# Regional Inflation and Consumption Behaviors

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**Abstract**

This paper analyzes empirically interaction between the inflation rates across regions using consumption data on services and the geographical location of regions in Japan. The service sector has been expanding rapidly in terms of its contribution to the total economic activity in advanced countries, and further demographic changes have accelerated its speed in Japan over recent decades. After providing a theoretical relationship between regional inflation and consumption of non-tradable goods, we find evidence that different consumption patterns of services across regions explain heterogeneity in regional inflation in Japan.

**Keywords:** Regional inflation, non-tradable goods, services, demographic changes, spatial models.
**JEL classification:** F3, R1, E3

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# 1 Introduction

Since Cassel (1918) introduced the purchasing power parity (PPP) theory linking exchange rates and prices, the PPP remains an important economic theory in international finance; therefore, numerous researchers have analyzed it using international data.[1] Other than such an international implication, the PPP suggests the equalization of prices or inflation in monetary unions where there is a common currency.[2] Thus, it has also drawn the interest of experts in the field of regional economics focusing on deviations in regional prices (inflation rates) within a country (e.g., Engel and Rogers (1996), European Central Bank (2003), Esaka (2003), Chen (2004), Vaona and Ascari (2012)). A surge in interest in this area has been reinforced by the introduction of the euro in 1999 which created a single currency area by combining a number of European countries where inflation rates would be expected to be homogenous as stated in the Maastricht treaty (1992). However, the recent financial crises (the Greek and European debt crises (2009–)) have highlighted heterogeneity in euro member countries and a paucity of regional convergence, and thus provided opportunities to question the homogeneity assumption depicted in the Maastricht treaty.

In fact, there is a lot of empirical evidence against the PPP from international and regional data (see Bahmani-Oskooee and Nasir (2005), European Central Bank (2003), Chen (2004)). By the same token, there are also a number of theoretical explanations for the violation of the PPP. Apart from the classic reasons such as the presence of trade impediments (e.g., Dumas (1992)), productivity differentials between regions may cause heterogeneity in regional prices, known as the Balassa-Samuelson (BS) effect (Balassa (1964), Samuelson (1964)) in international finance literature. According to them, the real exchange rate of a country with higher productivity will appreciate over time due to relatively more increases in prices and wages in her non-tradable sector than other countries. For intra-country analysis, this implies increased deviations in the relative

[1] See, for example, Rogoff (1996) for a survey of previous studies on the PPP.

[2] The equalization of factor prices is also inferred from international trade theories such as the Heckshcer (1919).

price.

Against this background, we shall analyze the PPP using regional data from Japan. Due to her homogeneity in many respects, by international standards, which allows researchers to focus only on economic factors preventing from price equality, a number of studies have been carried out over the past decade and have confirmed regional heterogeneity using comprehensive price data, i.e., CPI, (e.g., Esaka (2003), Nagayasu and Inakura (2009), Ikeno (2014)).[3] Previous research related to the BS puzzle has often used price data; for example, the wholesale price index as a proxy for prices for tradables and the consumer price index as a proxy for prices for non-tradables. Unlike previous studies, we analyze consumption behaviors because Japanese consumption data allow us to distinguish more clearly between tradable and non-tradable components, which is impossible using the price data available to researchers.

In addition, the recent surge in interest in the non-tradable sector has been attributable to the increased contribution of this sector to the overall economic activity in advanced countries (see Section 2). Among related topics, the Japan Cabinet Office (2005) summarizes the recent consumption trend where services have been increasing across all generations, but in particular pensioners, whose expenditures on services such as medical expenses, travel and socializing have increased rapidly. Those retirees' consumption behaviors also have international implications. The recent reduction in the Japanese savings ratio, which has been strongly linked with the worsening Japanese trade balance, has been discussed as being due, in part, to the increased expenditure of retirees paid for from their savings (Horioka (2010)).

The second distinguishing feature of this paper is the investigation of spillovers of the BS effect. While recognizing a region affected by other regions, there has been a tendency to ignore this effect in previous studies.[4] The non-tradable consumption behaviors in one region are expected to affect those in others, and furthermore consumption behaviors in

[3]In this connection, this study is also related to another well-known unresolved problem in international finance (the Buckus-Smith puzzle)–the poor correlation between consumption and the real exchange rate in the international context.

[4]Exceptions are, for example, Ikeno (2014) analyzing regional dependence in the relative price.

neighboring regions may influence those at home. We attempt to study these spillover effects by estimating spatial models which have become increasingly popular in economic research.

## 2 Economic Theory

Here we shall briefly explain the PPP (Balassa (1964), Samuelson (1964)) and extend it by introducing the consumption behaviors of economic agents into the model. As mentioned, recognition of the non-tradable sector is one important element in the BS theorem as an explanation for real exchange rate appreciation. They assume that the PPP holds only in the tradable sector and argue that productivity improvements occurring in the tradable sector will eventually lead to wage increases in both tradable and non-tradable sectors in the country. This will bring about higher inflation there, and as a consequence a country with higher productivity will experience appreciation in its real exchange rate. Therefore, the BS theorem is often used in the global context to explain a failure of the PPP, especially for fast-growing countries (e.g., Japan in the 1960s to 70s and the South East Asian countries).

Following Balassa and Samuelson's general framework, but adjusting it for intra-country analyses, we analyze Japanese regions which confront the socio-economic problems of an ageing society. First, we assume that there are home and other regions in the world, and the overall price ($P$) can be decomposed to tradable ($P_T$) and non-tradable ($P_N$) prices as:

$$P = P_T^{\alpha} P_N^{1-\alpha} \tag{1}$$

where $0 < \alpha < 1$ represents a share of the tradable sector in the overall price, and the subscripts ($T$ and $N$) represent the tradable and non-tradable sectors respectively. We assume the same expression would also hold in other regions.

The real exchange rate ($Q$) becomes identical to the relative price in the analysis of intra-country analysis where the same currency is used. Then according to the BS theorem, the real exchange rate ($Q$), or the relative price, can be expressed using Eq. (1) as:

$$Q = \frac{P^*}{P} = \left(\frac{P_N^*}{P_N}\right)^{1-\alpha} \tag{2}$$

where the asterisk indicates a variable for other regions. The BS theorem assumes that the PPP holds only in the tradable sector and thus we have used $P_T = P_T^*$ in order to derive Eq. (2). This equation asserts that $Q$ will decline in response to increases in the domestic price.

Now, let us explain the consumption behaviors of economic agents, and consider a representative agent who maximizes the following constant-elasticity-of-substitution (CES) function:

$$\left[\gamma^{\frac{1}{\vartheta}} C_T^{\frac{\vartheta-1}{\vartheta}} + (1-\gamma)^{\frac{1}{\vartheta}} C_N^{\frac{\vartheta-1}{\vartheta}}\right]^{\frac{\vartheta}{\vartheta-1}} \tag{3}$$

where $0 < \gamma < 1$ shows a share of tradable goods consumed by an agent. The $\vartheta > 0$ shows the elasticity of substitution between tradable ($C_T$) and non-tradable ($C_N$) goods consumption, and when $\vartheta \to 1$, this becomes analogous to the Cobb-Double function.

Assume that in each period an agent maximizes Eq. (3) for consumption given the linear constraints imposed by the total expenditure ($Y$) : $Y = C_T + \delta C_N$, where $\delta$ is the relative price of nontradable goods to tradable goods.

$$\frac{1-\gamma}{\gamma}\frac{C_T}{C_N} = \delta^{\theta} \tag{4}$$

These expressions are also presented in Obstfeld and Rogoff (1996). We extend it to include analysis of the relative price and consumption: using Eqs. (2) and (4), the relative price can be expressed in terms of consumption of tradable and non-tradable goods.

$$\frac{P^*}{P} = \left(\frac{P_N^*}{P_N}\right)^{1-\alpha} = \left(\frac{\frac{P_N^*}{P_T^*}}{\frac{P_N}{P_T}}\right)^{1-\alpha} = \left[\frac{\delta^*}{\delta}\right]^{1-\alpha} \tag{5}$$

In order to derive Eq. (5), we have again assumed that the PPP holds only in the tradable, but not in the non-tradable sector, consistent with the BS theorem. Further, to be in line with a spatial panel model specification for regions ($i$ = 1,..., $N$) and time ($t = 1, ..., T$), the statistical model equivalent to Eq. (5) can be expressed using Eq. (4) as:

$$\ln P_{it} = \beta_0 + \beta_1 \ln P_{it}^* + \beta_2 \ln \left(\frac{C_T}{C_N}\right)_{it} + \beta_3 \ln \left(\frac{C_T^*}{C_N^*}\right)_{it} + u_{it} \tag{6}$$

The residual ($u_{it}$) is distributed normally with zero mean: $u_{it} \sim N(0, \sigma^2)$, and $\beta$s are parameters to be estimated by the data, with theoretical predictions of $\beta_1 > 0$ and $\beta_2 > 0$ and $\beta_3 < 0$. These parameters can be interpreted as follows; for example, increases in non-tradable goods consumption at home will decrease the relative consumption ($C_T/C_N$) and the relative price ($\delta$) (through Eq. (4)), other things being constant. This will in turn reduce $P$ (Eq. (5)), and therefore consumption of non-tradable goods is negatively correlated with the overall price at home. (Note that this implies that there is a positive relationship between $P$ and the relative consumption at home.) Following the same logic, changes in non-tradable goods in neighboring regions will have a positive effect on the home price. We can interpret Eq. (6) in the same manner, and obviously, when the PPP holds, we expect that $\beta_1 = 1$ and $\beta_2 = \beta_3 = 0$, indicating equality in regional prices.[5]

We shall estimate the following inflation equation, which can be obtained by differencing Eq. (6), and thus the parameter signs are expected to remain the same as those in Eq. (6)

$$\Delta \ln P_{it} = \beta_0 + \beta_1 \Delta \ln P_{it}^* + \beta_2 \Delta \ln \left(\frac{C_T}{C_N}\right)_{it} + \beta_3 \Delta \ln \left(\frac{C_T^*}{C_N^*}\right)_{it} + e_{it} \tag{7}$$

[5] Therefore, our definition of the consumption ratio differs from the one used by Backus and Smith (1993) who predicted a positive relationship between the real exchange rate and the relative consumption ratio between countries.

where $\Delta$ is the difference operator, and our inflation is defined as the annual rate.

Consistent with Balassa (1964), we assume that the services are non-tradable in the subsequent study. However, unlike previous studies using price data which assumed that there are non-tradable components only in the service sector, our data set allows us to collect service items from all economic sectors, including the manufacturing sector which has often been assumed to be a 100% tradable sector in previous studies. Thus our data must be more appropriate for assessing the BS effect than the price data disseminated to the public.

As reviewed in Section 1, the consideration of the service sector has been recognized as increasingly important in explaining the real exchange rate or the relative price, and there are a number of studies using international and/or regional data often providing empirical evidence against the PPP. Furthermore, services have been discussed as important due to the number of retired people which has increased over recent decades, in Japan which has experienced rapid demographic change. Different spending patterns at different life stages are reported in the US (e.g., Danziger, et. al. (1982), Abdel-Ghany and Sharpe (1997)). Similarly partly because of the reduction in wages and salaries after retirement, the average propensity to consume is quite high for those aged more than 55 years old in Japan (Japan Center for Economic Research (2011)).

Furthermore, according to a 2014 survey by Dentsu (`http://www.dentsu.co.jp/`) conducted to understand the activities of the elderly (i.e. 65 years old and above) 39% of respondents answered that, among various types of expenditure, travelling with a spouse was the most popular activity, followed by physical exercise (22%). Similarly, the Japan Center for Economic Research (2011) made a prediction of economic activity through 2020, and concluded that, despite a low birthrate, people are expected to spend more on education by sending children to private school and cram schools, which can both be regarded as non-tradable goods. Interestingly, food expenditure is expected to shrink due to the smaller number of young people although there will be higher demand for eating out and for ready-meals.

The importance of services can be understood by looking at their proportion out of the total production for each economic sector. As can be seen from Table 1 which classifies economic activities into 13 sectors, the service-related economic activities ($\approx$ the service activities + producers of government services + producers of private non-profit services to households) account for nearly 30% of the total economic activity in 2012. It follows that the assumption of no non-tradable goods, as in the PPP, does not hold in the real world.[6]

# 3 Data

Our data on prices and consumption cover the period 2000M1-2015M3 for 47 regions (or prefectures). This is the period when the Japanese economic recovery remained weak after the financial crises in Southeast Asia and the banking crisis in Japan where banks suffered from non-performing loans. Indeed, Japan experienced deflation during this period as will be shown later, and it is only in 2014/15 when there are signs of economic recovery. The beginning of our analysis is determined by the availability of consumption data, and our data set comprises a total of 8,601 observations ($= 183 \times 47$).

The price data are based on the Consumer Price Index (CPI, 2010 = 100) and are obtained from the Ministry of Internal Affairs and Communication (MIAC), Japan. Table 2 summarizes the basic statistics of the CPI for all regions, and Figure 1 plots the average value of regional CPIs. This figure shows that while there is a price recovery after the Lehman Shock (2008) and over recent periods when the Abeno-mix policy has been implemented, Japan experienced deflation on many occasions during our sample period. Furthermore, from Table 2 price levels appear to be more or less the same across regions, but Table 3 confirms the heterogeneity in regional prices using statistical tests by rejecting strongly the null hypothesis of price equality. This is consistent with Nagayasu (2011) who shows that regional inflation is indeed different.

[6]In contrast, the agriculture, forestry and fishing sector – one important area for debate for deciding participation in the Free Trade Agreement known as the Trans-Pacific Partnership – accounts for only 1% of the total economic activity.

Consumption data are obtained from the Family Income and Expenditure Survey (FIES), also compiled by MIAC. Each survey covers 168 cities and villages with more than 8,000 households for families of two or more members and 600 for single person households. The probability of households being chosen for the survey differs among regions, ranging from about 1/5,500 for the main areas (Ku) in Tokyo to 1/500 elsewhere. The surveyed households are chosen so that over time they are not selected more than once. Across several frequencies, monthly survey data contain consumption data per capita expressed in yen and are available from 2000M1 for households with two or more members. Thus this data set possesses sufficient observations, focusing on a period of a weak economy, to conduct sensible statistical analyses.

The consumption data are further disaggregated into durable, semi-durable, non-durable and service components. The non-durable goods are expected to be consumed within a year. The durable and semi-durable goods are expected to last more than one year, and the former are more expensive items than the latter. Some goods do not have such disaggregated classifications, such as the durable goods in the food category, due to the characteristics of the food products. Table 4 classifies consumption goods into 1) food, 2) housing, 3) furniture & household utensils, 4) clothing & footwear, 5) medical care, 6) transportation & communication, 7) education, 8) culture & recreation, and 9) other consumption expenditures. Notably, all these consumption items contain services, and Figure 2 shows that the consumption ratio is quite volatile over time.

# 4 Empirics

## 4.1 Preliminary investigation

The conventional spatial models have been developed under a condition of stationary data. In this connection, we use three types of popular panel unit root tests (Levin, Liu and Chu (2002), Harris and Tzayalis (1999), and Choi (2001)) in order to analyze the null hypothesis that panels follow a unit root process. For the former, the cross-sectional average has been removed before the estimation since this test has been developed with an assumption of cross-sectional independence. Further, Choi's test has been presented in several forms of Fisher's test in Table 5.

Given that the prices are often found to be integrated of order one ($I(1)$) which motivated many researchers to investigate the PPP in the co-integration framework (see Rogoff (1996)), we have applied these tests to data on changes in prices (i.e., inflation) and in the consumption ratio. The test results show evidence that both data are stationary (Table 5) and ensure that we can obtain statistically reliable estimates using the conventional spatial model. The former result on stationary inflation is consistent with its treatment in previous studies (Nagayasu and Inakura (2009), Ikeno (2014)).

Furthermore, as part of the preliminary analysis, we investigate the theoretical relationship between the relative price and the consumption ratio, implied by the BS theorem. We study its theoretical implication by using different types of statistical methods: the OLS and the Mean Group (MG, Pesaran and Smith (1995)) estimation methods. Neither method considers the spillover effect assuming that home inflation is independent of its neighbors' inflation. However, unlike the OLS, the MG approach allows heterogeneous responses of inflation to developments in consumption (i.e., $\beta$s), which is enabled by first estimating individual-specific slopes for consumption and then calculating the group-level parameters and standard errors. Thus the MG has an advantage over the OLS in the presence of regional heterogeneity since the OLS will bring about inconsistent estimates. In other words,

$$\bar{\beta}_j = \sum_{i=1}^{47} \beta_{j,i}$$

where $j = 0, ..., 3$. The MG estimate ($\bar{\beta}_j$) is obtained by averaging the OLS estimates ($\beta_{j,i}$) from individual regional analyses (where $i$ represents regions and $j$ subscripts used for parameters in Eq. (7)). Table 6 summarizes the estimates from these two statistical methods, where for presentation purposes all statistics are multiplied by 100. The estimates reported in this table do not differ much in terms of their parameter size and statistical significance although they are obtained from different types of statistical methods. However, inconsistent with theoretical prediction, we find a negative and statistically significant relationship between home inflation and her consumption ratio.

However, this result changes when neighbors' variables are added to the specification. Here the neighbors' variable is obtained by calculating the simple average value of the variable for other regions. Thus this variable corresponds to that with the asterisk in Eq. (7), and is created for both inflation and the consumption ratio. When they are included in the simple relationship, the home consumption ratio turns out to be statistically insignificant. Furthermore, the neighbors' variables enter the inflation equation significantly with a parameter sign consistent with theoretical predictions. The different results obtained from a specification with or without the neighbors' data suggest that the simpler specification suffers significantly from a mis-specification bias. In the next section, we check if these results are robust to the estimation method.

## 4.2 The empirical analysis of inflation and consumption

Spatial models have rapidly become popular in many areas of economics research over the years (LeSage and Pace (2009)), and are one approach to introduce spillover effects into statistical models. While there are many forms of spatial models, we shall use the Spatial Durbin Model (SDM) which is more appropriate than others for capturing spillover effects due to its general specification of the model (Vega and Elhorst (2013)).

For $N$ regions ($i = 1, ..., N$) and time ($t = 1, ..., T$), the SDM can be expressed as:

$$y = \rho W y + x\beta + W x\theta + u \tag{8}$$

where $y$ is a vector of inflation at home, and $x$ is a vector of the consumption ratio. Both variables are assumed to be stationary ($x, y \sim I(0)$). The Greek letters are the parameters to be estimated, and $u$ is a residual term assumed to be normally distributed. When there is spatial dependence in regional inflation, a spatial autoregressive coefficient ($\rho$) should be statistically significant. In particular, we expect $\rho > 0$ when regional inflation rates are positively correlated. For presentation purposes, the region-specific constant and the common time effect are suppressed in Eq. (8).

$W$ is a distance weight determined by the distance ($D$) between regions (capital cities) using information from the most popular method of transportation, i.e., transportation time by trucks or ships if a region is surrounded by the sea. More specifically, the neighboring inflation can be expressed as $Wy = \sum_{i=1}^{N} w_{ij} y_j = (I_T \otimes W_N)y$ where $\otimes$ is the Kronecker product. Note that elements of $W$ are based on:

$$w_{ij} = D_{ij}^{-2} \tag{9}$$

where $i,j = 1,...,N$. The $w$ is symmetrical, and its diagonal elements are equal to zero. Thereby we assume a non-linear relationship between inflation rates and geographical distance. Here, the weight is row-normalized such that the elements of each row sum to one, following the standard practice in spatial analyses, and is defined as zero if the region is located further from the home region than 200 km.[7]

Geographical distance has been probably the most popular proxy for transaction costs in previous studies (LeSage and Pace (2009)). It has been frequently used when analyzing the BS effect using price data (e.g., Chen (2004), Nagayasu and Inakura (2009)), and generally has been shown to be a good proxy for transaction costs and thus is suitable for defining a country's neighbors.

After demeaning variables, the fixed and random effects version of Eq. (8) will be estimated by the maximum likelihood method. For the fixed effects model, the following log-likelihood function is used (see e.g., Elhorst 2010).

$$L = T \ln |I_T \otimes (I_N - \rho W| - 0.5NT \ln(2\pi\sigma_u^2) - \frac{u'u}{2\sigma_u^2}$$

where $I$ is an identity matrix and $u$ is specified in Eq. (8). For the random effects

[7] We have also considered other types of a spatial weight matrix, for example, by changing the neighbors to be located within 150km or assuming a linear relationship between inflation rates and geographical distance. Those results are not reported here as the general conclusion remains the same as those reported in this paper.

model, the general specification of the log-likelihood function is the same as the one above. But it follows a different method of data transformation before the estimation: $y$ in Eq. (8) should be considered as $y_{it} - (1-\varphi)T^{-1}\sum_{t=1}^{T} y_{it}$, where $\varphi$ is the weight attached to each region and $\varphi = 0$ indicates that the transformation becomes identical to demeaning data and the fixed effects model. Further, the endogeneity of $Wy$ in Eq. (8) is dealt with during the estimation by the second component of the right hand side of this log-likelihood function.

Before estimating Eq. (8), we study whether regional inflation rates are spatially correlated; otherwise, there is little point in carrying out further analyses using spatial models. This is tested if $\rho$ is statistically significant in the Spatially Auto-Regressive Model (SAR) and Spatial Error Model (SEM). While the SAR is a simplified version of the SDM where there is no explanatory variable apart from $Wy$, the SEM captures spatial correlation in the error term (for further detail see LeSage and Pace (2009)). Thus they offer different specifications to capture spatial correlation in data, but if a spatial autoregressive parameter ($\rho$ for SAR) and a spatial correlation coefficient ($\rho$ for SEM) are found to be significant, this offers strong evidence in favor of spatial correlation. This null hypothesis is tested using the $\chi^2$ test with one degree of freedom, and Table 7 shows that the null is strongly rejected at the one percent significance level and supports spatial correlation in regional inflation data.

Given the presence of spatial correlation, we have estimated the SDM. The results from two (fixed and random effects) estimation methods are reported in Table 8. There the outcomes are very similar, and the results do not seem to be sensitive to the specification of the latent factors. (This is in line with our estimate of $\phi$ in the random effects model which is reported to be statistically insignificant.) For example, the conclusion that home inflation is positively and significantly affected by neighbors' inflation remains valid according to these statistical exercises.

Furthermore, while the home consumption ratio is reported not to affect the home inflation, in line with theoretical predictions the neighbors' consumption ratio influences home inflation significantly and negatively. It follows that increases in consumption of non-tradable goods in neighboring regions will raise inflation pressures at home. Further, our finding of spatial dependence implies the high level of integration of regional economies, but the market integration is imperfect, i.e., it constitutes evidence in favor of the BS effect. Thus our results suggest that it is essential to consider neighbors' effects in order to understand developments in prices at home.

Although it was not statistically significant, there may be two reasons why we have obtained a negative sign for the consumption ratio at home. First, there is a potential problem of measurement errors in our data. While consumption data capture economic activities in regions, the CPI covers mainly prices in the capital cities of the regions. Therefore, when home inflation is estimated with its own consumption ratio, home consumption outside capital cities may dominate consumption behaviors in a home region, leading to the home consumption ratio having a negative relationship with home inflation.

Second, it may be more appropriate to relax the assumption that home and neighbors' goods are perfect substitutes which was assumed in Section 2. If the domestic goods become imperfect substitutes, her total expenditure does not need to remain constant and may vary in response to changes in consumption of non-tradable goods. It follows that there is a possibility that both consumption of tradable and non-tradable goods increases, and in that case their effects on the home price will be offset by each other.

Next, we have calculated the spillover effects by means of obtaining the direct and indirect effects based on Eq. (8). The latter effect can be regarded as a spillover of regional inflation, and the sum of these effects become equal to the total effect. LeSage and Pace (2009) discuss potential problems of interpreting parameters when $\rho \neq 0$ in Eq. (8) and propose the decomposition of the total effect into two effects. In this connection, these effects for the SDM are calculated by rewriting Eq. (8) as:

$$y = (I_N - \rho W)^{-1}(x\beta + Wx\theta) + e \tag{10}$$

where $e = (I_N - \rho W)^{-1}u_t$. The impacts from neighbors disappear with the increasing power of $\rho W$. Our focus is on productivity and thus the second component on the right hand side. The sensitivity of $y$ with respect to the $k$th element in $x$ can then be expressed using the partial derivative of (10):

$$\left[\frac{\partial y}{\partial x_{1k}} \cdots \frac{\partial y}{\partial x_{Nk}}\right] = \begin{bmatrix} \frac{\partial y_1}{\partial x_{1k}} & \cdots & \frac{\partial y_1}{\partial \mathrm{x_{Nk}}} \\ \vdots & \ddots & \vdots \\ \frac{\partial y_N}{\partial x_{1k}} & \cdots & \frac{\partial y_N}{\partial x_{Nk}} \end{bmatrix} =$$

$$(I - \rho w)^{-1} (\beta_k I + w_k \theta_k) = (I - \rho w)^{-1} \begin{pmatrix} \beta_k & w_{12}\theta_k & \cdots & w_{1N}\theta_k \\ w_{21}\theta_k & \beta_k & & \vdots \\ \vdots & \cdots & \ddots & \\ w_{N1}\theta_k & w_{N2}\theta_k & \cdots & \beta_k \end{pmatrix} \quad (11)$$

A direct effect is calculated as the average of the diagonal elements of the matrix, and the indirect effect as the row sums of the off-diagonal elements of the matrix.[8] As can be seen from (11), off-diagonal elements in the parentheses become zero when $\theta = 0$ and/or $W = 0$. Thus the SDM offers a more general framework for analyzing spillovers compared with the SAR model which assumes $\theta = 0$ from the outset. Finally, the total effect becomes equal to the sum of the direct and indirect effects, and our standard errors for these effects are obtained on the basis of 1,000 simulations.

While we have investigated the transmission channels of changes in consumption, the general conclusion drawn from previous exercises remains valid. In other words, we have confirmed the importance of spillovers in regional inflation: indirect effects are reported to have negative and statistically significant impacts on home inflation. The higher the consumption ratio in neighboring regions, the less the inflationary pressure at home. Finally, the Hausman test statistic shows $\chi^2(1) = 0.000$ which gives evidence in favor of the random effects due to higher efficiency of that model.

[8]The indirect effect can also be calculated by the column sums of the off-diagonal elements of the matrix, but this approach will result in the same outcome as that from the row sums approach.

# 5 Conclusion

This paper has investigated the economic determinants of regional inflation using recent Japanese regional consumption data, and is equivalent to verifying the PPP, one of the most important economic theories in international finance. We have used a unique data set which has information about the service components in all consumption activities. Such a distinction between tradable and non-tradable elements is impossible if price data are used as in previous studies.

In short, our regional data provide evidence against the relative version of the PPP, and confirm heterogeneity in regional inflation even in a country like Japan which is considered relatively more homogenous in many respects by international standards. This study also provides economic reasons for heterogeneous regional inflation using spatial models while considering the consumption behaviors of economic agents. In particular, we have confirmed the importance of non-tradable goods (services), as pointed out by Balassa (1964) and Samuelson (1964). Given that the service sector has become the largest component of the overall economic activity and the proportion of retirees will be increasing in the populations of many advanced countries including Japan, we believe that our conclusion is not tentative, but will become more significant in the future. As the proportion of the population in urban areas made up of retirees increases, this study suggests that disparities in regional inflation will widen unless some economic measures are implemented.

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Table 1: Contribution of industries to total economic activity

| Industry | Percent |
|---|---|
| Agriculture, forestry and fishing | 1.091 |
| Mining | 0.086 |
| Manufacturing | 18.344 |
| Construction | 5.191 |
| Electricity, gas, and water supply | 2.085 |
| Wholesale and retail trade | 13.582 |
| Finance and insurance trade | 4.679 |
| Real estate | 14.040 |
| Transportation | 4.875 |
| Information and communication | 5.213 |
| Service activities | 19.713 |
| Producers of government services | 8.943 |
| Producers of private non-profit services to households | 2.158 |

**Notes:** Data for 2012. Department of National Accounts, Economic and Social Research Institute, Cabinet Office, Japan.

Table 2: Summary statistics of log prices (CPI)

| Capital cities | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| Sapporo | 4.619 | 0.013 | 4.598 | 4.651 |
| Aomori | 4.606 | 0.014 | 4.579 | 4.646 |
| Morioka | 4.616 | 0.012 | 4.599 | 4.652 |
| Sendai | 4.617 | 0.014 | 4.589 | 4.641 |
| Akita | 4.623 | 0.015 | 4.592 | 4.657 |
| Yamagata | 4.616 | 0.012 | 4.597 | 4.651 |
| Fukushima | 4.614 | 0.013 | 4.596 | 4.648 |
| Mito | 4.611 | 0.014 | 4.592 | 4.659 |
| Utsunomiya | 4.617 | 0.014 | 4.595 | 4.651 |
| Maebashi | 4.621 | 0.015 | 4.593 | 4.644 |
| Saitama | 4.619 | 0.014 | 4.599 | 4.652 |
| Chiba | 4.618 | 0.015 | 4.592 | 4.655 |
| Tokyo | 4.617 | 0.014 | 4.587 | 4.652 |
| Yokohama | 4.611 | 0.010 | 4.596 | 4.637 |
| Niigata | 4.617 | 0.012 | 4.595 | 4.645 |
| Toyama | 4.620 | 0.015 | 4.593 | 4.657 |
| Kanazawa | 4.610 | 0.013 | 4.583 | 4.647 |
| Fukui | 4.616 | 0.014 | 4.594 | 4.651 |
| Kofu | 4.611 | 0.012 | 4.594 | 4.644 |
| Nagano | 4.616 | 0.012 | 4.595 | 4.643 |
| Gifu | 4.618 | 0.015 | 4.594 | 4.657 |
| Shizuoka | 4.614 | 0.013 | 4.595 | 4.648 |
| Nagoya | 4.617 | 0.012 | 4.593 | 4.642 |
| Tsu | 4.608 | 0.012 | 4.592 | 4.649 |
| Otsu | 4.613 | 0.012 | 4.590 | 4.641 |
| Kyoto | 4.618 | 0.011 | 4.598 | 4.650 |
| Osaka | 4.626 | 0.017 | 4.591 | 4.659 |
| Kobe | 4.616 | 0.014 | 4.592 | 4.655 |
| Nara | 4.625 | 0.019 | 4.590 | 4.666 |
| Wakayama | 4.605 | 0.014 | 4.583 | 4.643 |
| Tottori | 4.619 | 0.013 | 4.599 | 4.645 |
| Matsue | 4.611 | 0.011 | 4.597 | 4.645 |
| Okayama | 4.613 | 0.010 | 4.596 | 4.643 |
| Hiroshima | 4.614 | 0.011 | 4.592 | 4.638 |
| Yamaguchi | 4.617 | 0.013 | 4.591 | 4.642 |
| Tokushima | 4.609 | 0.010 | 4.588 | 4.639 |
| Takamatsu | 4.616 | 0.011 | 4.595 | 4.646 |
| Matsuyama | 4.615 | 0.010 | 4.596 | 4.648 |
| Kochi | 4.614 | 0.012 | 4.589 | 4.642 |
| Fukuoka | 4.620 | 0.016 | 4.594 | 4.662 |
| Saga | 4.616 | 0.013 | 4.590 | 4.651 |
| Nagasaki | 4.614 | 0.011 | 4.595 | 4.637 |
| Kumamoto | 4.610 | 0.011 | 4.585 | 4.637 |
| Oita | 4.615 | 0.012 | 4.597 | 4.646 |
| Miyazaki | 4.622 | 0.014 | 4.598 | 4.650 |
| Kagoshima | 4.608 | 0.009 | 4.588 | 4.633 |
| Naha | 4.610 | 0.012 | 4.589 | 4.644 |

**Notes:** Samples from 2000M1-2015M3. The total observation is 183 for each prefecture. The CPI data from the Statistics Bureau, Ministry of Internal Affairs and Communications, Japan.

Table 3: Heterogeneity in regional prices

| | Statistic | $F$(df1, | df2) | $F$ | $p$-value |
|---|---|---|---|---|---|
| Wilks' lambda | 0.890 | 46 | 8554 | 22.940 | 0.000 |
| Pillai's trace | 0.110 | 46 | 8554 | 22.940 | 0.000 |
| Lawley-Hotelling trace | 0.123 | 46 | 8554 | 22.940 | 0.000 |
| Roy's largest root | 0.123 | 46 | 8554 | 22.940 | 0.000 |

**Notes:** The null hypothesis is homogenous regional prices.

Table 4: The proportion of service components in consumption goods (%)

| Variable | Mean | Variable | Mean |
|---|---|---|---|
| All items | | | |
| Durable | 6.359 | Transportation & communications | |
| Semi-durable | 9.447 | Durable | 11.699 |
| Non-durable | 42.030 | Semi-durable | 4.080 |
| Service | 42.164 | Non-durable | 15.009 |
| Food | | Service | 69.212 |
| Non-durable | 82.042 | Education | |
| Service | 17.958 | Non-durable | 1.300 |
| Housing | | Service | 97.498 |
| Durable | 8.105 | Culture & recreation | |
| Semi-durable | 2.105 | Durable | 9.189 |
| Service | 89.789 | Semi-durable | 11.680 |
| Furniture & household utensils | | Non-durable | 23.039 |
| Durable | 36.739 | Service | 56.093 |
| Semi-durable | 31.664 | Other consumption expenditures | |
| Non-durable | 23.270 | Durable | 2.742 |
| Service | 8.327 | Semi-durable | 9.339 |
| Clothing & footwear | | Non-durable | 22.202 |
| Semi-durable | 93.043 | Service | 65.716 |
| Service | 6.957 | | |
| Medical care | | | |
| Durable | 7.152 | | |
| Semi-durable | 2.997 | | |
| Non-durable | 33.657 | | |
| Service | 56.194 | | |

**Notes:** Samples from 2000M1-2015M3. Consumption data are from the Statistics Bureau, Ministry of Internal Affairs and Communications, Japan.

Table 5: The panel unit root tests

| | | Inflation | *p*-value | Consumption Ratio | *p*-value |
|---|---|---|---|---|---|
| LLC | | -71.582 | 0.000 | -12.972 | 0.000 |
| Harris-Tzayalis | | -0.192 | 0.000 | -0.456 | 0.000 |
| Fisher | 1) Inverse chi-square P | 3305.476 | 0.000 | 3335.188 | 0.000 |
| | 2) Inverse normal Z | -54.956 | 0.000 | -55.216 | 0.000 |
| | 3) Inverse logit L* | -133.193 | 0.000 | -134.390 | 0.000 |
| | 4) Modified inverse chi-square Pm | 234.221 | 0.000 | 236.388 | 0.000 |

**Notes:** The null hypothesis that data are nonstationary is tested against the alternative of the stationarity. For further explanation, see also the main text. Fishers test is based on Choi (2001).

Table 6: Inflation equation estimation

| | Coef. | Std.Err. | $p$-value(%) | Coef. | Std.Err. | $p$-value(%) |
|---|---|---|---|---|---|---|
| OLS | | | | | | |
| $\Delta \ln(P_{it}^*)$ | – | – | – | 6.962 | 0.551 | 0.000 |
| $\Delta \ln(C_T/C_N)$ | -0.116 | 0.023 | 0.000 | -0.045 | 0.035 | 20.800 |
| $\Delta \ln(C_T^*/C_N^*)$ | – | – | – | -0.017 | 0.005 | 0.100 |
| Constant | 0.001 | 0.004 | 77.300 | -0.066 | 0.021 | 0.200 |
| Mean Group (MG) | | | | 0.000 | 0.000 | 0.000 |
| $\Delta \ln(P_{it}^*)$ | – | – | – | 7.000 | 0.327 | 0.000 |
| $\Delta \ln(C_T/C_N)$ | -0.119 | 0.018 | 0.000 | -0.044 | 0.034 | 18.900 |
| $\Delta \ln(C_T^*/C_N^*)$ | – | – | – | -0.017 | 0.003 | 0.000 |
| Constant | 0.001 | 0.001 | 33.300 | -0.068 | 0.010 | 0.000 |

**Notes:** For presentation purposes, all statistics are multiplied by 100.

Table 7: The presence of spatial correlation in regional inflation

| | SAR | SEM |
|---|---|---|
| $\chi^2(1)$ | 6.660 | 9.330 |
| $p$-value | 0.0098 | 0.0023 |

**Notes:** Based on the random effects model.

Table 8: The relative price equations using the spatial models

| | Coef. | Std.Err. | $p$-value(%) | Coef. | Std.Err. | $p$-value(%) |
|---|---|---|---|---|---|---|
| | Fixed effects | | | Random effects | | |
| Log-likelihood | 39527.16 | | | 39521.2 | | |
| $\Delta \ln(C_T/C_N)$ | -0.006 | 0.015 | 69.100 | -0.006 | 0.015 | 69.100 |
| $\Delta \ln(C_T^*/C_N)$ | -0.084 | 0.032 | 1.000 | -0.084 | 0.032 | 1.000 |
| $\Delta \ln(P_{it}^*)$ | 88.169 | 0.597 | 0.000 | 88.159 | 0.598 | 0.000 |
| logit $\varphi$ | | | | 1712.213 | 88191.530 | 98.500 |
| $\sigma_u^2$ | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| Direct | -0.020 | 0.016 | 20.700 | -0.020 | 0.016 | 20.700 |
| Indirect | -0.755 | 0.242 | 0.200 | -0.754 | 0.242 | 0.200 |
| Total | -0.775 | 0.247 | 0.200 | -0.775 | 0.247 | 0.200 |

**Notes:** All statistics, except for the value of Log-likelihood, are multiplied by 100 for the presentation purposes. The estimated equation is based on Eq. (7). The standard error is based on simulations with 1,000 replications.

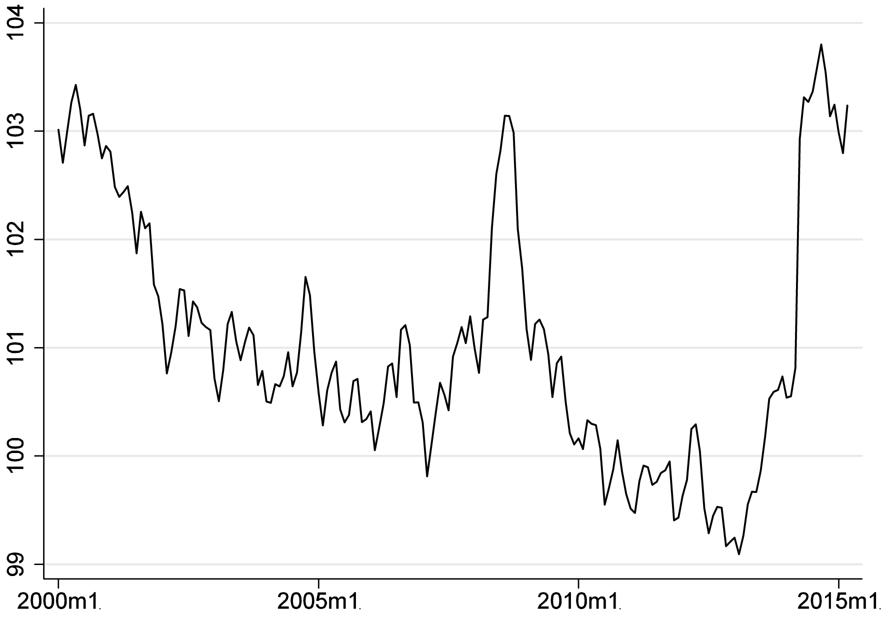


Figure 1: Regional CPI (average)

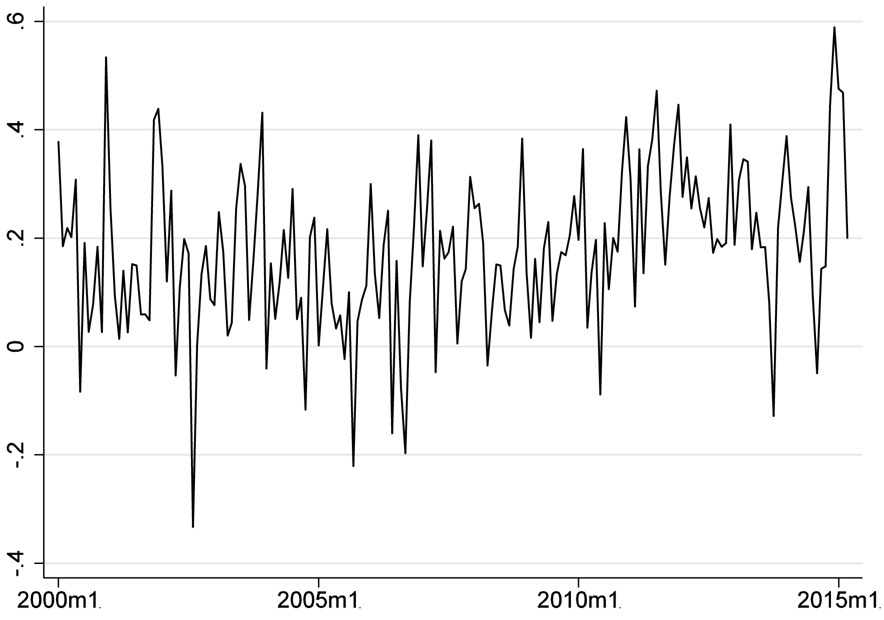


Figure 2: Regional consumption ratio (average)