Regional inflation, spatial location and the Balassa-Samuelson effect

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Abstract

We empirically analyze regional inflation using data from Japan where there is no regulation to impede the free movement of labor, capitals, goods and services across regions. In particular, our analysis will focus on the geographical location of regions and the productivity effect as explanation for the dynamics of regional inflation. Technically, given that home inflation is often affected by that of neighbors, spatial models have been employed in order to explicitly capture this spillover effect. Similarly, the productivity spillover is modelled in the specification. Then we find that both spatial location and productivity are important determinants of regional inflation. Furthermore inflation persistence is reported to play an important role in explaining regional data.

Keywords: Regional inflation, Balassa-Samuelson effect, transaction costs, spatial econometric models
JEL classification: F3, R1, E3

1 Introduction[1]

A recent surge in empirical analysis of regional inflation has been driven by the creation of the euro in 1999 (e.g., EUROPEAN CENTRAL BANK (ECB) 2003, LOPEZ and PAPELL 2012). As stated in the Maastricht Treaty signed in 1992, homogeneous inflation is considered as one convergence criterion[2] and essential for the sustainability of the monetary union.[3] In contrast to this expectation however, the ECB (2003) documents that inflation differentials in the euro area have increased since 1999. A lack of price/inflation convergence has been also reported by intra-country analysis for, e.g., Italy (BUSETTI et al., 2006) and Japan (NAGAYASU 2011). This complicates the formulation of monetary policy since, with the prevalence of heterogeneous inflation, there is no single monetary policy which fits all regions. [4]

The heterogeneity in regional prices (inflation) has been frequently analyzed in the theoretical framework of the purchasing power parity (PPP) (CASSEL 1918), which suggests the equalization of regional prices and/or inflation in monetary unions. Thus economic factors contributing to a violation of the PPP have been considered as explanations of heterogeneous regional prices/inflation. Such economic factors include transaction costs, and tariff and non-tariff barriers (e.g., DUMAS 1992). Indeed, researchers have confirmed that transaction costs are one driving force of price differentials using geographical distance between regions as a proxy for transaction costs. For example, ENGEL and ROGERS (1996) and CEGLOWSKI (2003) study the law of one price (LOOP) using the CPI for Canada and the USA, and confirm that price differentials are explained by the distance between cities. Furthermore, they find the border effect; i.e., the variation in price differentials in the same country is lower than one between different countries. In addition, PARSLEY and WEI (1996) report that the convergence of price differentials is slow as cities are located distant from each other.

Similarly, distance has been reported to be a reason for heterogeneous prices/inflation in other countries. For 6 euro countries, CHEN (2004) uses

[1]Due to the space limitations, the literature survey is largely limited to intra-country studies. See e.g., SARNO and TAYLOR (2003) and BAHMANI-OSKOOEE and NASIR (2005) for a more comprehensive review of the PPP.

[2]In order to adopt the euro, a country needs to have an inflation rate which is no more than 1.5% above the average of that of the 3 members of the European Union (EU) with the lowest inflation.

[3]See also MUNDELL (1961), a seminal paper in this field, about a priori conditions required for optimal currency areas

[4]The importance of the convergence criteria in a monetary union has been highlighted more recently by a number of recent financial crises (e.g., the Greek crisis in 2009 and thereafter).

sectoral prices, and also finds evidence that distance can explain the persistence of relative prices. NAGAYASU and INAKURA (2009) show that relative prices (All items) are positively correlated with distance. Similarly, IKENO (2014) reports evidence of transaction costs for nondurable and semi-durable goods. Furthermore, KANO et al (2013) focus on wholesale prices of 8 vegetables and confirm that geographical barriers are a reason for the failure of the LOOP in Japan.

Another classic explanation for heterogeneity in prices/inflation has been put forward by the Balassa-Samuelson (BS) theorem (BALASSA 1964; SAMUELSON 1964).[5] This theory assumes that countries consist of tradable and nontradable sectors, and productivity in the tradable sectors is different among countries. Under these settings, higher productivity in the tradable sector pushes up prices in the nontradable sector in the country, and as a result a more productive country will experience real exchange rate appreciation over time. Thus, according to this theorem, deviations from the PPP are supply-driven, and unlike the PPP the real exchange rate cannot be assumed to be constant over time. While it may be difficult to draw a consensus out of the literature, the BS effect also seems to be an important explanatory variable in explaining inflation heterogeneity (e.g., ALTISSIMO et al. (2006) for the euro area,[6] NAGAYASU and LIU (2008) for China, and VAONA (2010) for Italy).

Furthermore, MARQUES et al. (2013) argue that regional inflation differentials occur even when all goods are tradable if the size of regions differs in terms of population. The external demand shocks will then have asymmetric effects on income and consumption. Thus such shocks will alter the trade pattern, and with price rigidities they will result in a persistent difference among regional prices. Similarly, the demand-side argument is put forward by DE HAAN (2010) who discusses how heterogeneous inflation may be attributable to asymmetric demand shocks caused by different fiscal policies in response to different stages in business cycles.

Against this background, this paper will analyze the evolution of regional inflation in Japan. This is a unique country (monetary union) consisting of regions which share a high degree of similarity in many respects (i.e., language, religion, tastes, etc.) by international standards. Furthermore, there are virtually no regulations, such as tariff and non-tariff barriers, to impede the free movement of labor, capital, goods and services across regions.

[5] Alternatively, regional inflation has been modelled on the new Keynesian framework. But this approach requires a proxy for expected inflation which is unobservable and needs to be estimated.

[6] But RABANAL (2009) suggests that the BS is not an important reason for inflation differentials between Spain and the rest of the euro area.

Another unique feature of this paper is to consider both the spatial location of regions and the BS effect as determinants of regional inflation. As discussed, the distance (i.e., spatial location) between Japanese regions has also been examined as a source of heterogeneous regional prices in the past; however, these studies did not consider the BS effect together with the distance. In this regard, we employ spatial econometric models, which have rarely been applied to regional inflation analysis although these models are useful for taking account of not only inflation spillovers but also productivity spillovers implied by the BS effect. Exceptions are MARQUES et al. (2013) who have applied spatial models to regional data in Chile, and YESILYURT and ELHORST (2013) to Turkish regional data.

2 The Balassa-Samuelson effect and the spatial location of regions

Since there are many ways to derive this intuitive implication of the Balassa-Samuelson (BS) effect, we summarize below a theoretical framework which depicts the relationship between regional inflation and productivity. Several economic assumptions are required to explain the BS effect.

For simplicity, first consider a world which consists of a home region and all other regions. Second, each region is assumed to be classified into tradable and nontradable sectors, and in the absence of international trade, the PPP will not hold in the nontradable sector but only in the tradable sector. In monetary unions, this leads to an equalization of regional prices only in the tradable sector:

$$P_T = P_T^* \tag{1}$$

where the asterisk indicates a variable for all other regions, and subscripts (T and N) refer to the tradable and nontradable sectors respectively.

Third, assume that the simple production function in which labor (L) is only input for output (Y).

$$\begin{aligned} Y_T &= f(L_T) \\ Y_N &= f(L_N) \\ Y_T^* &= f(L_T^*) \\ Y_N^* &= f(L_N^*) \end{aligned} \tag{2}$$

Fourth, assume the perfect competitive market where firms attempt to maximize their profits (π). For example, such behaviors for domestic trading firms can be expressed as:

$$\max \pi_T = P_T f(L_T) - w_T L_T - F_T \tag{3}$$

where w is a wage and F is a fixed cost. The firms will employ labor until the following first order condition meets:

$$\frac{d\pi_T}{dL_T} = P_T f'(L_T) - w_T = 0 \tag{4}$$

where $f'(L_T) = \frac{dY_T}{dL_T} > 0$

Fifth, assume perfect labor mobility within a region. This assumption will bring about the equalization of wages in different sectors within a country.

$$\begin{aligned} P_T f'(L_T) = w_T = w_N = P_N f'(L_N) \\ P_T^* f'(L_T^*) = w_T^* = w_N^* = P_N^* f'(L_N^*) \end{aligned} \tag{5}$$

In contrast to domestic labor mobility, we assume no labor mobility across regions. Therefore, there is no need for wages to be equalized within a country (or a monetary union). This assumption appears to be restrictive in the context of regional analysis, but is reasonable since only 0.33% of workers have moved to other regions (i.e., prefectures) over a 5 year period according to the 2002 Employment Status Survey by the Statistical Bureau of Japan.

We can write country level prices (P) as a composite of prices for tradable and nontradable goods.

$$\begin{aligned} P &= P_T^\alpha P_N^{1-\alpha} \\ P^* &= (P_T^*)^\alpha (P_N^*)^{1-\alpha} \end{aligned} \tag{6}$$

where $0 < \alpha < 1$ and it represents a share of the tradable sector in a region. Using $P_T = P_T^*$,

$$\frac{P}{P^*} = \frac{(P_T)^\alpha (P_N)^{1-\alpha}}{(P_T^*)^\alpha (P_N^*)^{1-\alpha}} = \left(\frac{P_N}{P_N^*}\right)^{1-\alpha} \tag{7}$$

Furthermore, using (5) and $P_T = P_T^*$ and assuming the same productivity in nontradable sectors across regions, relative prices can be expressed as:

$$\frac{P}{P^*} = \left(\frac{f'(L_T)}{f'(L_T^*)}\right)^{1-\alpha} \tag{8}$$

Using natural logarithmic form (e.g., $p = \ln(P)$) and differencing this equation to express in terms of domestic inflation (Δp),

$$\Delta p = \Delta p^* + (1-\alpha)\Delta a_T - (1-\alpha)\Delta a_T^* \tag{9}$$

where $a = \ln(f'(L_T))$ and $a^* = \ln(f'(L_T^*))$. The small letter indicates a log value, and Δ is a difference operator, i.e., $\Delta p = \ln(P_t/P_{t-1})$ This equation asserts that domestic inflation increases along with rises in neighbors inflation and its own productivity improvements, and declines with advances in productivity in other regions. Thus, Eq. (9) implies that heterogeneity in regional inflation is attributable to different speeds of developments in regional productivity.[7] With an assumption that productivity in the nontradable goods sector remains the same across regions and in the absence of data on sectoral productivity, the subsequent analysis will use regional level productivity (a) as a proxy for a_T. Furthermore, neighbors' variables (p^* and Δa^*) will be calculated in our spatial models with weights which are determined by geographical distance between regions.

3 Data

We analyze 47 regions (prefectures) over the period of 1976-2010, which creates an annual data set with a total of 1,645 observations. The date of the beginning of our sample is determined by the data availability for Okinawa which was returned to Japan by the USA in 1972, and the end of the sample by the availability of regional GDP data.[8] Our regional inflation is measured by annual CPI growth, and annual productivity by regional GDP per employer. Regional inflation is obtained from the Ministry of Internal Affairs and Communication, the same data source used in previous studies (e.g., ESAKA 2003 and NAGAYASU 2011). This CPI mainly measures the price level of capital cities. The other data, regional GDP and the number of employers in regions, are from the Cabinet Office. Here, the annual grow rate of variable M is calculated for each region i ($i = 1, \cdots, 47$) as:

$$m_{it} = \left(\frac{M_{it} - M_{it-1}}{M_{it-1}}\right) * 100 \tag{10}$$

[7] See Section 3. It is difficult to obtain data from different sources which are compiled using the same statistical methodologies (e.g., data classification). The assumption of the same level of productivity in nontradable sectors is consistent with the BS theorem. A classic example is the productivity of haircuts, a labor-intensive service.

[8] Thus our samples do not include observations at the time of the Great East Japan Earthquake.

Table 1 lists inflation (All items) for the 47 regions broadly in the order of the location of the regions from north to south and suggests that all regions have experienced a relatively low inflation by international standards of around 1.5% per annum, ranging from 1.4% in Nara, Yamaguchi and Okinawa to 1.8% in Aomori. Inflation volatility in terms of standard deviations seems to be very similar among regions, ranging from 2.3 in Okinawa to 2.8 in Aomori and Akita. In this regard, prices seem to be most stable in Okinawa. We also plot the average, minimum and maximum regional inflation (Figure 1), showing that inflation is time-varying and reaches relatively high levels (around 10%) at times of oil shocks. In contrast, inflation has been stable and low in more recent periods when Japan underwent economic recession and deflation.

Figure 2 plots the geographical locations of each region. The geographical distance (d) between regions (measured by the distance between capital cities) is obtained from the Geospatial Information Authority of Japan (http://www.gsi.go.jp/KOKUJYOHO/ kenchokan.html). The distance is calculated using the Geodetic Reference System 1980(GRS80) and is summarized in Figure 3, which depicts the average distance between regional capitals for each region. According to this average value, Okinawa is located significantly distant from others, while Shiga is surrounded by other regions within a short distance. This distance is used to create a weight matrix for a pair of regions i and $j (i \neq j$ and $i, j = 1, \cdots, N)$ following the standard approach (i.e., power distance weights):

$$w = d_{ij}^{-\theta} \tag{11}$$

The w is a symmetric matrix and the diagonal elements are zero, and for estimation of the model each row of the weight matrix will be normalized such that the row sum of w becomes equal to one. We shall use two different values for θ ($\theta = 1$ or 2) in order to check the robustness of our results to the assumption of the weight matrix.[9] In the academic literature, distance is often used as a proxy for transaction costs, but can have wider implications. For instance, a short distance between regions would mean that neighbors tend to share a similar history, economic structure and culture, and trade more with each other.

[9] In addition to the abovementioned definition of w, we also used the weight matrix on which a constraint is imposed; for instance, the distance between Ibaraki and Yokohama, the longest distance between capitals in the Tokyo (Kanto) area, is used to define neighbors. But results are found to remain the same as those presented in this paper, and thus are not reported.

4 Preliminary investigation of data

The standard assumptions required for spatial models are the presence of spatial autocorrelation and the stationarity of data among others; therefore, we shall conduct several tests to understand the statistical characteristics of the data. First, in order to examine the spatial independence of regional inflation, we have implemented Moran's I test which for regions $(i, j, i \neq j)$ can be summarized as:

$$\text{Moran's}I = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}(\mathbf{y}_i - \bar{\mathbf{y}})(\mathbf{y}_j - \bar{\mathbf{y}})}{\sum_{i=1}^{N}(\mathbf{y}_i - \bar{\mathbf{y}})^2} \tag{12}$$

where $\mathbf{y}$ is a vector of regional inflation rates, and a bar indicates the average value of the corresponding variable. Like the standard correlation coefficient, Morans I statistics range from -1 to 1, and the insignificance of the statistics (i.e., Moran's $I = 0$) suggests the absence of spatial autocorrelation. When regional inflation rates are positively correlated, we would expect to have positive and significant statistics from this test.

This test is conducted for not only the most comprehensive measure of CPI inflation (i.e., All items), but also sectoral inflation in order to check whether inflation in one region has been affected by developments in others or vice versa. Following the CPI classification method, 10 major sector specific items are reported in this table; namely, 1) food, 2) housing, 3) fuel, light and water charges, 4) furniture and household utensils, 5) clothes and footwear, 6) medical care, 7) transportation and communication, 8) education, 9) culture and recreation, and 10) miscellaneous.

Since Morans I test has been developed for cross section data, we shall implement it for each year. The results show that the null hypothesis of no spatial autocorrelation is rejected in many cases, and imply the importance of spatial autocorrelation among regional inflation (Table 2).

However, the degree of spatial autocorrelation is rather sector-specific. Notably, spatial autocorrelation is strongly present in sectors in 3) fuel, light and water charges and 7) transportation and communication. In such cases, the average value of Morans I test is reported to be positive. This is an expected outcome since our samples are all drawn from a single country where regions tend to share a similar (if not the exactly the same) type of economic policies and are prone to facing similar exogenous shocks due to their geographical proximity (i.e., a relatively small country). Furthermore, the market structure is closely related to price setting practices in these industries; since there are a limited number of supplies, these companies tend to set similar (if not the same) prices in regions nearby.[10] In contrast, very weak evidence of spatial autocorrelation is reported for economic sectors such as 4) furniture and household utensils and 6) medical care. In these industries, Morans I statistics are often negative and statistically insignificant.

Table 3 examines the stationarity of regional inflation, which is required for estimation of the standard spatial models. Three panel unit root tests; namely, the Levin-Lin-Chu (LLC), Im-Pesaran-Shin (IPS) and Fisher-type ADF tests, have been implemented to examine the null hypothesis of the unit root. The alternative hypothesis differs according to the tests: while that of the LLC is that all panels are stationary, the latter two tests evaluate the alternative that some panels are stationary. In any case, all these tests lead to a conclusion against the null, and this is consistent with that the study on the European Monetary Union (EMU) (BECK et al. 2006).

Finally, we also examine the relationship between regional inflation and its own productivity growth (Figure 4). While it is difficult to draw a clear conclusion from this figure, it appears that a negative relationship exists between these variables. This is inconsistent with theoretical predictions and shall be discussed later when interpreting our empirical results (Section 6). Furthermore, the causality tests based on the panel vector auto-regression (VAR) confirm the theoretical prediction of the BS theorem (Table 4); in other words, productivity growth results in changes in regional inflation. But no evidence is found that inflation has caused productivity growth. This ensures our a priori assumption about the exogeneity of productivity growth in our spatial econometric models which will be explained next.

5 Spatial Econometric models

The spatial econometric approach has been rapidly developed over the past decade, and today it has been applied in many areas of research (see the survey in LESAGE and PACE 2009). But as discussed in the Introduction, there are few attempts at inflation analysis probably due to the fact that inflation has often been analyzed at the national level with a presumption of equality in regional inflation. However, spatial autocorrelation is pertinent here since we relax this resumption. Furthermore, the consideration of geographical space is more relevant here compared with analysis of other prices, e.g., of financial assets (stocks and bonds) since these assets can easily be

[10] For example, region specific companies (e.g., the Hokkaido Railway Company, East Japan Railway Company, Central Japan Railway Company, West Japan Railway Company, Shikoku Railway Company, and Kyushu Railway Company) exist in the railway industry.

traded using modern technologies, and there is a less significant amount of transaction costs involved in trading compared with consumer goods, the main components of the CPI, which need to be physically shipped.

While the majority of spatial models have been designed for cross-section analysis, we use spatial panel data models which make use of time-series information. More concretely, while different types of spatial models are available, this paper uses the spatial autoregressive model (SAR) and the spatial Durbin model (SDM). However, it is the SDM which we use as the main vehicle of the research due to its proximity to the theoretical specification (9) and its appropriateness for analyzing spillover effects (VEGA and ELHORST 2013, p. 10). We present results from the SAR, the most basic spatial model, for the purposes of comparison.

For the endogenous variable ($\mathbf{y}$) which consists of $N(i = 1, \cdots, N)$ regions and time $T(t = 1, \cdots, T)$, the SAR can be expressed as[11] :

$$\mathbf{y}_t = \alpha\boldsymbol{\tau}_N + \boldsymbol{\mu} + \xi_t\boldsymbol{\tau}_N + \rho\mathbf{w}\mathbf{y}_t + \mathbf{x}_t\boldsymbol{\beta} + \mathbf{e}_t \tag{13}$$

Here, $\mathbf{y}_t$ is a $N \times 1$ vector consisting of regional inflation, and $\boldsymbol{\tau}_N$ is a $N \times 1$ vector of one. Further, $\mathbf{x}$ is a $N \times k$ matrix of explanatory variables (i.e., productivity), and their parameters $\boldsymbol{\beta}$ is a $k \times 1$ vector. The $\mathbf{w}$ is a spatial weight which, as mentioned in the previous section, is determined in this paper by the location of the regions. Thus our definition of $\mathbf{w}$ is closely associated with transaction costs: home inflation is not strongly correlated with that of distant neighbors. One interesting feature of this spatial model (13) is the inclusion of a spatially lagged variable ($\mathbf{w}\mathbf{y}_t(\mathbf{w}\mathbf{y}_t = \sum_{j=1}^{N} w_{ij}y_{jt}$, where w_{ij} is an element of the spatial weight matrix w)), which represents a linear combination of neighbors contemporaneous inflation and thus is Δp^* in (9). So ρ captures the sensitivity of $\mathbf{y}_t$ to spatially lagged variables. This is a notable advantage of the spatial model over the conventional panel data estimation models.[12]

Given the presence of spatial dependence (Table 2) and significant discrepancies between regional inflation rates (e.g., NAGAYASU 2011), we use the SAR (Eq. (13)), the most general specification of this kind due to inclusion of both the spatial fixed effect μ) and the time period fixed effect ($\xi_t\boldsymbol{\tau}_N$). [13] Finally, e_{it} is the residual ($\mathbf{e}_t = (u_{1t}, u_{2t}, \cdots, u_{Nt})', u_{it} \sim N(0, \sigma^2)$). We

[11]Our expression of spatial models is consistent with ELHORST (2014).

[12]Otherwise, one needs to construct a neighbors variable (i.e., a variable with an asterisk in (1)) using their average with some arbitrary weights prior to the estimation.

[13]When estimating spatial models, we follow the transformation approach to deal with the incidental parameter problems which may arise from the large size of the parameters to be estimated. See LEE and YU (2010a) about this statistical method.

expect $\rho > 0$ following the result from Moran's I for All items: neighbors' inflation is positively related with inflation at home (i.e., $\mathbf{y}_{it}$). Similarly, home productivity increases its own inflation through raising wages and thus $\boldsymbol{\beta} > 0$.

One potential problem in (13) is related to the endogeneity of explanatory variables. It is fairly easy to accept that our weight matrix ($\mathbf{w}$) is exogenous. However, even though productivity ($\mathbf{x}$) is found to be exogenous (Table 4), OLS estimators are still biased due to the inclusion of $\mathbf{wy}_t$ in the SAR. In other words, changes in home inflation because of neighbors inflation are likely to have feedback effects which then influence the neighbors inflation. In order to circumvent this bias, our estimation is based on the maximum likelihood (ML) method which corrects this bias when obtaining the residual term to carry out the ML (see ELHORST 2012).

Since the SAR is incapable of capturing the effects of neighbors productivity on home inflation, we also consider the SDM. This model is more consistent with our theoretical model and is an extension to the SAR:

$$\mathbf{y}_t = \alpha\boldsymbol{\tau}_N + \boldsymbol{\mu} + \xi_t\boldsymbol{\tau}_N + \rho\mathbf{wy}_t + \mathbf{x}_t\boldsymbol{\beta} + \mathbf{wx}_t\boldsymbol{\theta} + \mathbf{e}_t \tag{14}$$

This equation includes spatially lagged explanatory variables, $\mathbf{wx}_t$. In our setting, this extra variable represents neighbors' productivity, i.e., a^*. We expect that improvements in neighbors' productivity will reduce home inflation and thus $\boldsymbol{\theta} < 0$; the expected sign for other parameters remains the same as in (13). The specification in which prices (inflation rates) are determined by productivity (growth) is consistent with previous studies analyzing the BS effect (see survey articles, e.g., SARNO and TAYLOR 2003, BAHMANI-OSKOOEE and NASIR 2005). This model is also used in the hybrid Phillips curve model (YESILYURT and ELHORST 2013), one of two previous studies which employed spatial models in regional inflation analysis.

Finally, we shall add a lagged endogenous variable ($\mathbf{y}_{t-1}$) in (14) in order to introduce inflation persistence. Inflation persistence is often observed worldwide and a classic explanation is "menu costs" which prevent instantaneous adjustments in prices in response to exogenous shocks (e.g., BANK OF JAPAN (BOJ) 2000).

$$\mathbf{y}_t = \alpha\boldsymbol{\tau}_N + \boldsymbol{\mu} + \xi_t\boldsymbol{\tau}_N + \tau\mathbf{y}_{t-1} + \rho\mathbf{wy}_t + \mathbf{x}_t\boldsymbol{\beta} + \mathbf{wx}_t\boldsymbol{\theta} + \mathbf{e}_t \tag{15}$$

The inflation persistence is expected to be captured by $\tau (0 < \tau < 1)$ where for computational purposes we impose a homogeneity assumption about the speed of adjustment in each region. While one could carry out statistical tests to find the best model, models (14) and (15) are congruent with our theoretical model (9). [14] In this respect, model (13) suffers from a misspecification bias on theoretical grounds since neighbors' productivity (a^*) is omitted. The estimation procedure for a spatial dynamic panel model is explained by LEE and YU (2010b). See also MARQUES et al. (2013) who analyzed Turkish regional inflation using the dynamic spatial model in order to introduce price inertia.

6 Empirical results

Tables 5 to 7 presents the empirical results from these spatial models applied to the most comprehensive CPI (All items) as it has been most frequently monitored by policymakers and analyzed by researchers. Tables 5 and 6 summarize parameter estimates using two different types of weight matrices ($\theta = 1$ or 2 in Eq. (11)) to check the robustness of results to our assumption about the weight matrix. We generally find the results to be consistent with economic theory, confirming the BS effect, spillovers of inflation and productivity, and inflation persistence.

First, we have confirmed that neighbors' inflation and geographical distance between regions are important factors affecting regional inflation. The ρ is positive and statistically significant in all models; a rise in neighbors' inflation tends to increase inflation at home. This result can also be interpreted as evidence that distant neighbors do not affect home inflation very much at all. While the size of this parameter drops when the time period fixed effect is included in the model, this parameter remains significant.

Second, productivity growth is also found to have a significant effect on inflation on many occasions. In contrast to the BS prediction, productivity improvements in neighboring regions (a^*) are found to increase domestic inflation ($\boldsymbol{\theta} > 0$) when the time period fixed effect is not included. However, while the statistical significance differs by the definition of the weight matrix, $\boldsymbol{\theta}$ turns out to be negative ($\boldsymbol{\theta} < 0$) in the SDM and DSDM with the time period fixed effect. Since there is a tendency for regional inflation to move in a similar direction and the time period fixed effect is relevant in our data, we consider that $\boldsymbol{\theta} < 0$ is a more reliable result (see [6], [9], [15] and [18] in Tables 5 and 6).

The other productivity variable (a) is reported to enter negatively and significantly in all models, implying that technological developments at home will reduce inflation rates. This parameter sign is inconsistent with theo-

[14] PIRAS and PRUCHA (2013) cast some doubt on a pre-testing strategy (using e.g., Lagrange multiplier tests) in selecting the best model.

retical predictions, and may result from the measurement error in data. While our CPI is compiled mainly for capital cities, productivity here covers economic activities in all cities and villages in regions. Therefore, home productivity in this study covers a wider spatial area than the CPI, and incudes productivity changes in cities and villages that should actually be included in those in neighboring regions. Given that there is heterogeneity between urban and rural economic developments and that productivity is higher in rural areas, i.e., capital cities (SAKAMOTO 2013), the inclusion of productivity in rural areas may have a downward bias in the parameter. Alternatively, the negative sign for a may simply reflect the excess supply situation during the recent prolonged recession/deflation period; weak private consumption is a notable economic phenomenon in this period suggesting that productivity improvements did not lead to increases in wages (and prices).

Furthermore, the results about ρ and $\boldsymbol{\theta}$ imply that there is a significant discrepancy between regional inflation rates. Spatial models with two fixed effects generally reject equality among regional inflation ($\rho = 1$) and also support the significant role of productivity in explaining heterogeneity in regional inflation. Therefore, our results confirm previous results (e.g., NAGAYASU 2011) of heterogeneous inflation across Japan.

We have also introduced the lagged endogenous variable (i.e., lagged inflation) in the SDM, and empirical results are presented under the DSDM. While our analysis is at the regional level, as expected, we confirm inflation persistence with a positive and significant parameter for τ (Tables 5 and 6). Inflation persistence is discussed to be yielded by a number of economic factors (BOJ 2000). According to the BOJs survey, for instance, in addition to menu costs, contracts and royalties to customers and business partners are reported to have prevented instantaneous adjustments in prices in response to exogenous shocks. Similarly, CRUCINI et al. (2010) consider both price persistence and geographical distance in explaining variations in heterogeneity in Japanese regional prices. Further, CHOI and MATSUBARA (2007) document the persistence of relative prices in Japan, and argue that it is attributable to the market structure and the tradability of goods. The persistence in regional inflation is also consistent with experiences in other countries, e.g., the euro area (BECK et al. 2006), Italy (VAONA and ASCARI 2012) and Korea (TILLMANN 2013). Note that our analysis based on a fixed effects model (as opposed to random effects model) is supported by the Hausman test (Chi^2 in Tables 5 and 6).

Finally, we calculate the direct and indirect effects of productivity growth on regional inflation; a direct effect is one where productivity growth influences its own inflation, and an indirect effect is one where productivity in other regions affects home inflation. Thus the indirect effect can be considered as a spillover. It is essential to calculate these effects since, as LESAGE and PACE (2009) have explained, the parameters in Tables 5 and 6 do not present precise information about the effects of explanatory variables due to the presence of spatially lagged variables. In this connection, one needs to consider the mutual influences of regional inflation, and presentation of these effects has become the standard format in spatial analysis. These effects can be seen by rewriting (15) as:

$$\mathbf{y}_t = (\mathbf{I} - \rho\mathbf{w})^{-1}\tau\mathbf{y}_{t-1} + (\mathbf{I} - \rho\mathbf{w})^{-1}(\mathbf{x}_t\boldsymbol{\beta} + \mathbf{w}\mathbf{x}_t\boldsymbol{\theta}) + \boldsymbol{\epsilon} \tag{16}$$

where $\boldsymbol{\epsilon}_t = \alpha\boldsymbol{\tau}_N + \boldsymbol{\mu} + \xi_t\boldsymbol{\tau}_N + \mathbf{e}_t$, and $\mathbf{I}$ is an identity matrix. Our focus is on productivity and thus the second component on the right hand side. The sensitivity of y with respect to the kth element in x can then be expressed using the partial derivative of (16):

$$\begin{bmatrix} \frac{\partial \mathbf{y}}{\partial \mathbf{x}_{1k}} & \cdots & \frac{\partial \mathbf{y}}{\partial \mathbf{x}_{Nk}} \end{bmatrix} = \begin{bmatrix} \frac{\partial \mathbf{y}_1}{\partial \mathbf{x}_{1k}} & \cdots & \frac{\partial \mathbf{y}_1}{\partial \mathbf{x}_{Nk}} \\ \vdots & \ddots & \vdots \\ \frac{\partial \mathbf{y}_N}{\partial \mathbf{x}_{1k}} & \cdots & \frac{\partial \mathbf{y}_N}{\partial \mathbf{x}_{Nk}} \end{bmatrix} = (\mathbf{I} - \rho\mathbf{w})^{-1}(\beta_k\mathbf{I} + \mathbf{w}_k\theta_k) \tag{17}$$

$$= (\mathbf{I} - \rho\mathbf{w})^{-1} \begin{pmatrix} \beta_k & w_{12}\theta_k & \cdots & w_{1N}\theta_k \\ w_{21}\theta_k & \beta_k & & \vdots \\ \vdots & \cdots & \ddots & \\ w_{N1}\theta_k & w_{N2}\theta_k & \cdots & \beta_k \end{pmatrix} \tag{18}$$

The 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.[15] As can be seen from (17), off-diagonal elements in the parentheses become zero when $\boldsymbol{\theta} = 0$ and/or $w = 0$. Thus the SDM and DSDM offer a more general framework to analyze spillovers compared with the SAR which assumes $\boldsymbol{\theta} = 0$ from the outset. Finally, the total effect becomes equal to the sum of the direct and indirect effects.

Table 7 summarizes estimates of the total, direct and indirect effects, and suggests that both direct and indirect effects are important for understanding regional inflation. All parameters are negative which is consistent

[15] 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.

with our estimates for this variable in Tables 5 and 6 with two fixed effects. Furthermore, there is evidence from the SDM and DSDM that the indirect (i.e., spillover) effect is nonnegligible, confirming the close economic relationship between regions in Japan. Since the first stage estimation (i.e., Tables 5 and 6) did not calculate the standard errors without distinguishing between these effects, the inferences of these effects are obtained by simulations (1,000 replications) following LESAGE and PACE (2009) in order to evaluate separately the significance of these effects.

7 Conclusion

This paper analyzes heterogeneity in regional inflation in Japan. Unlike previous empirical studies, we consider both the Balassa-Samuelson (BS) effect and the geographical locations of regions which are often regarded as theoretically reasons for heterogeneity in regional inflation. Furthermore, in order to capture these effects, we employ spatial econometric models which have been developed rapidly over recent years but have rarely been applied in inflation analysis.

In short, we have provided further evidence of heterogeneity in regional inflation in Japan and confirmed that it can be explained by the spatial locations of regions and by productivity growth. In particular, inflation in one region is closely associated with developments in neighbors inflation and productivity, consistent with the BS effect. Finally, inflation inertia, which has been observed in the national level data, is present in regional data as well. This result is also in line with regional inflation analysis in other countries (e.g., YESILYURT and ELHORST 2013). Thus, our findings imply that heterogeneous inflation in Japan is caused by productivity and transaction costs, and complements previous studies (NAGAYASU 2011, KANO et al. 2013) that have provided empirical evidence of heterogeneous price/inflation from Japanese regional data but which considered only the transaction costs.

Given the widening economic structure among regions and urbanization in Japan due partly to demographic changes, we predict that inequality in regional inflation will not disappear in the future. Rather, it is more likely that this phenomenon will become more significant, which complicates the formulation of monetary policy. Therefore, our study leads to a conclusion that, unlike the conventional wisdom, the assumption of homogenous inflation does not necessarily hold in monetary unions.

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Table 1: Summary statistics of regional inflation (%)

	Mean	Std	Max	Min		Mean	Std	Max	Min
Hokkaido	1.5	2.7	-2.4	10.3	Shiga	1.5	2.5	-1.4	9.7
Aomori	1.8	2.8	-2.1	9.9	Kyoto	1.7	2.5	-0.9	9.5
Iwate	1.6	2.6	-1.6	9.3	Osaka	1.6	2.6	-2.1	9.5
Miyagi	1.5	2.7	-1.7	9.5	Hyogo	1.5	2.6	-2.2	9.2
Akita	1.7	2.8	-2.0	10.2	Nara	1.4	2.5	-1.8	8.9
Yamagata	1.6	2.7	-1.7	9.9	Wakayama	1.5	2.5	-1.5	9.8
Fukushima	1.7	2.6	-1.6	9.8	Tottori	1.6	2.7	-1.3	10.1
Ibaraki	1.6	2.6	-1.6	9.1	Shimane	1.7	2.7	-1.3	9.8
Tochigi	1.6	2.5	-1.3	8.3	Okayama	1.5	2.4	-1.7	8.5
Gunma	1.5	2.6	-1.4	8.8	Hiroshima	1.5	2.5	-1.3	8.4
Saitama	1.6	2.6	-1.7	9.9	Yamaguchi	1.4	2.7	-1.6	9.6
Chiba	1.5	2.5	-1.6	8.8	Tokushima	1.5	2.5	-1.1	9.6
Tokyo	1.6	2.6	-1.2	9.6	Kagawa	1.5	2.4	-1.7	8.7
Kanagawa	1.6	2.6	-1.1	9.4	Ehime	1.5	2.4	-1.5	8.4
Niigata	1.6	2.6	-1.6	10.0	Kochi	1.5	2.6	-1.0	9.4
Toyama	1.5	2.6	-1.7	8.5	Fukuoka	1.6	2.7	-1.5	9.5
Ishikawa	1.5	2.5	-1.4	8.7	Saga	1.6	2.7	-1.0	9.4
Fukui	1.5	2.6	-1.7	9.5	Nagasaki	1.6	2.5	-1.0	8.3
Yamanashi	1.7	2.6	-1.3	8.7	Kumamoto	1.5	2.4	-1.0	8.5
Nagano	1.6	2.5	-1.7	8.7	Oita	1.5	2.6	-1.4	9.3
Gifu	1.5	2.6	-1.5	9.7	Miyazaki	1.5	2.6	-1.6	8.9
Shizuoka	1.6	2.4	-1.1	8.3	Kagoshima	1.6	2.5	-1.1	8.8
Aichi	1.5	2.5	-1.5	9.5	Okinawa	1.4	2.3	-1.1	8.7
Mie	1.7	2.6	-1.2	9.6	**AVERAGE**	1.5	2.5	-1.4	9.2

Table 2: Moran's I tests

Year	All items	Food (2)	Housing(15)	Fuel, light and water charges (18)	Furniture and household utensils (23)	Clothes and footwear (31)	Medical care (40)	Transportation and communication (44)	Education (48)	Culture and recreation (52)	Miscellaneous (57)
p-values											
1976	**0.005**	0.240	0.080	**0.040**	0.245	0.311	0.249	**0.000**	0.426	**0.022**	**0.000**
1977	**0.001**	**0.000**	**0.000**	**0.002**	0.203	0.136	0.108	**0.011**	0.124	0.057	0.183
1978	**0.001**	**0.000**	0.378	0.289	0.265	**0.038**	**0.021**	0.316	0.330	0.178	0.185
1979	0.229	0.113	0.303	**0.000**	0.245	0.201	0.495	0.376	0.495	0.388	**0.048**
1980	**0.002**	**0.001**	**0.033**	**0.000**	0.196	0.261	0.236	**0.000**	0.099	0.312	0.210
1981	**0.009**	**0.000**	0.221	**0.002**	0.498	0.142	0.137	**0.000**	0.351	0.053	0.379
1982	**0.000**	**0.003**	0.319	**0.000**	0.313	0.420	0.392	0.162	0.064	0.427	0.277
1983	0.445	0.406	0.307	0.089	0.376	0.297	0.454	**0.045**	0.144	0.339	**0.049**
1984	0.486	0.115	0.392	**0.006**	0.252	0.086	0.430	**0.002**	0.207	**0.001**	0.246
1985	0.283	0.344	0.280	**0.003**	0.368	0.102	0.129	**0.022**	0.376	0.251	0.256
1986	0.275	0.089	0.349	**0.000**	0.417	0.272	0.336	0.073	0.255	0.425	0.138
1987	0.296	0.399	0.336	**0.007**	0.325	0.426	0.219	**0.000**	0.200	0.309	0.060
1988	**0.000**	**0.000**	0.065	**0.000**	0.352	0.482	0.141	**0.025**	0.216	0.074	0.342
1989	**0.008**	0.277	**0.002**	**0.001**	0.357	0.316	**0.012**	0.409	0.394	0.295	0.414
1990	0.074	**0.001**	**0.002**	**0.000**	0.125	0.473	0.326	0.122	0.374	0.117	0.363
1991	0.117	**0.001**	**0.013**	**0.002**	0.367	**0.003**	0.448	0.051	0.316	0.192	0.094
1992	**0.000**	0.335	**0.022**	**0.013**	0.361	0.479	0.195	**0.000**	0.401	0.241	0.403
1993	0.155	**0.000**	**0.024**	**0.012**	0.087	**0.040**	0.434	0.163	0.424	0.307	0.384
1994	**0.028**	**0.004**	0.489	0.258	0.285	0.448	0.292	**0.035**	0.215	0.161	**0.007**
1995	0.415	0.069	0.309	0.461	0.386	0.232	0.211	**0.001**	0.439	0.121	0.426
1996	**0.044**	0.258	**0.040**	**0.001**	0.060	0.286	0.253	**0.000**	0.440	**0.014**	0.370
1997	**0.049**	**0.044**	0.220	0.222	0.187	0.226	0.243	0.482	0.394	0.349	0.442
1998	0.176	0.395	0.190	**0.000**	0.106	0.318	0.385	**0.002**	0.350	0.121	0.122
1999	0.230	**0.000**	0.280	0.353	0.335	0.464	0.405	**0.000**	0.369	**0.006**	0.240
2000	**0.050**	**0.037**	0.316	**0.000**	0.363	0.456	0.077	**0.023**	0.292	0.416	0.161
2001	0.253	0.240	0.296	**0.029**	0.200	0.371	0.210	0.385	0.360	**0.018**	**0.032**
2002	0.480	0.145	**0.039**	**0.000**	0.333	**0.039**	0.446	0.471	0.106	0.277	0.300
2003	0.148	0.276	0.357	**0.000**	0.053	0.337	**0.001**	0.293	0.414	0.181	0.068
2004	0.088	0.369	0.161	**0.000**	0.073	0.453	0.335	0.214	0.184	0.248	0.199
2005	0.069	0.225	0.332	**0.000**	**0.043**	0.481	0.081	**0.005**	**0.027**	0.143	0.362
2006	0.118	0.104	0.233	**0.000**	0.286	0.463	0.090	**0.005**	0.459	0.426	0.331
2007	**0.017**	0.107	0.443	**0.007**	0.201	0.189	0.217	0.317	0.456	0.475	0.388
2008	0.082	0.129	0.366	**0.000**	0.433	0.100	0.470	**0.000**	0.158	**0.014**	0.297
2009	**0.000**	**0.009**	0.494	**0.000**	0.488	0.189	0.196	**0.000**	0.377	0.430	0.438
2010	0.403	0.264	**0.046**	**0.000**	0.472	0.420	0.140	**0.001**	**0.000**	0.158	0.178
Ave. Moran's I	0.022	0.025	-0.001	0.098	-0.019	-0.021	-0.020	0.041	-0.011	-0.013	-0.014

Note: The numbers in parentheses indicate the code numbers for data classification used by the Ministry of Internal Affairs and Communication. Statistics significant at the 5% level are marked in bold.

Table 3: The stationarity of regional inflation

	LLC	IPS	Fisher-ADF
All items	-15.3064^{**}	-18.3617^{**}	795.4853^{**}
Food (2)	-19.7453^{**}	-22.8192^{**}	954.2189^{**}
Housing (15)	-17.7332^{**}	-20.3622^{**}	869.1275^{**}
Fuel, light and water charges (18)	-17.6268^{**}	-22.5343^{**}	944.3937^{**}
Furniture and household utensils (23)	-15.6058^{**}	-18.6328^{**}	811.5773^{**}
Clothes and footwear (31)	-21.2889^{**}	-24.4985^{**}	1013.8402^{**}
Medical care (40)	-19.4160^{**}	-23.6366^{**}	984.0173^{**}
Transportation and communication (44)	-18.4106^{**}	-24.7262^{**}	1021.9635^{**}
Education (48)	-12.8192^{**}	-17.6173^{**}	775.2560^{**}
Culture and recreation (52)	-16.8591^{**}	-20.0646^{**}	859.5731^{**}
Miscellaneous (57)	-17.3087^{**}	-21.5294^{**}	910.4215^{**}

Note: See Table 3. The panel unit root tests are based on Levin, Lin and Chu (LLC), Im, Pesaran Shin (IPS), and Fisher-type ADF tests. These tests examine the null hypothesis that data have a unit root. Given strong evidence of spatial autocorrelation (Table 2), the time period effect is included in all these tests, so is the spatial fixed spatial effect. The one lag is taken in order to adjust for autocorrelation.

Table 4: Panel Granger non-causality test between regional inflation and productivity growth

H_0	Productivity growth $\nrightarrow$ Regional inflation	Regional inflation $\nrightarrow$ Productivity growth
Lag=1	242.277 **	18.017
Lag=2	361.161 **	106.969
Lag=3	405.167 **	150.175

Note: See Table 2. The test is based on the VAR. "$X \nrightarrow Y$" means that X does not cause Y. Heterogeneity in coefficients and variance is considered. The statistic is distributed as Chi^2 with 47^{Lag} degrees of freedom.

Table 5: Results from the panel spatial econometric models ($\theta = 1$)

	Coef.	Std. Dev.	Coef.	Std. Dev.	Coef.	Std. Dev.
SAR	[1]		[2]		[3]	
Home productivity	-0.020**	0.003	-0.037**	0.005	-0.037**	0.005
Neighbors' inflation	0.976**	0.003	0.313**	0.074	0.307**	0.075
sigma^2	0.174**	0.006	0.175**	0.006	0.168**	0.006
chi^2(2)	498.70**		258.13**		225.00**	
Obs	1645		1645		1645	
Spatial fixed effects	○		×		○	
Time fixed effects	×		○		○	
SDM	[4]		[5]		[6]	
Home productivity	-0.034**	0.005	-0.037**	0.005	-0.037**	0.005
Neighbors' productivity	0.028**	0.006	-0.074**	0.028	-0.072**	0.027
Neighbors' inflation	0.976**	0.003	0.277**	0.077	0.270**	0.077
sigma^2	0.171**	0.006	0.174**	0.006	0.167**	0.006
Chi^2(3)	505.92**		210.69**		188.80**	
Obs	1645		1645		1645	
Spatial fixed effects	○		×		○	
Time fixed effects	×		○		○	
DSDM	[7]		[8]		[9]	
Lagged inflation	0.039**	0.006	0.165**	0.024	0.130**	0.024
Home productivity	-0.033**	0.005	-0.035**	0.005	-0.035**	0.005
Neighbors' productivity	0.025**	0.006	-0.076**	0.028	-0.074**	0.028
Neighbors' inflation	1.010**	0.006	0.249**	0.079	0.248**	0.079
sigma^2	0.173**	0.006	0.172**	0.006	0.166**	0.006
Chi^2(4)	84.81**		256.01**		194.01**	
Obs	1598		1598		1598	
Spatial fixed effects	○		×		○	
Time fixed effects	×		○		○	

Note: See Table 2. The sample period is from 1976-2010. The weight matrix is determined by the inverse of geographical distance between capitals of regions. The Hausman test results are shown as Chi^2.

Table 6: Results from the panel spatial econometric models ($\theta = 2$)

	Coef.	Std. Dev.	Coef.	Std. Dev.	Coef.	Std. Dev.
SAR	[10]		[11]		[12]	
Home productivity	-0.020**	0.003	-0.037**	0.005	-0.036**	0.005
Neighbors' inflation	0.968**	0.003	0.250**	0.04	0.248**	0.04
sigma^2	0.180**	0.006	0.172**	0.006	0.165**	0.006
chi^2(2)	258.39**		870.11**		796.45**	
Obs	1645		1645		1645	
Spatial fixed effects	○		×		○	
Time fixed effects	×		○		○	
SDM	[13]		[14]		[15]	
Home productivity	-0.033**	0.004	-0.036**	0.005	-0.036**	0.005
Neighbors' productivity	0.025**	0.006	-0.02	0.012	-0.019	0.012
Neighbors' inflation	0.969**	0.003	0.237**	0.405	0.235**	0.041
sigma^2	0.178**	0.006	0.172**	0.006	0.165**	0.006
Chi^2(3)	300.09**		824.75**		796.53**	
Obs	1645		1645		1645	
Spatial fixed effects	○		×		○	
Time fixed effects	×		○		○	
DSDM	[16]		[17]		[18]	
Lagged inflation	0.052**	0.006	0.163**	0.024	0.128**	0.024
Home productivity	-0.033**	0.005	-0.034**	0.005	-0.034**	0.005
Neighbors' productivity	0.023**	0.006	-0.019	0.012	-0.019	0.012
Neighbors' inflation	0.936**	0.007	0.213**	0.041	0.215**	0.042
sigma^2	0.182**	0.006	0.170**	0.006	0.164**	0.006
Chi^2(4)	1.38		708.76**		608.46**	
Obs	1598		1598		1598	
Spatial fixed effects	○		×		○	
Time fixed effects	×		○		○	

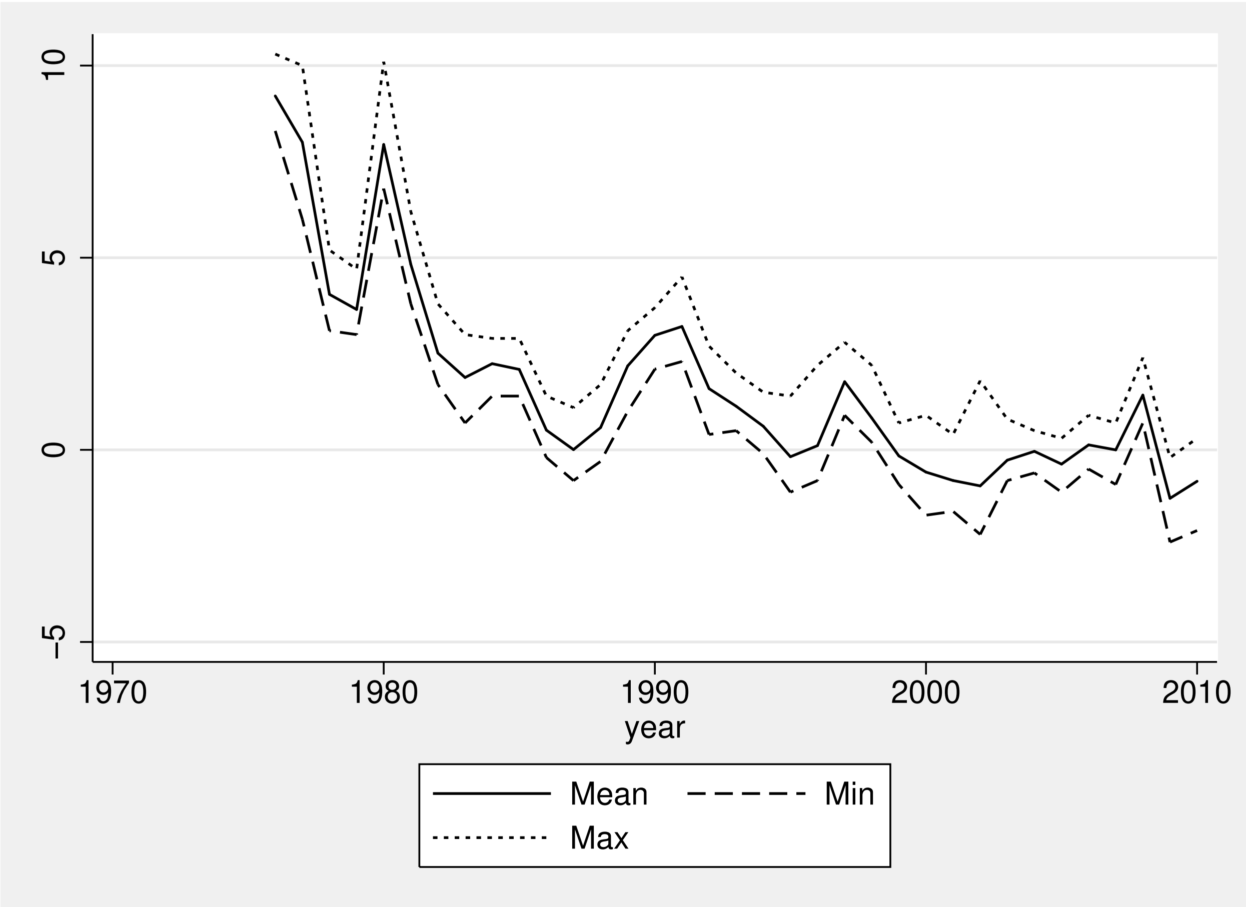
Notes: Sample period from 1976-2010. The weight matrix is determined by the inverse of squared geographical distance between capitals of regions. ** indicates that statistics are significant at the 1% level. The Hausman test results are shown as Chi^2.

Table 7: Total, direct and indirect effects of changes in home productivity

	Coef.	Std. Dev.	Coef.	Std. Dev.	Coef.	Std. Dev.
SAR	[1]		[2]		[3]	
Direct	-0.037**	0.006	-0.037**	0.005	-0.037**	0.005
Indirect	-0.764**	0.159	-0.017**	0.006	-0.016**	0.006
Total	-0.827**	0.165	-0.054**	0.009	-0.053**	0.009
SDM	[4]		[5]		[6]	
Direct	-0.039**	0.006	-0.038**	0.005	-0.038**	0.005
Indirect	-0.237**	0.184	-0.119**	0.04	-0.115**	0.039
Total	-0.276**	0.188	-0.158**	0.041	-0.152**	0.04
DSDM	[7]		[8]		[9]	
Direct	-0.016	0.144	-0.037**	0.005	-0.037**	0.005
Indirect	0.787	6.644	-0.112**	0.04	-0.110**	0.039
Total	0.77	6.788	-0.148**	0.04	-0.146**	0.04
	[10]		[11]		[12]	
Direct	-0.040**	0.006	-0.037**	0.004	-0.037**	0.004
Indirect	-0.601**	0.12	-0.012**	0.003	-0.012**	0.003
Total	-0.641**	0.126	-0.049**	0.006	-0.048**	0.006
SDM	[13]		[14]		[15]	
Direct	-0.040**	0.006**	-0.038**	0.004	-0.037**	0.004
Indirect	-0.208	0.149	-0.035*	0.016	-0.034*	0.016
Total	-0.248	0.154	-0.073**	0.017	-0.071**	0.017
DSDM	[16]		[17]		[18]	
Direct	-0.037**	0.006	-0.035**	0.005	-0.035**	0.005
Indirect	-0.116	0.072	-0.031*	0.016	-0.031*	0.016
Total	-0.153*	0.075	-0.066**	0.017	-0.066**	0.017

Notes: Sample period from 1976-2010. ** and * indicate that statistics are significant at the 1 and 5% level respectively.

Figure 1: Average, minimum, and maximum regional inflation rates (%)



Source: http://www.japan-guide.com/list/e1002.html

Figure 2: Japanese regions (prefectures)

Figure 3: Average distance between regional capitals (Km)

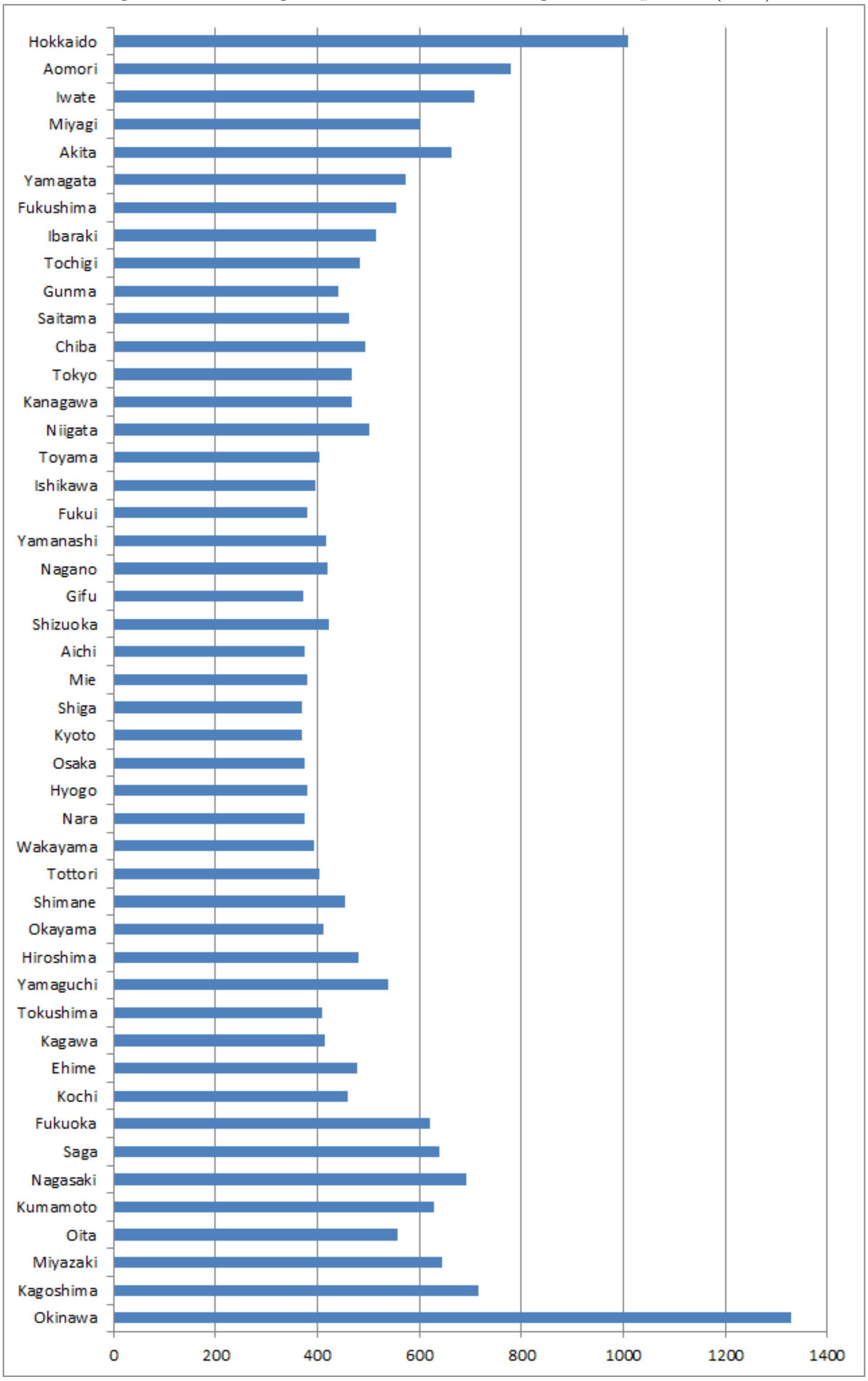


Figure 4: Regional inflation vs Productivity growth per employer