【Articles】

Nonparametric Approach to Convergence of Japanese Local Price Levels: A Failure of Purchasing Power Parity

ノンパラメトリック・アプローチによる 日本国内地域物価水準の収束の分析：購買力平価の不成立

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(**Abstract**)

This paper studies the convergence of local price levels within Japan using a recently developed nonparametric method, and investigates convergence among time series while allowing the possibility of convergence in subgroups, i.e., club convergence. The results show that Japanese local price levels have not been converging to a single value. Purchasing power parity fails to hold within Japan even in the long run. A long history of a single currency does not lead to price convergence. Instead, they form into a few groups. Japanese local price levels indicate club convergence. A group of higher price levels is associated with higher local income levels. When disaggregate price indexes are examined, a group of higher price levels of services is associated with higher local income levels. The results are consistent with the Penn effect.

(Key words)
Japanese local price index; purchasing power parity; club convergence; Penn effect

1. Introduction

This paper on the Japanese local price levels has two aims. The first aim is to investigate the convergence of local price levels while allowing for multiple convergences. If the price level is affected by economic fundamentals such as income, heterogeneity may lead to different price levels within Japan. Convergence within subgroups is investigated, as well as the convergence of all areas of Japan. The second aim is to investigate the factors driving high and low price levels. In the study of international economics, income is often regarded as affecting positively price levels through nontradable goods. This is known as the Penn effect. The Penn effect is considered for local economies within Japan. Even within a single country some goods are nontradable, so that a Penn effect may arise there.

This paper investigates the convergence of local price levels within Japan, using a nonparametric method. Phillips and Sul (2007 and 2009) developed a simple nonparametric test for convergence among time series while allowing the possibility of convergence in subgroups, often termed 'club convergence'. The present work uses that method and does not involve a unit root test, which has been used in most previous studies of domestic price convergence. The results indicate that Japanese local price levels have not been converging to a single value. Purchasing power parity (PPP) fails to hold in Japan even in the long run. Instead, prices form into a few groups. Local general price levels in each group converge, and different groups converge to different values. It is also found that average price levels of the groups have recently been diverging from each other. Local general price levels are positively correlated with local per-capita income. This work proceeds by compiling local disaggregate price indexes and examining their convergence. Most of the disaggregate indexes indicate club convergence rather than unanimous convergence. The indexes of services are positively correlated with per-capita income levels. These results are consistent with the Penn effect.

Convergence of price levels and inflation rates within single-currency areas have recently been extensively investigated. In particular, convergence of price levels and inflation rates in the Euro area has been closely studied.[1] Numerous studies also exist of convergence of domestic local price levels within a single country, which generally comprises a single currency area. In general, PPP is regarded as being more likely to hold within a single country than across countries. There are fewer barriers to trade between areas within a country than there are between different countries, in which there are differences in distribution systems and in the customs of residents. Japan has had a single currency for many years. Its society is considered as being relatively homogeneous, and it enjoys developed and efficient distribution systems. Fielding et al. (2015) show that language and culture differences increase regional price disparity even within a single country by examining the Canadian and Nigerian economies. Japan is considered as being among the most homogeneous countries with regard to language and culture. Convergence is more likely to hold in a country like Japan than in a large single-currency area such as the Euro area, which is regarded as less homogeneous than Japan and has a much shorter history of being under a single currency.

Most of former studies in this area, including those of the Japanese economy, employ unit root tests. Unit root tests have made a great contribution to the study of convergence of price levels, but they can handle only a restricted notion of convergence. They assume that a time series is generated by a certain class of stochastic process. The method developed by Phillips and Sul (2007 and 2009) can handle less restricted forms of convergence, and allows heterogeneous transitions to convergence. It can also be used to identify groups of time series that converge to different equilibria. This makes it possible to investigate the factors that give rise to convergent values.

A standard methodology in the literature is to use a unit root test to examine whether relative price levels between areas follow a stationary process. If relative local price levels are stationary, it is concluded that local price levels converge in the long run. This convergence is often termed 'the relative PPP'. Most studies in this area, including Parsley and Wei (1996) and Cecchetti et al. (2002), which are the most prominent studies, follow this methodology.[2)]

The standard methodology is represented as follows. The relative price level in cities i and j at period t is defined logarithmically as

$$p_{ij,t} \equiv \ln(P_{i,t}/P_{j,t}) \qquad t = 1,\cdots,T, \tag{1}$$

where $P_{i,t}$ and $P_{j,t}$ are the price levels in cities i and j at period t. If p_{ij} follows a stationary process, then the local price level in city i relative to the local price level in city j moves around a particular long-term level, implying a relative PPP. In order to examine stationarity, a unit root test is performed according to the following equation,

$$\Delta p_{ij,t} = \mu_i = \delta_{ij} p_{ij,t-1} + \sum\nolimits_{l=1}^{q_{ij}} a_{ij,l} \Delta p_{ij,t-l} + e_{ij,t} \tag{2}$$

in which the number of lag terms, q_{ij}, is determined on the basis of an information criterion, such as the Akaike information criterion. This methodology requires that the price levels in the two cities in logs be cointegrated if the price levels are found to be converging.

In fact there may be differing transitions to convergence, some of which do not necessarily satisfy a cointegrated relation.[3)] The nonparametric test developed by Phillips and Sul (2007 and 2009) allows heterogeneous transition paths to convergence. Convergence considered in the test and cointegration are related, but they have distinct features. Convergence in the test does not require a cointegrated relation. Further, the procedure developed along with the test allows examination of club convergence and identifies which cities form a convergent group.

This test has already been applied in many empirical works, particularly in the field of economic growth.[4)] It has not been used in many studies of convergence of price levels, however. It has been used by Phillips and Sul (2007), which studies US local general price levels; Kim and Rous (2012), which studies US local housing prices; Fischer (2012), which studies convergence of washing machine prices in Europe; and Nagayasu (2011), and Ikeno (2014b), both of which study Japanese local general price levels. The present work uses the test to analyze not only general price levels but also disaggregate price indexes in Japan.

What affects local price levels within a single country? In order to investigate it, the present work examines what characterizes each group after identifying the members of convergent groups. The positive relation between incomes and price levels is well known in international economics, and is called the Penn effect.[5] There are diverse theories explaining the effect, but a common point is the positive relation between incomes and general prices through the channels of nontradable goods. The present work investigates empirically the relation between regional incomes and regional general price levels, and also the relation between regional incomes and regional price levels of nontradable services within Japan. There are already some studies on the effect within a single country. Massida and Mattana (2008) consider the effect of incomes in their studies of the convergence of domestic price levels within Italy, and they assert that the positive effect of incomes on the price levels is irrelevant. Vaona (2011) states that regional productivity growth and regional inflation rates are negatively correlated in Italy, which would be inconsistent with the positive effect. Nagayasu and Inakura (2009) assert that the positive effect is relevant in Japanese regional economies, and Cheung and Fujii (2014) extensively investigate the relation between local price levels and local incomes levels within Japan and conclude that there exists the positive effect. They assert the Penn effect holds there. These studies on the Japanese economy investigate contemporaneous correlation between price levels and incomes. The present paper investigates long-run correlation between price levels and incomes.

The present paper uses two sets of price data to investigate convergence and also the relation between the price level and income. Statistical examination of the general price levels is firstly conducted with data which are readily available. The data used are compiled by the Statistics Bureau of Japan (SBJ). A similar statistical examination is then conducted on disaggregate price indexes, using data compiled specifically for the current work.

Results from the Phillips-Sul procedure indicate that all local general price levels in Japan fail to converge to a single price level. They do, however, form into two groups; members of each group converge. Local per-capita incomes also fail to converge to a single income level. They form into several groups, in most of which there is convergence. Based on price levels and income levels, Japanese economies are divided into groups. The results also show a positive correlation between general price levels and income levels. Many disaggregate price indexes indicate club convergence, and some undergo unanimous convergence. It is also shown that price indexes of nontradable services are positively correlated with income levels. These results are consistent with the Penn effect.

This paper is organized as follows. Section 2 explains the methodology used in investigating convergence, following Phillips and Sul (2007 and 2009). Section 3 explains the data used in this work. Section 4 discusses convergence of general price levels and per-capita incomes within Japan. This section also analyzes the relation between general price levels and incomes, using probit models. Section 5 compiles original data for local disaggregate price indexes within Japan, and then analyzes convergence of the indexes and their relation with incomes. Section 6 sets out conclusions.

2. Methodology

The procedure developed by Phillips and Sul (2007 and 2009) is as follows.

Consider N time series; $y_{i,t}$ for $i = 1,\cdots, N$ and $t = 1,\cdots, T$. Suppose that a time series y_{it} can be decomposed into two elements: an idiosyncratic loading factor $\delta_{i,t}$, and a common factor θ_t which is the same for all i's as follows:

$$y_{i,t} = \delta_{i,t}\theta_t \qquad t = 1,\cdots,T, \tag{3}$$

Phillips and Sul consider the following model:

$$\delta_{i,t} = \delta_i + \sigma_i \xi_{i,t} L(t)^{-1} t^{-\alpha} \qquad t = 1,\cdots,T, \tag{4}$$

where $\xi_{i,t}$ is iid(0,1) across i but is weakly dependent on t, and $L(t)$ is a slowly varying function for which $L(t)\to\infty$ as $t\to\infty$. They consider convergence as meaning that

$$\lim_{k\to\infty}(y_{i,t+k}/y_{j,t+k}) = 1 \quad \text{for all } i \text{ and } k. \tag{5}$$

This is termed 'relative convergence' in their studies. This condition is equivalent to

$$\lim_{k\to\infty}\delta_{i,t+k} = \delta \quad \text{for all } i. \tag{6}$$

This definition of convergence allows for diverse patterns of transition.

Convergence is tested by a 'log t test'. Specifically, it is tested using the following null and alternative hypotheses:

$$H_0:\ \delta_i = \delta \ \text{ for all } i \text{ and } \alpha \geq 0 \tag{7}$$
$$H_1:\ \delta_i \neq \delta \ \text{ for some } i \text{ or } \alpha < 0. \tag{8}$$

The null hypothesis implies that all times series converge; the alternative hypothesis implies failure of convergence. Phillips and Sul show that the null hypothesis of convergence can be tested using the following equation:

$$log\,(H_1/H_t) - 2\ log\ L(t) = a + b\ log\ t + u_t \qquad t = T_0,\cdots,T, \tag{9}$$

where $H_t = \sum_{i=1}^{N}(h_{i,t}-1)^2/N$, $h_{i,t} = y_{i,t}/(\sum_{j=1}^{N}y_{j,t}/N)$, and $T_0 = [rT]$ for some r. They show that the null hypothesis of convergence is adequately tested by a one-sided t-test with $b \geq 0$, by using a variance estimator that is robust to heteroskedasticity and autocorrelation (HAC). They propose using $log\,(t)$ for $L\,(t)$ and choosing $r = 0.3$. The null hypothesis is rejected at the 5% significance level if the t-statistic of b is less than −1.65.

If convergence is rejected for the overall time series, the procedure is then applied to subgroups. Phillips and Sul also provide an algorithm of clustering for examining the convergence of subgroups, i.e., club convergence. First, all time series are sorted on the basis of the last observation. Second, the log t test is executed starting with the time series of the highest last observation by adding time series one by one, according to descending order of the last observation. The procedure is continued until the t-statistic of b is less than -1.65. Then a subconvergent group of time series is formed for which the t-statistic of b is not less than zero. Use of the sign test, i.e., the positive t-statistic, minimizes the sum of type I and II errors. Third, the log t test is performed on the remaining time series. If convergence is rejected, then the procedure is started with the remaining time series. The log t test is performed with the time series of the highest last observation, adding one by one as above. Finally, the possibility of merger is explored so as to avoid overdetermination of convergent subgroups. The log t test is executed on a combination of subconvergent groups. They are merged if the t-statistic of b is not less than -1.65.

This procedure is applied below to both local price levels and local per-capita income levels with recommended parameter values. The Newey-West estimator is used as a HAC estimator. Following the suggestion in Phillips and Sul (2005), time series to which the log t test and the Phillips-Sul procedure are applied are Hodrick-Prescott (HP) filtered.[6)]

3. Data

For the investigation of local general and disaggregate price levels, this work uses three sets of price index series, all of which are compiled by the SBJ for statistical analysis. These three sets are the regional difference indexes of consumer prices (RDICPs), the local consumer price indexes (CPIs), and the price indexes from the 'National Survey of Prices'.

The first set is the series of RDICPs. They are compiled for inter-regional comparison of price levels within Japan, and they indicate relative local price levels on the national common base for each year. The data is annual, and comprises general consumer prices. The series do not contain disaggregate price indexes. Compilation of the RDICP is based on the weight of the national CPI, which means that the weights are common among all cities investigated. The data used in the present analysis are from 1974 to 2013. The base of the RDICP, which is always set to 100, changed over time; it was the national CPI for the period 1974 to 2009; and from 2011 to 2013 it was the average of all cities covered, which included all prefecture capitals as well as other cities. The sources of the RDICP are various issues of "*The Annals of Consumer Price Survey*". The data used in the present work covers 47 prefecture capitals, i.e., all prefecture capitals.[7)] These series are used to examine the convergence of general price levels.

The second data set is the series of local CPIs. The local CPIs are compiled for inter-temporal comparison of price levels for each area. They are not suitable for inter-regional comparison of absolute price levels. They contain the general price series and disaggregate price indexes in all prefecture capitals and other cities, and are not compiled on the basis of national common weights. They are compiled both monthly and annually. The annual series of the 47 prefecture capitals are used below. The local CPIs are used over the period 1975 to 2013.

The third set is the National Survey of Prices. Indexes were compiled from the Survey so as to study price differences among regions and outlets. The Survey was based on more extensive investigation than the survey from which the RDICPs and the CPIs are compiled. This Survey was conducted only periodically, however, mostly every five years. The most recent Survey was conducted in 2007, and it is no longer conducted. Data compiled from the Survey cover all prefecture capitals as well as many other cities and areas. Data include the general price index and disaggregate price indexes.

This work uses annual series of the local disaggregate CPIs together with indexes from the National Survey of Prices in order to compile new price series which are in an inter-regionally comparable form. These are used to investigate the Penn effect. Disaggregation of indexes is common between the local CPIs and the National Survey of Prices. As a result, it is possible to combine the two data sets.

This work uses two variables per prefecture to represent income: the per-capita prefectural income, and the per-capita compensation of employees in the prefecture in which the city is located, over the periods 1974 to 2011 and 1975 to 2011 respectively. They are denoted in thousand yen. Income variables of cities are generally unavailable in a suitable form over a long period, partly because the boundaries of many cities have changed substantially over time. The per-capita prefectural income is the counterpart of the per-capita Gross National Product (GNP).[8] The per-capita compensation of employees does not include incomes of firms and property income. Because of the concentration of firms in Tokyo, per-capita prefectural income is sometimes regarded as being disproportional to household income in each prefecture.

The sources of all data, except the RDICPs, are contained in the dataset at the home page of the SBJ.[9]

4. Convergence of general price levels and incomes

This section analyzes convergence of general price levels and per-capita incomes among areas within Japan, using the RDICPs as well as income variables.

4-1 Price levels

The RDICP is transformed using two steps, as follows. The index is first divided by the average over the 47 prefecture capitals, and is then transformed into a logarithmic form, i.e.,

$$price_{i,t} = log(rdicp_{i,t}/\overline{rdicp}_t)$$

where $rdicp_{i,t}$ is the RDICP in city i at period t, and $\overline{rdicp}_t$ is the average of $rdicp_{i,t}$ over all i's, $i = 1 \cdots 47$, i.e., $\overline{rdicp}_t \equiv (1/47)\ \Sigma_{i=1}^{47} rdicp_{i,t}$. The HP filter is then applied to $price_{i,t}$.[10]

Convergence is tested in two stages. First, the log t test is executed on the full set of RDICPs with the data from 1974 to 2013, with r set to 0.3. The result is:

$$\log(H_1/H_t) - 2\log(\log(t)) = \underset{(-2.22)}{-0.83} - \underset{(-3.50)}{0.40}\log(t). \tag{10}$$

T-statistics are shown in parentheses. This result strongly rejects convergence of price levels in all cities. It implies a failure of unanimous convergence and also a failure of PPP in the long run. This result is consistent with Ikeno (2014b), which uses the RDICP data for longer than the data used here, but exclude Naha due to its unavailability and are not HP-filtered.

Convergence of subgroups is explored. The Phillips-Sul procedure discerns two convergent subgroups. These are shown in Table 1. Cities are listed in descending order of the last observation. There are only two subgroups and convergence of the full set is rejected, so the possibility of merger is not investigated. Figure 1 shows the variances of both groups and the

Table 1. Club convergence of RDICPs

Group	cities	$\hat{b}$	t-values
Group 1	Yokohama, Tokyo, Saitama, Kanazawa, Nagasaki, Wakayama, Kobe, Kyoto, Fukushima, Yamagata, Hiroshima, Matsue, Utsunomiya, Osaka, Okayama, Tokushima, Yamaguchi, Naha,	0.01	0.05
Group 2	Tsu, Kumamoto, Otsu, Kofu, Shizuoka, Sapporo, Kochi, Nagoya, Matsuyama, Aomori, Kagoshima, Morioka, Chiba, Niigata, Fukui, Mito, Toyama, Tottori, Oita, Takamatsu, Nagano, Gifu, Saga, Sendai, Maebashi, Nara, Fukuoka, Akita, Miyazaki	0.21	1.14

Notes: Data used in the regression start in 1974 and ends in 2013. Cities are in descending order on the basis of the observation of the index in 2013.

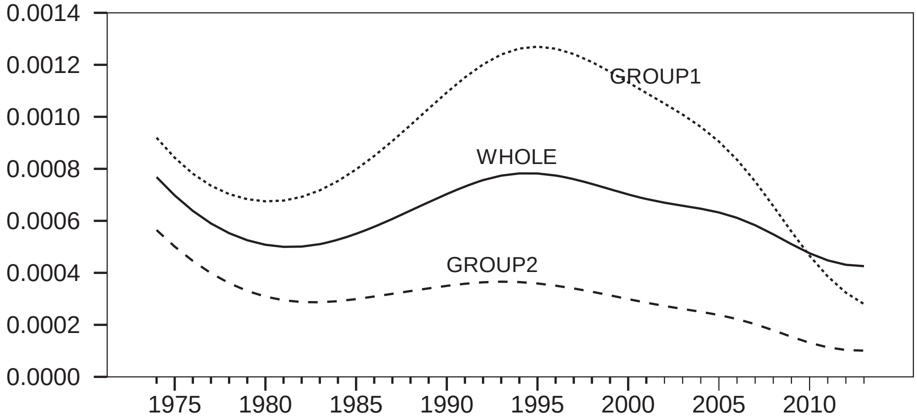

Figure 1. General price levels: variances of the whole set and Groups 1 and 2

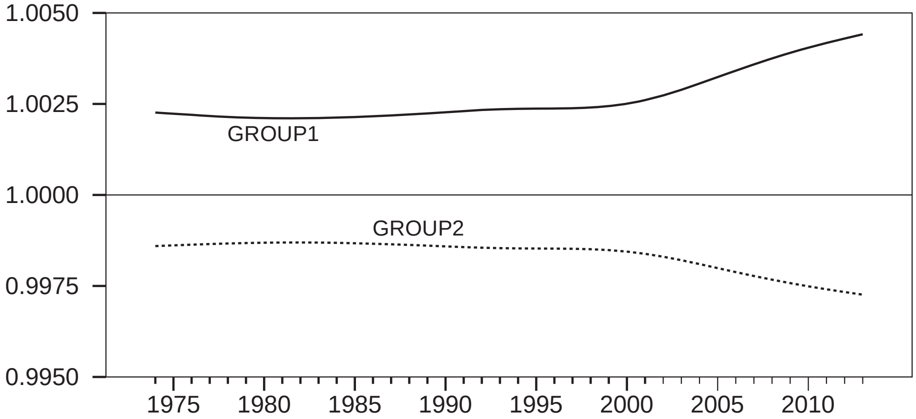

Figure 2. General price levels: averages of Groups 1 and 2

whole set. The variance of Group 1 increased from the beginning of the 1980s to the mid-1990s, and has since been decreasing rapidly. The counterpart of Group 2 indicates a similar shift, but its change over time is much smaller. The variance of the whole set has also been decreasing since the mid-1980s but its long-run decease is less clear than those of Groups 1 and 2; the variance was almost the same around 1980 and around 2010. The figure shows that each of the two groups has been σ (sigma)-converging since the mid-1990s. Figure 2 shows the averages of the two convergent groups. The RDICPs used for the figure are not in logs but are normalized by the average, i.e., $rdicp_{i,t}/\overline{rdicp_t}$, and are then HP-filtered in order to set the average over the cities equal to one. Divergence between the two groups is remarkable from the mid-1990s, before which the relation between the two had been stable. This divergence implies that a single price index is not appropriate to represent the full set of Japanese local economies over a long run. The figures show convergence in each group and divergence between the two groups in the long run. Shaded parts in Figure 3 are areas belonging to Group 1. It indicates that Group 1 mainly consists of most areas of the Japanese two major megalopolitan areas, i.e., the Shutoken Megalopolitan Area and the Kansai Megalopolitan Area, and their adjoining areas.

4-2 Incomes

The convergence of incomes is now examined. The Penn effect predicts the positive correlation between the income and the price level. Then, incomes and price levels should converge in tandem in case of convergence. When local price levels fail to converge unanimously, then local incomes should not all show convergence.

Per-capita prefectural income and per-capita compensation of employees are transformed in two steps, as follows. The indexes are first normalized by dividing by the national level. Then the HP filter is applied to the log of the normalized index, as with the price index.

First, a log t test is executed on the full set of income indexes with r set to 0.3. The

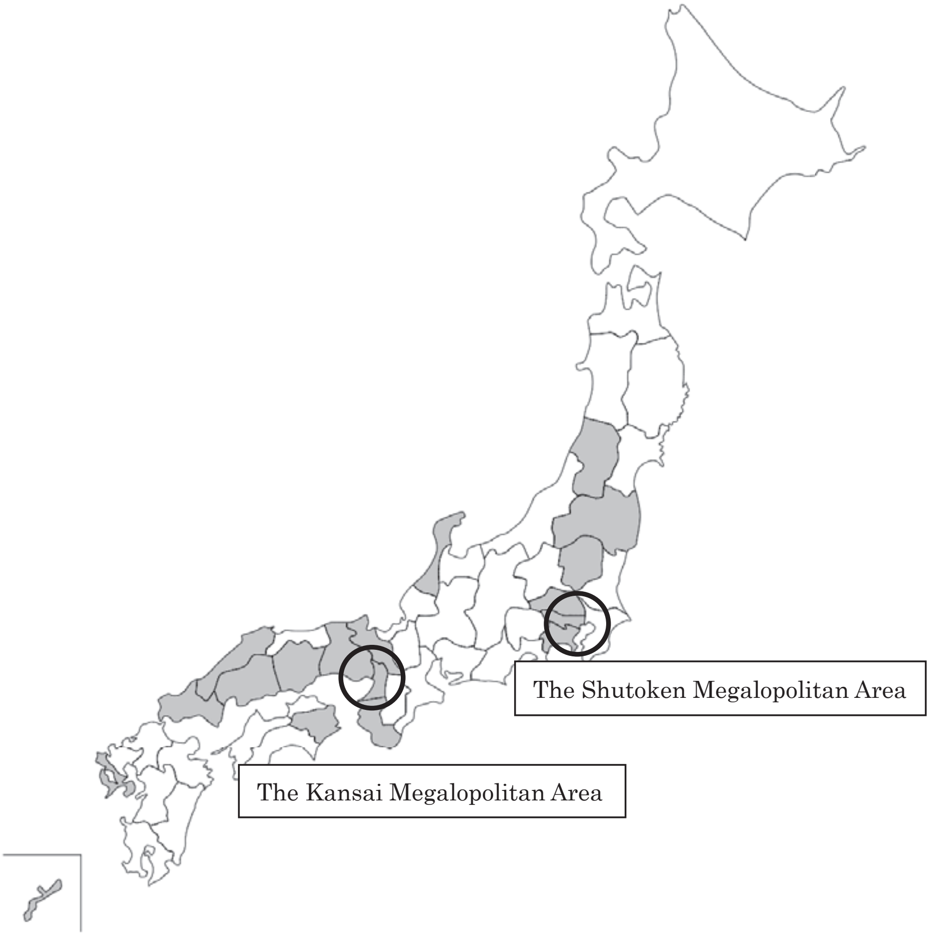

Figure 3. General price levels: geographical locations of Group 1

results from per-capital prefectural income and per-capita compensation of employees are, with data over the periods 1974 to 2011 and 1975 to 2011, respectively as follows;

$$log(H_1 / H_t) - 2\,log(log(t)) = \underset{(-2.62)}{-0.26} - \underset{(-21.95)}{0.69}\,log(t) \tag{11}$$

and

$$log(H_1 / H_t) - 2\,log(log(t)) = \underset{(-3.21)}{-0.07} - \underset{(-84.79)}{0.62}\,log(t) \tag{12}$$

The t-statistics are shown in parentheses. Both results imply strong rejection of convergence of the whole set. Incomes fail to indicate unanimous convergence.

The convergence of subgroups is now explored. The Phillips-Sul procedure based on per-capita prefectural income gives rise to five groups, three of which indicate convergence.[11] Any merger of groups is rejected. These groups are shown in Table 2. Cities are listed in descending order of the last observation. Tokyo and Naha do not show convergence with any other city.

Table 3 shows results from the per-capita compensation of employees. The procedure eventually gives rise to five groups. Tokyo and Miyazaki do not show convergence with any other city. The other three groups indicate convergence. Any merger of groups is rejected. Both of the income indexes indicate that Japan is divided into several groups. Both indexes

Table 2. Club convergence of prefectural income per capita

Group	cities	$\hat{b}$	t-values
Group 1	Tokyo		
Group 2	Shizuoka, Nagoya, Otsu, Mito, Hiroshima, Toyama, Yokohama, Utsunomiya	0.06	0.68
Group 3	Osaka, Yamaguchi, Kyoto, Tsu, Chiba, Maebashi, Fukui, Kanazawa, Fukuoka, Saitama, Takamatsu, Nagano, Kofu, Okayama, Tokushima, Niigata, Gifu, Kobe, Wakayama, Matsuyama, Fukushima, Saga, Oita, Sapporo, Nara, Sendai, Kagoshima, Yamagata, Kumamoto	0.04	0.27
Group 4	Nagasaki, Matsue, Aomori, Morioka, Akita, Tottori, Miyazaki, Kochi	0.08	0.34
Group 5	Naha		

Notes: Data used in the regression start in 1974 and ends in 2011. Cities are in descending order on the basis of the observation of the index in 2011.

Table 3. Club convergence of per-capita compensation of employees

Group	cities	$\hat{b}$	t-values
Group 1	Tokyo		
Group 2	Osaka, Yokohama, Nara, Utsunomiya, Saitama, Kobe, Sapporo, Nagoya, Kyoto, Tsu, Nagano, Chiba, Kofu	2.31	4.61
Group 3	Mito, Fukuoka, Takamatsu, Kochi, Hiroshima, Yamaguchi, Tokushima, Toyama, Shizuoka, Okayama, Sendai, Maebashi, Otsu, Gifu, Fukui, Fukushima, Niigata, Wakayama, Kanazawa, Matsue, Yamagata, Oita, Kumamoto, Matsuyama, Morioka, Kagoshima, Nagasaki, Aomori, Tottori	0.01	0.18
Group 4	Miyazaki		
Group 5	Naha, Akita, Saga	0.67	1.88

Notes: Data used in the regression has start in 1975 and end in 2011. Cities are in descending order on the basis of the observation of the index in 2011.

indicate that Tokyo has a different time path from other areas, and has the highest rank of per-capita income.

4-3 Price levels and incomes

This section studies the relation between regional price levels and regional per-capita incomes. A probit model is used. Since the price levels form into two convergent subgroups, the following equation is estimated by maximizing the likelihood;

$$g_i = f(\alpha + \beta x_i). \tag{13}$$

where $f(\cdot)$ is a standard normal distribution function, $g_i = 1$ if city i belongs to Group 1, the highest convergent group, of the RDICPs, and $g_i = 0$ otherwise. The variable x_i represents the income level of the prefecture to which city i belongs, and is the average of the variable $income_i$ over the periods 1974 to 2011 and 1975 to 2011 respectively, in logarithms; $income_i$ is the ratio of either the per-capita prefectural income or the per-capita compensation of employees to the average of the 47 areas. If a high per-capita income is associated with a high convergent price level, β should be significant and positive.

Table 4 shows results using the per-capita prefecture income and the per-capita compensation of employees. With the per-capita prefectural income, β is estimated to be positive but is not significant. With the per-capita compensation of employees, β is estimated to be positive and it is significant. The results indicate that a high convergent price level is associated with the high per-capita income level, although there is a difference in the level of support between the two income indexes. When logit models are estimated, the results are mainly similar to results from probit models, and the results are not reported here.

5. Analysis of the disaggregate price indexes

The Penn effect predicts an association of high price levels with high income levels through nontradable goods. Section 4 shows that a high general price levels are associated with high income levels, and the present section examines the convergence of disaggregate price indexes, and also their relation with incomes.

Table 4. Probit model of RDICP with per-capita income

$g_i = f(\alpha + \beta \cdot x_i)$

income variable	α	β	*pseudo* R^2
prefectural income	–0.130 (0.238)	1.627 (1.415)	0.029
compensation of employees	0.038 (0.254)	3.962** (1.949)	0.096

Notes: '**' and '*' denote significance at the 5% and 10% significance levels, respectively. Standard errors are in parentheses. For the *pseudo* R^2, see Estrella (1998).

5-1 Compilation of disaggregate price indexes

Time series of local disaggregate price indexes are not readily available for Japan in an inter-regionally comparable form. Time series of local price indexes in an intertemporally comparable form are available in some countries, but even these are seldom in a form useful for inter-regional comparison. A few methods are capable of addressing this problem; Chen and Devereux (2003) compare absolute price levels in US cities, for example.[12] They used estimates of absolute price levels of areas at a certain point of time. They project the absolute price indexes of areas for other years by combining the estimates and inflation rates for areas calculated from individual city price indexes. Faber and Stockman (2009) and Nagayasu (2011) use a similar method to compile price data for European countries and Japan.

This work follows Chen and Devereux (2003). New series are compiled based on the local CPIs and on the National Survey of Prices. Inter-regional price indexes of the National Survey of Prices are combined with intertemporal changes in the local CPIs. The k th disaggregate series in city i at period t, $PRICE^k_{i,t}$, is defined using price indexes in the National Survey of Prices conducted in 2002 as follows;

$$PRICE^k_{i,t} = cpi^k_{i,t} \times (nsp^k_{i,2002}/cpi^k_{i,2002})$$

where $cpi^k_{i,t}$ is the k th disaggregate CPI in city i at period t, $cpi^k_{i,2002}$ is the k th disaggregate CPI in city i in 2002, and $nsp^k_{i,2002}$ is the k th disaggregate index in city i according to the National Survey of Prices conducted in 2002.[13] The new series is compiled for the period 1975 to 2013. The HP filter is applied to the log of the newly compiled series, i.e., $price^k_{i,t} = log\,(PRICE^k_{i,t})$.

Ten major disaggregate series were compiled, as follows: 'foods', 'fuel, light and water charges', 'furniture and household utensils', 'clothes and footwear', 'housing', 'education', 'medical care', 'transportation and communication', 'culture and recreation', and 'miscellaneous'. These are shown in Table 5 together with their weights in the national CPI of the 2010 base, and also with weights of goods and services in each disaggregate index according to the 2010 base. They are classified into three groups: Group A includes price indexes in which weights of goods are dominant; Group B includes price indexes in which weights of services are dominant; in Group C neither of the weights is dominant. Goods are regarded here as being tradable, and services as being nontradable.

5-2 Disaggregate price indexes

A log t test is first executed on the full set for each index with the data from 1975 to 2013, with $r = 3$. Table 6 shows the results of these log t tests. Convergence of the whole sample is rejected for all price indexes except 'furniture and household utensils' and 'medical care'. The nationwide strong regulation of medical costs is obviously the cause of the unanimous convergence of 'medical care'.

Both indexes in Group B, in which services are dominant, reject unanimous convergence. Further, many indexes in Group A, in which goods are dominant, and in Group C, in which nei-

Table 5. Weights of disaggregate price indexes

price index	Weights in the national CPI	Weights in each index	
		Goods	Services
Group A			
Foods	0.253	0.789	0.211
Fuel, light and water charges	0.070	0.909	0.091
Furniture and household utensils	0.035	0.910	0.090
Clothes and footwear	0.041	0.933	0.067
Group B			
Housing	0.212	0.034	0.966
Education	0.033	0.027	0.973
Group C			
Medical care	0.043	0.481	0.519
Transportation and communication	0.142	0.373	0.627
Culture and recreation	0.115	0.463	0.537
Miscellaneous	0.057	0.448	0.552
Total	1.000		

Table 6. Probit model of RDICP with per-capita income

$$log\,(H_1/H_t) - 2\,log\,(log\,(t)) = a + b \cdot log\,(t)$$

price index	$\hat{b}$	t-value
Group A		
Foods	–0.23*	–3.22
Fuel, light and water charges	–0.75*	–9.87
Furniture and household utensils	0.01	0.03
Clothes and footwear	–0.53*	–5.90
Group B		
Housing	–0.15*	–3.02
Education	–0.47*	–3.09
Group C		
Medical care	0.53	2.80
Transportation and communication	–0.44*	–12.70
Culture and recreation	–0.89*	–8.82
Miscellaneous	–0.64*	–15.87

Notes: Data used in the regression start in 1975 and end in 2013.
‘*’ denotes rejection of the null hypothesis at the 5% significance level.

Table 7. Clustering of price indexes

Price index	Number of convergent groups	Number of cities involved			
		Group 1	Group 2	Group 3	Group 4
Group A					
Foods	2	18	29		
Fuel, light and water charges	3	5	25	17	
Furniture and household utensils	1	47			
Clothes and footwear	3	2	36	9	
Group B					
Housing	2	43	4		
Education	3	26	19	2	
Group C					
Medical care	1	47			
Transportation and communication	4	1	1	22	23
Culture and recreation	3	1	36	10	
Miscellaneous	3	2	26	19	

ther of goods and services is dominant, reject unanimous convergence.[14)]

Convergence of subgroups is then examined for all price indexes except those showing unanimous convergence. Table 7 shows the number of convergent groups and the number of cities contained in each convergent group.[15)] Group 1 has the highest convergent price level, Group 2 has the second highest convergent price level, and so on. The numbers are based on the final clustering after merging of initial convergent groups according to the test proposed by Phillips and Sul (2007). Where the number in a group is equal to one, that is a city for which the price level does not converge with any other city.

5-3 Price levels and income

This section investigates the relation between the disaggregate price index and per-capita income. In the case with two convergent groups, a probit model is used as expressed by Eq. (13); the explanatory variable is the same as in Section 4. In the case with more than three convergent groups, a following ordered probit model is used;

$$g_i = f(\beta \cdot x_i) \tag{14}$$

where g_i is set to zero for the lowest convergent group, and for a group involving a higher convergent price level g_i is increased by one each time. In the case of three convergent groups, for instance, $g_1 = 2$, $g_2 = 1$, and $g_3 = 0$.

Table 8 shows results using the per-capita prefectural incomes, and Table 9 shows results using per-capita compensation of employees. For an ordered probit model, the cut points of $f(\beta x_i)$ between convergent groups, denoted by μ_i, are shown. The indexes ‘furniture and house-

Table 8. Probit models with per-capita prefectural income

$g_i = f(\alpha + \beta \cdot x_i)$ or $g_i = f(\beta \cdot x_i)$

Price index	α	β	μ_1	μ_2	μ_3	*pseudo* R^2
Group A						
Foods	–0.097	1.945				0.041
	(0.240)	(1.432)				
Fuel, light and	–5.014**	0.125	2.015***		0.233	
water charges		(2.343)	(0.301)	(0.513)		
Clothes and						
footwear	2.916*	–1.247***	1.520***		0.085	
		(1.613)	(0.342)	(0.353)		
Group B						
Housing	2.419***	6.320**				0.130
	(0.680)	(3.105)				
Education		4.538**	–2.461***	–0.648**		0.180
		(2.069)	(0.548)	(0.320)		
Group C						
Transportation and		2.385	–0.294	1.590***	2.007**	0.068
communication		(1.586)	(0.233)	(0.504)	(0.832)	
Culture and	2.821	–1.152***	1.908***		0.071	
recreation		(2.138)	(0.372)	(0.477)		
Miscellaneous		0.831	–0.331	1.642***		0.009
		(1.828)	(0.287)	(0.396)		

Notes: '*', '**', and '***' denote significance at the 10, 5, and 1 percent levels, respectively. x_i is the average income index (per-capita prefectural income) over 1974-2011 in log. Standard errors are in parentheses. For the *pseudo* R^2, see Estrella (1998).

hold utensils' and 'medical care' are excluded because they exhibit unanimous convergence. In Group A, both income indexes are significant and negative for 'fuel, light, and water charges'. They are not significant and positive for any disaggregate price index, except for 'clothes and footwear' using the per-capita prefectural income. In Group B, both or either of the two income indexes are significant and positive for both disaggregate price indexes. In Group C the income variables are not significant except for 'transportation and communication' using the per-capita compensation of employees. These results generally support the hypothesis that the disaggregate price indexes of services are positively correlated with incomes, showing the Penn effect. The negative correlation of the price index of 'fuel, light, and water charges' with the income indexes is noteworthy. It is presumably related to economies of scale. Most items covered by this index are subject to economies of scale.[16] Areas of high income tend to be populous, and therefore the costs of those items tend to be low, which are reflected in their prices. This negative correlation of items in 'fuel, light, and water charges' obviously affects the results for the correlation between the general price level and income. The negative effect

Table 9. Probit models with per-capita compensation of employees

$g_i = f(\alpha + \beta \cdot x_i)$ or $g_i = f(\beta \cdot x_i)$

Price index	α	β	μ_1	μ_2	μ_3	*pseudo* R^2
Group A						
Foods	−0.124	2.041				0.028
	(0.242)	(1.799)				
Fuel, light and		−7.232***	0.218	2.182***		0.282
water charges		(2.627)	(0.285)	(0.494)		
Clothes and		1.887	−1.057***	1.574***		0.024
footwear		(2.382)	(0.375)	(0.458)		
Group B						
Housing	1.816	3.897				0.039
	(0.487)	(3.136)				
Education		7.422***	−2.788***	−0.847**		0.254
		(2.576)	(0.681)	(0.348)		
Group C						
Transportation and		3.442*	−0.340	1.542***	1.951**	0.089
communication		(2.081)	(0.245)	(0.402)	(0.835)	
Culture and		5.482	−1.411***	1.950***		0.141
recreation		(3.467)	(0.532)	(0.558)		
Miscellaneous		3.301	−0.552*	1.548***		0.080
		(2.264)	(0.304)	(0.342)		

Notes: '*', '**', and '***' denote significance at the 10, 5, and 1 percent levels, respectively. x_i is the average income index (per-capita compensation of employees) over 1975-2011 in log. Standard errors are in parentheses. For the *pseudo* R^2, see Estrella (1998).

of this index obscures the positive effects of other indexes in the relation between the general price level and incomes.

6. Conclusion

The present results show that Japanese local economies do not unanimously converge for either the price level or the per-capita income level. Japanese local economies are not universally converging. In fact, Japanese local economies are partitioned into subgroups, in each of which price levels and per-capita incomes converge. A high convergent price level is associated with the high per-capita income level. Many disaggregate price indexes do not indicate unanimous convergence. Even the indexes in which goods are dominant fail to indicate unanimous convergence. Ikeno (2014a) claims that convergence of local general and disaggregate price indexes is limited in Japan, using a pairwise approach. The result in this paper is consistent with the failure of unanimous convergence of price indexes shown in the present work.

Convergent high price levels of the indexes in which services are dominant are associated with high per-capita income levels, showing the Penn effect. The difference in per-capita incomes is a cause of disparity of Japanese local price levels, leading to a failure of PPP.

Price convergence has not occurred in Japan even after a long history under a single currency. This suggests that it will not be easy for the Euro area to attain price convergence.

Notes

1) For example, Faber and Stockman (2009) investigate convergence of price levels in the Euro area. Fischer (2012) studies convergence of prices of washing machines in Europe, and contains a brief survey of studies of convergence of price levels in the Euro area. Studies of convergence of inflation rates are surveyed by de Haan (2010).
2) For the Japanese economy, Esaka (2003) and Ikeno (2014a) are some of the studies that use unit root tests.
3) Figure 1 in Phillips and Sul (2009) demonstrates various transition paths to convergence.
4) Among recent studies using the test is Bartkowska and Riedl (2012), which considers convergence of per-capita incomes in Europe.
5) It is often called the Balassa-Samuelson-Penn effect in the literature. Balassa (1964) and Samuelson (1964) are classical studies of the relation between incomes and price levels in international economics. Many studies have followed their work, and a few different approaches to the relation have emerged. Some studies stress the supply side, and some the demand side. Bhagwati (1984) is among the former, and De Gregorio et al. (1994a) and De Gregorio et al. (1994b) are among the latter. Samuelson (1994) draws a distinction between the Penn effect and the Balassa-Samuelson effect. He takes the Penn effect to refer to the general positive relation between incomes and the price levels, and the Balassa-Samuelson effect to refer to the positive relation caused by differences in productivity between tradable and nontradable sectors. In the present paper, the positive relation is investigated without reference to the difference in productivity between sectors. Hence, the positive relation is called the Penn effect here, following him.
6) For the HP filter, see Hodrick and Prescott (1997).
7) The Japanese prefecture capitals investigated in this paper are: Sapporo, Aomori, Morioka, Sendai, Akita, Yamagata, Fukushima, Mito, Utsunomiya, Maebashi, Saitama, Chiba, Tokyo, Yokohama, Niigata, Toyama, Kanazawa, Fukui, Kofu, Nagano, Gifu, Shizuoka, Nagoya, Tsu, Otsu, Kyoto, Osaka, Kobe, Nara, Wakayama, Tottori, Matsue, Okayama, Hiroshima, Yamaguchi, Tokushima, Takamatsu, Matsuyama, Kochi, Fukuoka, Saga, Nagasaki, Kumamoto, Oita, Miyazaki, Kagoshima, and Naha. They are listed here roughly from north to south.
8) Many residents commute across prefectural borders in Japan. The counterpart of the GNP is therefore chosen rather than that of the Gross Domestic Product.
9) http://www.stat.go.jp/index.htm and http://www.stat.go.jp/english/index.htm.
10) The tuning parameter of the HP filter λ is set to 100. This value of the parameter is used in all HP filters in this work.
11) Even where only a single city is included, the term 'group' is used here for brevity of expression.
12) An alternative way to address the problem is found in Phillips and Sul (2007), who investigate US local

price levels. They assume that absolute price levels of all cities investigated are equal at the initial observation, and project the price levels forwards using the local CPIs. They discard the first half of the observations in order to avoid initialization effects. Kim and Rous (2012) follow a similar method. Phillips and Sul (2007) use long-run data, which extends over almost a century.

13) The National Survey of Prices conducted in 2002 was chosen as the base for compilation of the new series as follows: New series of the general and disaggregate price indexes were compiled from the combination of the local CPIs and each of the four sets of the National Survey of Prices, which were conducted in 1992, 1997, 2002, and 2007, respectively. They are compared with each other. Closeness between the true values of disaggregate price series and the newly compiled disaggregate price series cannot be tested for, since disaggregate price series in an inter-regionally comparable form are not readily available. The set of the National Survey of Prices was chosen so that the newly compiled series of the general price and the RDICP (which is the only readily available series in an inter-regionally comparable form) may be close. The new series for the general price index, compiled from the combination of the local CPIs and the 2002 Survey, were judged to be close to the RDICPs when the difference between the two series was measured as the sum of squared differences. First, the last observations of those compiled from the 2002 Survey are closer to the counterparts of the RDICP than those compiled from any other Surveys. Second, when the difference is evaluated over the whole sample period, those from the 2002 Survey are the second closest series to the RDICPs.

14) Indexes in the present work represent retail price levels, not the wholesale price levels. Crucini and Yilmazkuday (2014) assert that nontradable costs at the retail stage cause a failure of price convergence.

15) A detailed description of the clustering is available from the author on request.

16) Dominant weights in this index are shared by electricity fees, gas fees, and water charges.

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References

Balassa, B. (1964) "The Purchasing-Power-Parity Doctrine: a Reappraisal", *Journal of Political Economy* Vol.72, No.6, pp.584-596

Bartkowska, M., and A. Riedl (2012) "Regional Convergence Clubs in Europe: Identification and Conditioning Factors", *Economic Modelling*, Vol. 29, Issue 1, pp.22-31

Bhagwati, J. N. (1984) "Why Are Services Cheaper in the Poor Countries?", *The Economic Journal*, Vol.94, No.374, pp.279-286

Cecchetti, S., N. Mark, and R. Sonora (2002) "Price Index Convergence among United States Cities", *International Economic Review*, Vol.43, Issue 4, pp.1081-1099

Chen, L.L., and J. Devereux (2003) "What can US City Price Data Tell us about Purchasing Power Parity?", *Journal of International Money and Finance*, Vol.22, Issue 2, pp.213-222

Cheung, J-W., and E. Fujii (2014) "The Penn Effect within a Country: Evidence from Japan", *Oxford Economic Papers*, Vol.66, Issue 4, pp.1070-1089

Crucini, M. J., and H. Yilmazkuday (2014) "Understanding Long-run Price Dispersion", *Journal of Monetary Economics*, Vol.66, Issue C, pp.226-240

De Gregorio, J., A. Giovannini, and T.H. Kruegar (1994a) "The Behavior of Nontradable-Goods Prices in Europe: Evidence and Interpretation", *Review of International Economics*, Vol.2, Issue 3, pp.284–305

De Gregorio, J., A. Giovannini, and H.C. Wolf (1994b) "International Evidence on Tradables and Nontradables Inflation", *European Economic Review*, Vol.38, Issue 6, pp.1225-1244

de Haan, J. (2010) "Inflation Ddifferentials in the Euro area: a Survey", in J. de Haan, and H. Berger (eds.), *The European Central Bank at Ten*, Springer, pp.11-32

Esaka, T. (2003) "Panel Unit Root Tests of Purchasing Power Parity between Japanese Cities, 1960 – 1998 : Disaggregated Price Data", *Japan and the World Economy*, Vo.15, Issue 2, pp.233-244

Estrella, A. (1998) "A New Measure of Fit for the Equations with Dichotomous Dependent Variables", *Journal of Business and Statistics*, Vol.16, Issue 2, pp.198-205

Faber, R. P., and A.P. Stockman (2009) "A Short History Price Convergence in Europe", *Journal of Money, Credit and Banking*, Vol.41, Issue 2-3, pp.461-476

Fielding, D., C. Hajzler, and J. MaCgee (2015) "Distance, Language, Religion, and the Law of One Price: Evidence from Canada and Nigeria", *Journal of Money, Credit and Banking*, Vol.47, Issue 5, pp.1007-1029

Fischer, C. (2012) "Price Convergence in the EMU? Evidence from Micro Data", *European Economic Review*, Vol.56, Issue 4, pp.757-776

Hodrick, R., and E. Prescott (1997) "Post-War US Business Cycles: an Empirical Investigation", *Journal of Money, Credit, and Banking*, Vol.29, No.1, pp.1-16

Ikeno, H. (2014a) "Pairwise Tests of Convergence of Japanese Local Price Level", *International Review of Economics and Finance*, Vol.31, Issue C, pp.232-248

Ikeno, H. (2014b) "Long-Run Analysis of Japanese Local Price Level: Pairwise Tests of Convergence", *Economic Modelling*, Vol.42, Issue C, pp.390-397

Kim, Y. S., and J.J. Rous (2012) "House Price Convergence: Evidence from US States and Metropolitan Area Panels", *Journal of Housing Economics*, Vol.21, Issue 2, pp.169-186

Massida, C., and P. Mattana (2008) "Regional Productivity and Relative Prices Dynamics: the Case of Italy", *Annals of Regional Science*, Vol.42, Issue 4, pp.945-966,

Nagayasu, J. (2011) "Heterogeneity and Convergence of Regional Inflation (Price)", *Journal of Macroeconomics*, Vol.33, Issue 4, pp.711-723

Nagayasu, J., and N. Inakura (2009) "PPP: Further Evidence from Japanese Regional Data", *International Review of Economics and Finance*, Vol.18, Issue 3, pp.419-427

Parsley, D. C., and S. -J. Wei, (1996) "Convergence to The Law of One Price without Trade Barriers or Currency Fluctuations", *Quarterly Journal of Economics*, Vol.111, Issue 4, pp.1211-1236

Phillips, P. C. B., and D. Sul (2007) "Transition Modeling and Econometric Convergence Tests", *Econometrica*, Vol.75, Issue 7, pp.1771-1855.

Phillips, P. C. B., and D. Sul (2009) "Economic Transition and Growth", *Journal of Applied Econometrics*, Vol.24, Issue 7, pp.1153-1185

Samuelson, P. A. (1964) "Theoretical Notes on Trade Problem", *Review of Economics and Statistics*, Vol.46, No.2, pp.145-154

Samuelson, P. A. (1994) "Facets of Balassa-Samuelson Thirty Years Later", *Review of International Economics*, Vol.2, Issue 3, pp.201-226

Vaona, A. (2011) "Intra-National Purchasing Power Parity and Balassa-Samuelson Effect in Italy", *Spatial Economic Analysis*, Vol.6, Issue 3, pp.291-309

（要旨）

この論文は，最近，開発されたノンパラメトリックな手法を用いて，日本国内の地域物価水準の収束を分析する。全体としての収束のみならず，その一部が収束するというクラブの収束可能性も考慮しながら，時系列データを用いて収束を分析する。結果は，日本国内では全ての地域物価水準が単一の値に収束していないことを示してる。つまり，購買力平価が日本国内で成り立っていない。日本国内の長い単一通貨の長い歴史にもかかわらず，物価水準は収束していない。その一方，地域物価水準はいくつかのグループを形成し，そのグループ内では収束を示している。高い物価水準のグループを形成する地域は，所得が高くなっている。品目グループごとの地域物価指数をみると，サービスが高い価格水準を示す地域は高い所得となっていることがわかる。このことは，日本国内でペン効果が観測されることを意味している。