment (MOE).

Table 2. Classification of industrial waste in Japan

1	Cinders	11	Waste rubber
2	Sludge	12	Metal scraps
3	Waste oil	13	Waste glass and ceramics
4	Waste acid	14	Slag
5	Waste alkali	15	Construction wastes
6	Waste plastics	16	Livestock excreta
7	Waste paper	17	Livestock corpses
8	Wood waste	18	Dust
9	Fibre waste		
10	Animal & vegetable residue		

General waste is typically treated by the municipalities within each prefecture. Although some municipalities may subcontract private waste treatment companies to perform this service, permission needs to be obtained from the relevant municipal authorities. In Japan, jurisdiction over industrial waste and general waste is completely separate. General waste is classified into ‘household waste’ and ‘business waste’, the categories of which are shown in Table 3. However, unlike industrial waste, the categories for general waste are not defined by the law. Rather, the difference between household waste and business waste is not a property of the waste itself, but simply a difference in the source of emissions themselves; the former is from households and the latter is from business offices.

Within the context of the WIO framework, industrial waste and business waste are produced by the industrial sector, while household wastes are produced by the final demand sectors. Thus, in Table 1, w_I^{rs} corresponds to industrial waste and business waste, and F_w^{rs} corresponds to household waste.

Table 3. Classification of general waste in Japan

Household waste		Business waste
Food waste	Returnable bottles	Food waste
Old newspapers	One-way bottles & cullet	Old newspapers & magazines
Old magazines	Other waste glass	Waste cardboard
Waste cardboard	Waste ceramics	Waste quality paper
Paper drink boxes	Waste rubber & leather	Other waste paper
Paper boxes, bags & packages	Waste vegetation	Waste textiles
Other waste paper	Bulky textiles	PET bottles
Waste textiles	Wooden furniture	Waste polystyrene foam
PET bottles	Bicycles & ovens	Other waste plastics
Other plastic bottles	Small electric appliances	Steel cans
Plastic containers, cusp & trays	TV sets	Aluminum cans
Plastic bags, sheets & packages	Refrigerators	Other waste metals
Other plastics article	Washing machines	Returnable bottles
Steel cans	Air conditioners	One way bottles
Aluminum cans	Automobiles	Other waste glass
Other iron scraps		Waste vegetation
Other non-ferrous scraps		Other business waste

3.2 Importance of producing a WIO table for the 47 prefectures in Japan

The multi-region WIO table produced as part of this study for the 47 prefectures in Japan was based on following statistical data. Data for the goods and services sectors are based on the 2005 multi-region IO table for the 47 Japanese prefectures compiled by Hasegawa et al. (2011). The emissions of wastes from industrial sectors are based on “Survey of waste emission and treatment in 2005” which was published in March 2008 by the MOE, Japan. In addition to the amounts of wastes produced by prefecture, industrial sector, and waste classification, the report also examined the rates of recycling by prefecture and by waste classification, which can in turn be utilized to estimate the amount of industrial waste that was recycled. To estimate waste transportation, we referred to “Survey of waste recycling and regional movement in 2005” (MOE, 2006). To obtain estimates for general waste, we adopted the estimation model of Habara et al. (2002). Household waste was estimated by multiplying the population by the amount of household wastes produced per capita. Business waste was estimated by multiplying the number of people on payrolls by the amount of business wastes produced per capita for each type of businesses.

4. Results and discussion

In this study, we assessed the value of compiling a multi-region WIO table for the 47 prefectures of Japan. As mentioned above, Kagawa et al. (2007) previously employed a WIO approach to examine the impact of household consumption on CO_2 and waste production for nine regions in Japan. However, given that the prefectures constituting a region could differ from each other in some way (e.g. production amount or production of wastes), then a framework consisting of only nine regions would be insufficient.

Table 4. Relationship between the nine regions and 47 prefectures of Japan

Region no.	Region name	Prefecture
1	Hokkaido	Hokkaido
2	Tohoku	Aomori, Iwate, Miyagi, Akita, Yamagata, Fukushima
3	Kanto	Ibaraki, Tochigi, Gunma, Saitama, Chiba, Tokyo, Kanagawa, Niigata, Yamanashi, Nagano, Shizuoka
4	Chubu	Toyama, Ishikawa, Gifu, Aichi, Mie
5	Kinki	Fukui, Shiga, Kyoto, Osaka, Hyogo, Nara, Wakayama
6	Chugoku	Tottori, Shimane, Okayama, Hiroshima, Yamaguchi
7	Shikoku	Tokushima, Kagawa, Ehime, Kochi
8	Kyushu	Fukuoka, Saga, Nagasaki, Kumamoto, Oita, Miyazaki, Kagoshima
9	Okinawa	Okinawa

Figure 1 and Figure 2 show the production values and amounts of industrial waste of the 47 prefectures, respectively. The blue boxes represent the nine geographic regions defined by METI, Japan, and which are listed in Table 4. The figures show that the economic and waste emission characteristics of individual prefectures differed from each other, even within the same region. Further, Figure 1 also shows that the economic activities of the nine regions also differed from each other; for example, the average production values for regions 2, 6, and 7 were slightly lower than those of the other regions. Region 3 was the most economically important.

Within the context of waste emissions, Hokkaido Prefecture, which has a very well established livestock industry, produced the most waste. Specifically, at 19.4 million tons, the value of the 'livestock excreta' waste category was the highest of all of the prefectures listed in Table 2.

Given that the amount of waste emissions are generally proportional to economic activity, the economic characteristics of each prefecture could be inferred by standardizing the waste emissions shown in Figure 2 by dividing the amount of waste produced by the production values shown in Figure 1. The red lines in Figure 3 represent the standardized waste production values obtained for each region. We also found that the standard deviation for Region 8 was the largest among Regions 2 to 8. Region 3 and Region 5, both of which are economically important regions in Japan, also exhibited marked differences in the standardized waste production values of their constituent prefectures. These findings implied that each prefecture has unique characteristics that do not always lend themselves well to the regional classification summarized in Table 4. We therefore propose that future investigations employing this multi-region WIO table for the 47 prefectures will highlight interesting and high-resolution data related to the characteristics and relationships between the different regions of Japan.

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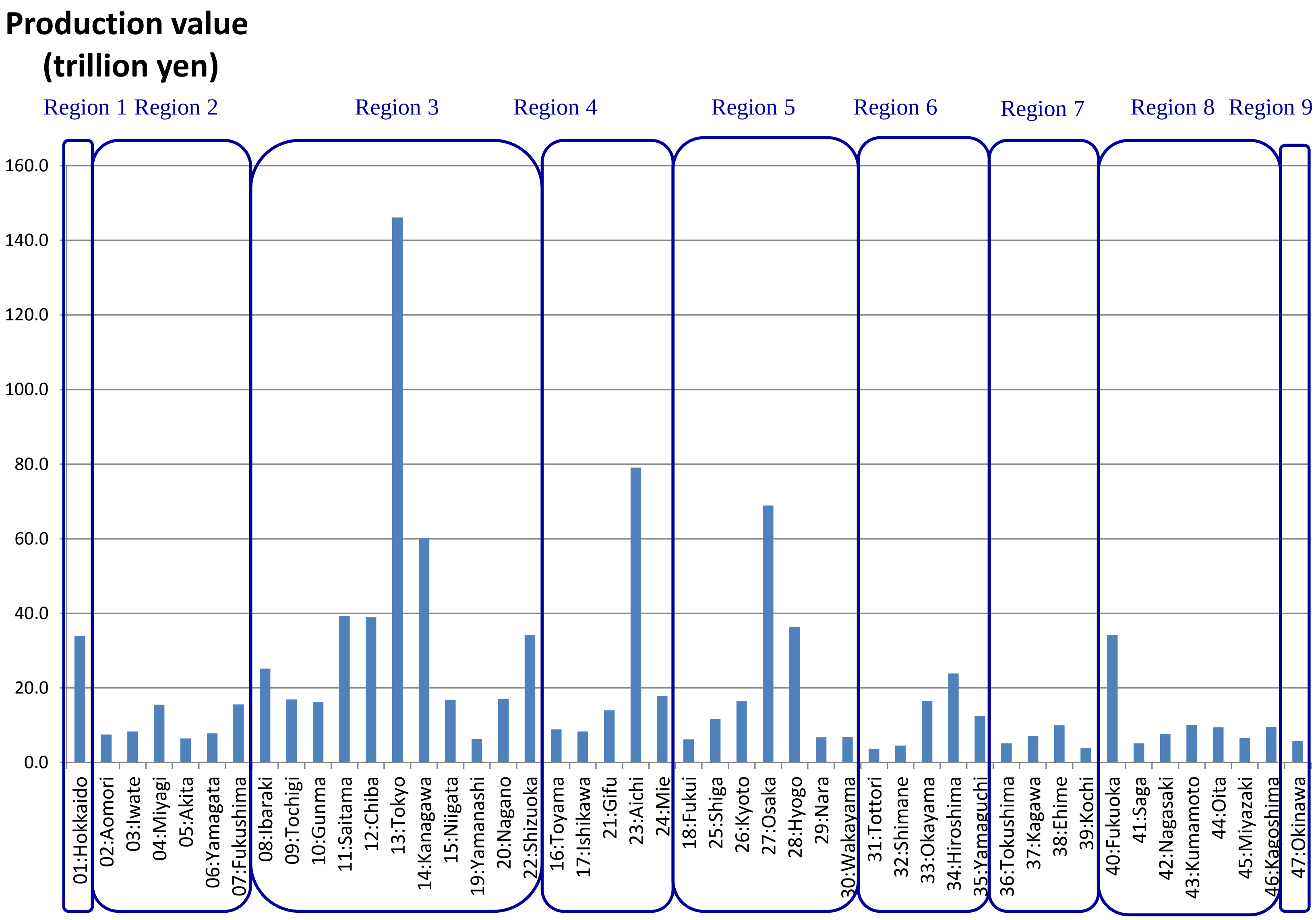

Figure 1. Production values for the 47 prefectures of Japan (A)

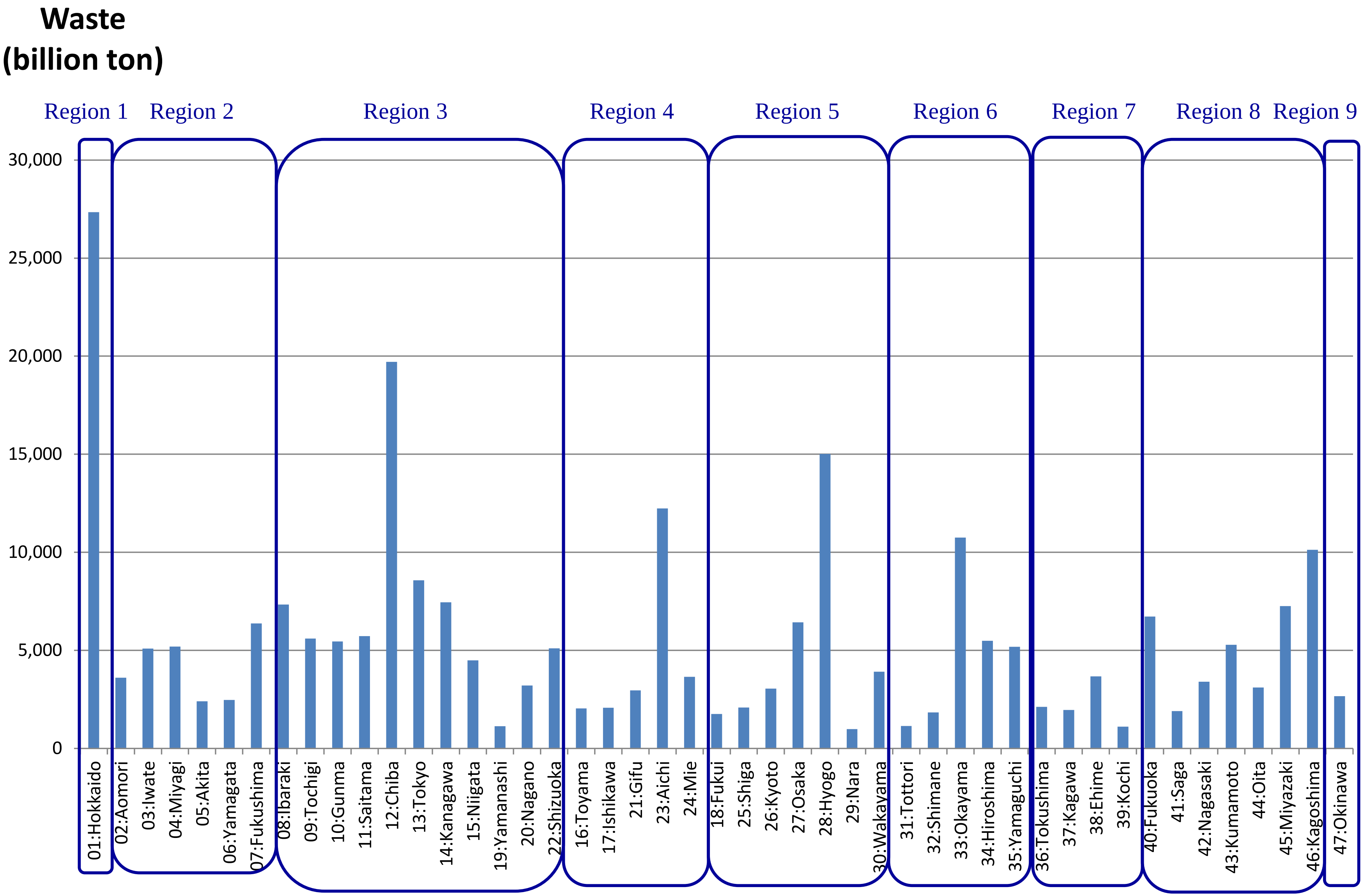

Figure 2. Industrial waste produced by the 47 prefectures of Japan (B)

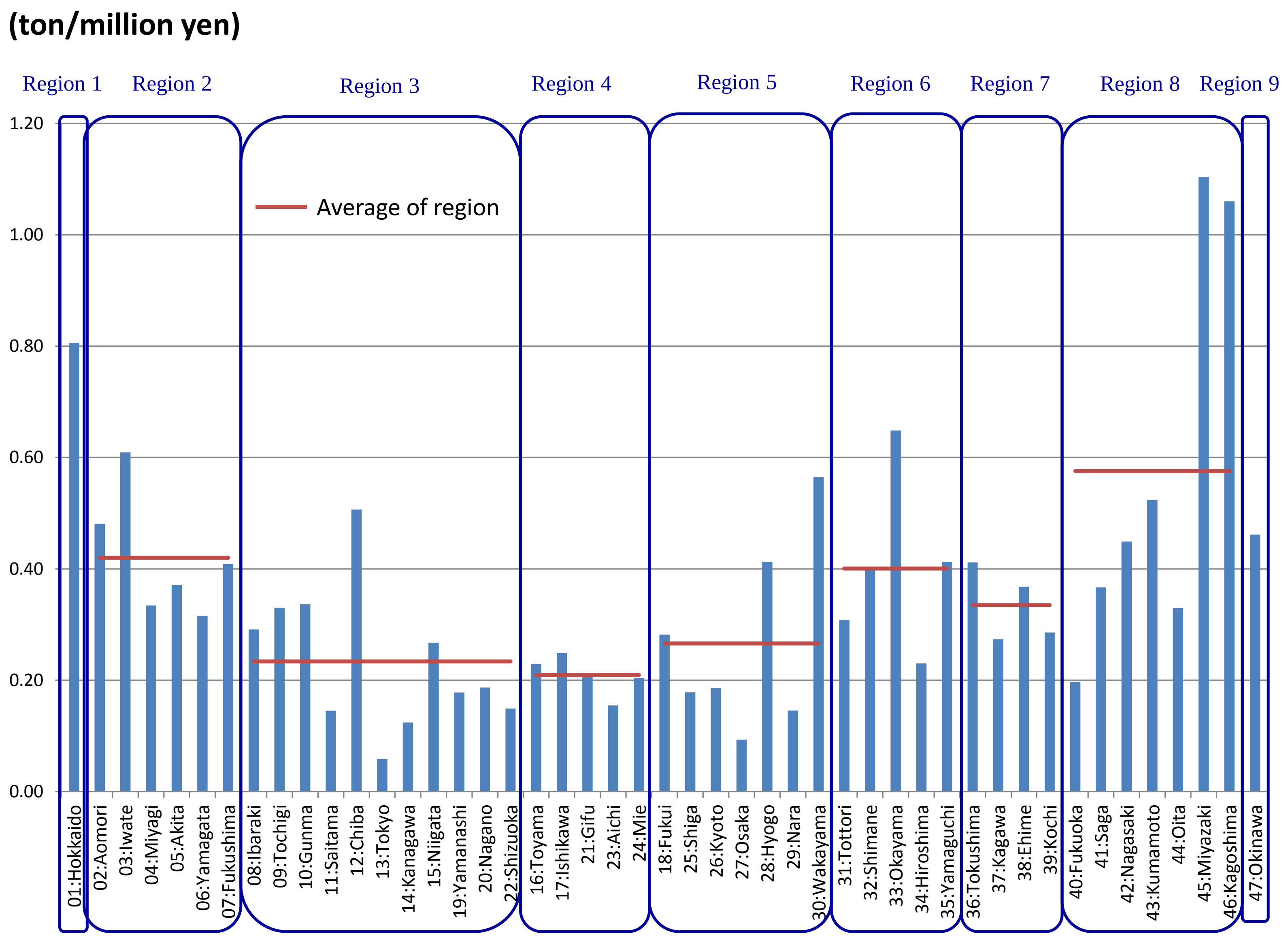

Figure 3. Industrial waste produced as divided by production value (B/A)