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A Big Mac test of price dynamics and dispersion across euro area

Fabio Clementi
University of Macerata

Mauro Gallegati
Polytechnic University of Marche

Antonio Palestrini
University of Teramo

Abstract

Based on the prices of McDonald's Big Mac hamburger in 11 Eurozone countries over the 1986–2009 period, the present article investigates whether the adoption of the euro was accompanied by an increase in inflation and how far it affected developments in price dispersion. Our results indicate that the Eurozone inflation rate after the introduction of the euro is on average significantly higher than prior to the changeover. Additionally, we find no evidence of a further significant reduction in price dispersion since the euro switchover in comparison with the previous period during which progress towards a leveling of existing price differentials had been made.

The Big Mac was created by Jim Delligatti, in Uniontown, Pennsylvania area - our lifetime friend, Domenico Delli Gatti, at this matter once commented: "Finally one guy with a successful idea in the family!". The Economist has used it as a reference point to determine the cost of living in different countries - the so-called "Big Mac Index", which forms the basis for the literature known as "Burgernomics". We are grateful to Liz Mann, member of The Economist Group, for providing the data on Big Mac prices for individual euro area countries since 2002. The usual disclaimer applies.

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1. Introduction

By now, enough years have passed since the physical euro was rolled out in January 2002. Certainly unlike any other economic event, its introduction created an excitement among the majority of euro-country citizens for the obvious benefit of removing the cost of exchanging currency and, theoretically, allowing businesses and individuals to consummate previously unprofitable trades. On the other hand, when the Maastricht agenda to create the European Monetary Union was set out, policy-makers expected the adoption of the euro to allow significantly lower inflation rates for most member countries compared with rates experienced before the single currency was conceived. Indeed, in order to meet the Maastricht Treaty's criteria, the member countries had to reduce their inflation rates. They followed extraordinary anti-inflation policy measures and did succeed in lowering inflation rates prior to the introduction of the euro. However, although the fathers of the monetary union promised that inflation would have remained low and stable after the introduction of the euro, the general public started to complain of price and inflation increases following the introduction of the physical euro notes and coins on 1 January 2002 (European Commission 2002, 2003, 2005). Officials from the European Central Bank, Eurostat and various national statistical offices admit that certain sectors experienced substantial price increases, but they strongly deny that there was any increase in the overall inflation rate after the introduction of the euro (*e.g.* European Central Bank 2002, 2003, and Deutsche Bundesbank 2004). This discrepancy between inflation as measured by official statistics and that perceived by the general public leaves an open question regarding the quantitative impact on the inflation rate in the Eurozone after the introduction of the common currency.

There has been some research on the alleged inflationary effects of the new currency, but the focus has been primarily on the one-time jumps in the price level. For example, Hobijn *et al.* (2006) find evidence of a jump in the price level of the restaurant sector, whereas Angelini and Lippi (2007) find that there was a small jump in the general price level. Furthermore, Dziuda and Mastrobuoni (2009) show that cheaper products experienced higher price increases. These works, however, do not test for changes in the overall inflation rate after the introduction of euro. An important exception is represented by Shiamptanis (2009), who finds evidence of a positive break in inflation after the euro was introduced as an electronic currency on 1 January 1999.

The introduction of the euro was also expected to give an additional boost to the existing innate tendency in the single market towards convergence in the prices of comparable goods. By eliminating exchange rate risk in trade among the member countries and making it easier to compare prices, the single currency was indeed to stimulate cross-border competition and thus contribute to a leveling of existing price differentials. Regardless the different approaches and data used by some recent studies that explored the nature of price dispersion in the Eurozone and the potential role of the common currency, they all share some common conclusions. For istance, Engel and Rogers (2004) report no tendency of a significant reduction in price dispersion after January 1999, although their data set ends in 2003. Similarly, Parsley and Wei (2008) find little evidence of a significant drop in price dispersion following the introduction of the euro.

The purpose of this study is to bring economic evidence to bear on these issues. Specifically, we address two questions related to the effects of the euro: first, was the changeover

to the euro associated with an increase in inflation; and second, did price differences in the Eurozone narrow as a result of the introduction of the single currency?

Crucial for a study like this is to focus on price data relating to products that are physically identical, or nearly so, across countries and over time, so as to minimize the effects of non-comparable products on inference. Therefore, our strategy is to look at the prices of McDonald's Big Mac hamburger in 11 Eurozone countries that are published annually in *The Economist* magazine since its inception in 1986. The prices of a Big Mac are informative and illustrative because it is produced locally in 120 countries around the world, with only minor changes in recipe, and generally uses the same ingredients everywhere. As well as being a "standard product", this means that its local prices are less likely to be distorted by international transportation and distribution costs.[1]

The empirical results, which rely on a before and after comparison around the time of the euro changeover, provide statistically significant evidence that Eurozone inflation after the introduction of the single currency is on average higher relative to the inflation before the euro cash changeover. Additionally, we find that the common currency has had no significant impact on price convergence so far. This is especially true in comparison with the time before the changeover, during which considerable progress towards a reduction in price dispersion had been made.

The structure of the work is as follows. Section 2 presents the data. Section 3 reports our empirical results. Section 4 concludes.

2. Data description

The data used in this article consist of the prices of McDonald's Big Mac hamburger in 11 Eurozone countries over the 1986–2009 period. These are published annually in *The Economist* magazine. The original dataset was derived from Pakko and Pollard (2003) at `http://research.stlouisfed.org/publications/review/03/11/0311mpd.xls`, but it only covers the years 1986 to 2001. Indeed, when the physical currency became available in January 2002, prices for Big Mac were posted in euro and *The Economist* started releasing Eurozone weighted average prices, thus ceasing the report of Big Mac prices for individual euro area countries. However, we had exclusive access to country disaggregated data after 2002 as a courtesy of the *Economist Intelligence Unit* (*EIU*), and were thus able to append them to the existing ones.[2] The final dataset we ended up with is shown in Table 1.

Unfortunately, the panel data set provided by *The Economist* is not an ideal balanced panel data set. Indeed, as can be seen from the table, only France and Germany were surveyed continuously over the whole period, while the other countries do not have complete

[1]Big Mac prices were used in previous work, usually to study issues related to the law of one price and market integration. Applications of "Burgernomics" include, among others, Annaert and De Ceuster (1997), Ashenfelter and Jurajda (2001), Caetano *et al.* (2004), Chen *et al.* (2007), Clements *et al.* (2010), Click (1996), Cumby (1996), Fujiki and Kitamura (2003), Haskel and Wolf (2000), Lan (2001), Lutz (2001, 2004), Ong (1997, 1998*a*,*b*, 2003), Ong and Mitchell (2000), Pakko and Pollard (1996, 2003) and Parsley and Wei (2007, 2008).

[2]Since only Big Mac price data after January 2002 are compiled in euro, national prices for the 1986–2001 period in the original dataset were converted using the irrevocable conversion rates for the euro calculated on 31 December 1998.

Table 1 The Eurozone countries surveyed by *The Economist* over the 1986–2009 period

Year	Austria	Belgium	Finland	France	Germany	Greece	Ireland	Italy	Netherlands	Portugal	Spain	Total
1986	–	1	–	1	1	–	1	–	1	–	1	6
1987	–	1	–	1	1	–	1	1	1	–	–	6
1988	–	1	–	1	1	–	1	1	1	–	1	7
1989	–	1	–	1	1	–	1	1	1	–	1	7
1990	–	1	–	1	1	–	1	1	1	–	1	7
1991	–	1	–	1	1	–	1	1	1	–	1	7
1992	–	1	–	1	1	–	1	1	1	–	1	7
1993	–	1	–	1	1	–	1	1	1	–	1	7
1994	1	1	–	1	1	1	–	1	1	1	1	9
1995	1	1	–	1	1	–	–	1	1	–	1	7
1996	1	1	–	1	1	–	–	1	1	–	1	7
1997	1	1	–	1	1	–	–	1	1	–	1	7
1998	1	1	–	1	1	1	–	1	1	–	1	8
1999	–	–	–	1	1	1	–	1	1	–	1	6
2000	–	–	–	1	1	1	–	1	–	–	1	5
2001	–	–	–	1	1	–	–	1	–	–	1	4
2002	1	1	1	1	1	1	1	1	1	1	1	11
2003	1	1	1	1	1	1	1	1	1	1	1	11
2004	1	1	1	1	1	1	1	1	1	1	1	11
2005	1	1	1	1	1	1	1	1	1	1	1	11
2006	1	1	1	1	1	1	1	1	1	1	1	11
2007	1	1	1	1	1	1	1	1	1	1	1	11
2008	1	1	1	1	1	1	1	1	1	1	1	11
2009	1	1	1	1	1	1	1	1	1	1	1	11
Total	13	21	8	24	24	12	16	23	22	9	23	195

historical data. In particular, Austria, Greece and Portugal were only rarely surveyed before 2002, whereas Big Mac price data for Ireland become unavailable starting on 1994 and up to 2002. Moreover, Finland was only recently added, with coverage starting in 2002. These inconsistencies and data lapses in Big Mac price information limit the possibility to apply the most recent developments in panel data econometrics and force us to rely extensively on hypothesis testing procedures.

3. Methodology and empirical results

In order to formally test whether inflation increased following the introduction of the euro, we use a simple t-test of the null hypothesis that the means of annual inflation rates in the 11 Eurozone countries during the two subperiods 1987–2001 and 2002–2009 are equal against the alternative that they are not.[3] The results are shown in Table 2. We determine if the test should be performed under the assumption of equal or unequal variances for the two subsamples by checking the results of the classical Levene (1960) test for homogeneity of variances and its robust version based on the absolute deviations from the median (Brown and Forsythe 1974), respectively labeled as W_0 and W_{50}. As shown in the table, the variances can not be assumed to be equal at the 5% level of significance. Therefore, we look at the test statistic having a value of -2.072 and a two-sided p-value of approximately 4%, which indicates a significant increase from an average annual inflation rate of 1.7% in the first subperiod to an average 3.6% in the second one at the level of 5%. A stronger result obtains in the case of a left-tail test—the alternative being that the average inflation prior to the euro adoption is less than after, which yields an approximate p-value of 2%. This inflationary pressure is also suggested by visual inspection of Figure 1, which shows that prices in the Eurozone are perceptibly higher from the time around the changeover.

We may want to note here that the t-test requires normality of the observations within each sample, a condition that in our case is not met. Indeed, as Table 2 shows, empirical distribution function (EDF) tests such as Cramér-von Mises (W^2) and Anderson-Darling (A^2) give rejection of the null hypothesis of normality of annual inflation rates both before and after the introduction of the euro, returning a p-value of approximately zero.[4] This significant departure from normality is also evident from Figure 2, where the empirical distribution of the two subsamples is contrasted to the Gaussian theoretical one. However, by the central limit theorem we may consider that our sample sizes are sufficiently large for concerns about non-normality of the subsamples to be ignored. Furthermore, as reported in the same table, a nonparametric alternative to the t-test when the normality assumption is in doubt like the Mann-Whitney (1947) test yields the same results, leading to acceptance at the 1% level of the alternative hypothesis that the difference in the location parameters (the medians) of the two subsamples is less than (left-tail case) or not equal to (two-tail case) zero—the p-values are approximately 0.2% and 0.3%, respectively.

Finally, we also note that our methodology is not influenced by nonstationarity of the

[3]For each country, the inflation rate is calculated as the difference of logarithmic Big Mac prices of two consecutive periods.

[4]The statistics used in these procedures are members of the general Cramér-von Mises family of quadratic goodness-of-fit tests, which are generally indicated as to be the most powerful among all EDF tests (see *e.g.* Stephens 1986).

Table 2 Results on pre- and post-euro inflation using data on Big Mac prices for 11 Eurozone countries over the 1986–2009 period

Statistics						
	1987–2001			2002–2009		
N	95			81		
Mean	0.017			0.036		
St. dev.	0.044			0.071		
t-test for equality of means[1]						
	Equal variances assumed			Equal variances not assumed		
	Value	DF	p-value	Value	DF	p-value
Two-tail	-2.146	174	0.033*	-2.072	129.583	0.040*
Left-tail			0.017*			0.020*
Tests for homogeneity of variances						
	Value			p-value		
W_0	4.041			0.046*		
W_{50}	4.047			0.046*		
EDF tests for normality[2]						
	1987–2001			2002–2009		
	Value	Adj. value	p-value	Value	Adj. value	p-value
W^2	1.095	1.101	0.000***	0.893	0.898	0.000***
A^2	5.534	5.579	0.000***	4.774	4.820	0.000***
Mann-Whitney test						
	Value			p-value		
Two-tail	2,876.500			0.003**		
Left-tail				0.002**		

[1] "DF" denotes the total number of degrees of freedom, calculated as $N_1 + N_2 - 2$, where 1 = first subsample and 2 = second subsample. When it can not be assumed that the two subsamples have the same variance, the Satterthwaite (1946), or Welch (1947), approximation to the degrees of freedom is used

[2] "Value" indicates the asymptotic test statistic, while "Adj. value" indicates the test statistic with finite sample correction. The p-value is computed from the latter according to Table 4.9 in Stephens (1986)

Star codes for significance: $***$ = 0.1%, $**$ = 1%, $*$ = 5%

data, since, as shown in Table 3, panel unit root testing procedures as developed by Breitung (2000), Choi (2001), Im *et al.* (2003), Levin *et al.* (2002) and Maddala and Wu (1999) clearly indicate that the null hypothesis of unit root can be rejected at standard levels of significance in all cases and for any type of their different versions with respect to the form of deterministic component (with and without individual effects, time effects and a time trend).

Next, we ask how the cross-country dispersion of Big Mac price *levels* has evolved over time, which means testing for price convergence.[5] To this end, we compare price dispersion at two different points in time before and after the introduction of the euro, namely the first period with non-missing data for all countries versus 2002 (but excluding Finland, for which no observations are made available before 2002) and 2002 versus 2009 (including Finland). Dispersion in prices is measured by some well-known inequality indices, such as the Gini

[5]Convergence in dispersion closely corresponds to the idea of "σ-convergence" as described by Barro and Sala-i-Martin (1995) and Sala-i-Martin (1996) in their studies of cross-sectional income dynamics.

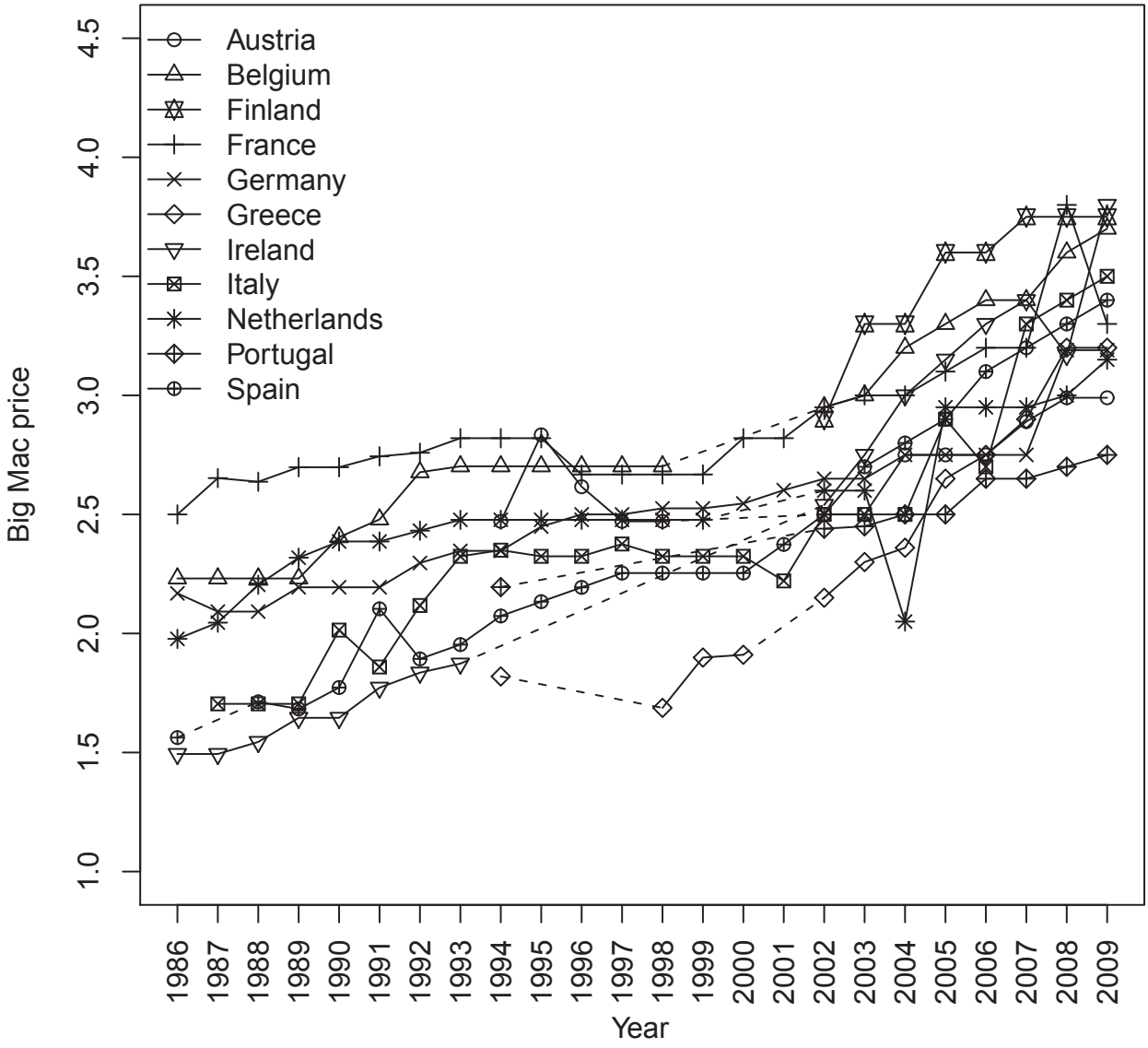


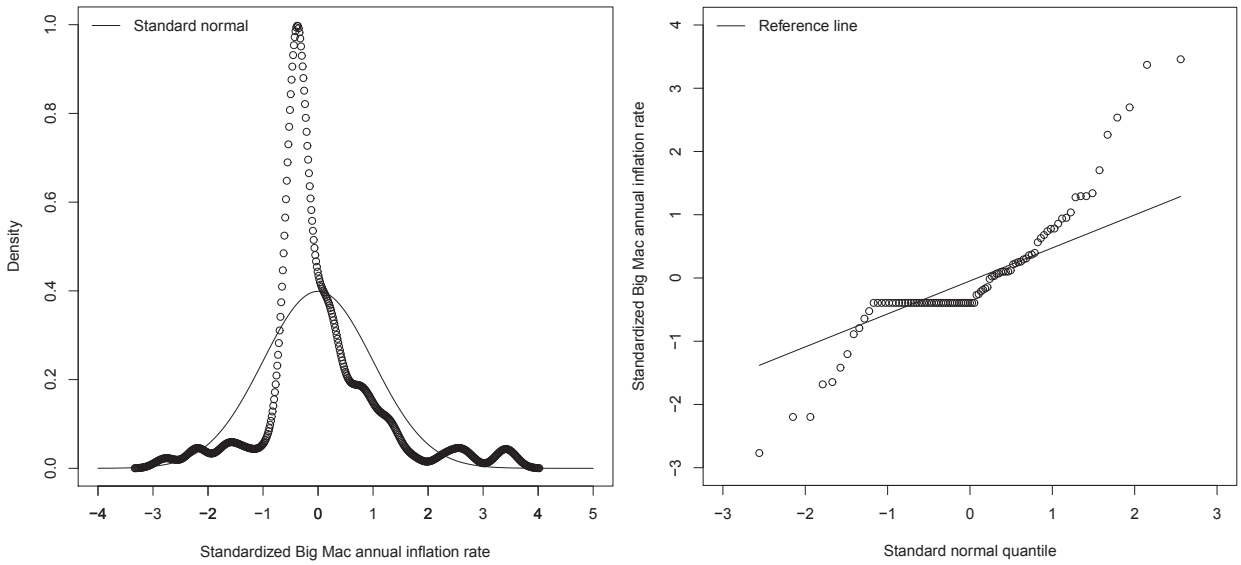
Fig. 1 Combined cross-section plot of Big Mac prices for 11 Eurozone countries over the 1986–2009 period. The dashed line bridges the gap left by missing data in the series

coefficient,

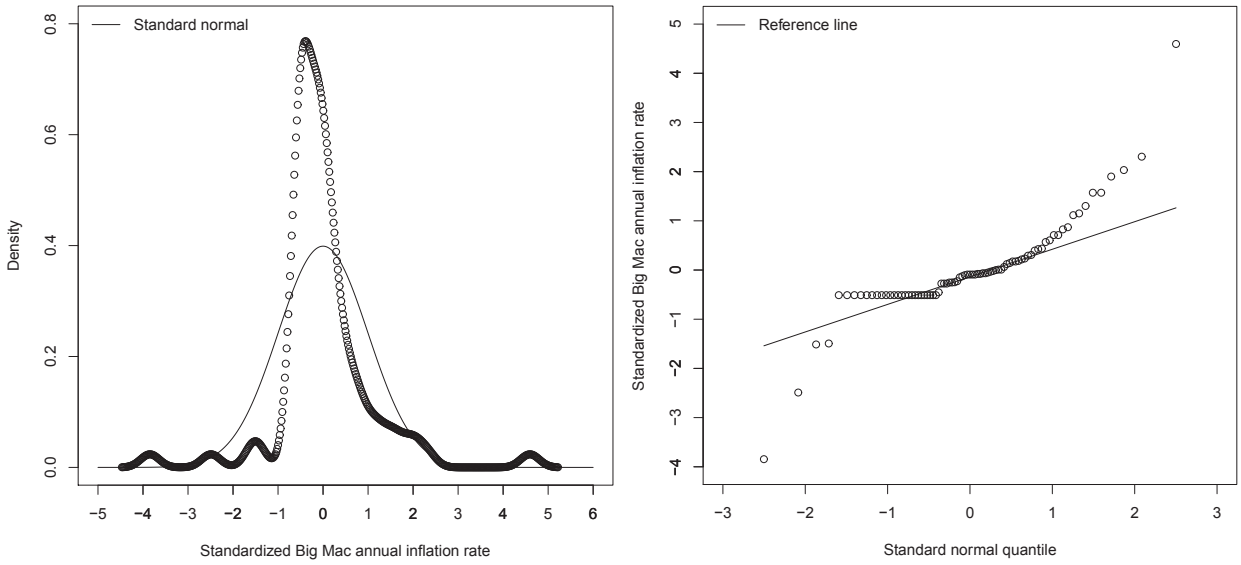
$$G_t = \frac{2\sum_{i=1}^{N_t} iP_{i,t}}{N_t \sum_{i=1}^{N_t} P_{i,t}} - \frac{N_t + 1}{N_t}, \tag{1}$$

and two special members of the generalized entropy class of inequality measures respectively known as the mean logarithmic deviation—or the logarithm of the ratio between the arithmetic and the geometric mean,

$$MLD_t = \frac{1}{N_t} \sum_{i=1}^{N_t} \ln \frac{\bar{P}_{.,t}}{P_{i,t}} = \ln \left[\frac{\bar{P}_{.,t}}{\left(\prod_{i=1}^{N_t} P_{i,t} \right)^{\frac{1}{N_t}}} \right], \tag{2}$$



[a] 1987–2001



[b] 2002–2009

Fig. 2 Empirical density plot with normal curve overlay (*left*) and normal Q-Q plot (*right*) of pre- and post-euro Big Mac annual inflation rates. The empirical density was estimated using a Gaussian kernel function after standardization

and the Theil index,

$$T_t = \frac{1}{N_t} \sum_{i=1}^{N_t} \frac{P_{i,t}}{\bar{P}_{.,t}} \ln \left(\frac{P_{i,t}}{\bar{P}_{.,t}} \right), \tag{3}$$

where $P_{i,t}$ is the Big Mac price of the i^{th} country, $\bar{P}_{.,t}$ is the (arithmetic) mean price across

Table 3 Summary of panel unit root tests for pre- and post-euro inflation. The null hypothesis is that of a unit root

	1987–2001[1]		2002–2009[2]	
Exogenous variables: none				
Common unit root process assumed				
	Value	*p*-value	Value	*p*-value
Levin-Lin-Chu	-6.012	0.000***	-4.925	0.000***
Breitung[3]	NA	NA	NA	NA
Individual unit root process assumed				
	Value	*p*-value	Value	*p*-value
Im-Pesaran-Shin[4]	NA	NA	NA	NA
Fisher - ADF	68.710	0.000***	56.639	0.000***
Fisher - PP	76.002	0.000***	81.311	0.000***
Exogenous variables: individual effects				
Common unit root process assumed				
	Value	*p*-value	Value	*p*-value
Levin-Lin-Chu	-6.097	0.000***	-11.935	0.000***
Breitung[3]	NA	NA	NA	NA
Individual unit root process assumed				
	Value	*p*-value	Value	*p*-value
Im-Pesaran-Shin	-5.940	0.000***	-6.821	0.000***
Fisher - ADF	51.389	0.000***	87.644	0.000***
Fisher - PP	87.754	0.000***	107.351	0.000***
Exogenous variables: individual effects, individual linear trends				
Common unit root process assumed				
	Value	*p*-value	Value	*p*-value
Levin-Lin-Chu	-5.803	0.000***	-28.877	0.000***
Breitung	-3.270	0.000***	-2.128	0.017*
Individual unit root process assumed				
	Value	*p*-value	Value	*p*-value
Im-Pesaran-Shin	-2.253	0.012*	-4.706	0.000***
Fisher - ADF	36.110	0.001**	79.324	0.000***
Fisher - PP	79.521	0.000***	118.166	0.000***

[1] Automatic selection of maximum lags based on Schwarz (1978) information criterion: 0 to 2
[2] Automatic selection of maximum lags based on Schwarz (1978) information criterion: 0 to 1
[3] Not available (NA) when individual trends are not included in the test equation
[4] Not available (NA) with no exogenous variables in the test equation
Star codes for significance: $***$ = 0.1%, $**$ = 1%, $*$ = 5%

countries, and N_t is the number of countries at time t.[6] The results are shown in Table 4. The statistics suggest that price disparity decreased from one point in time to another in the first subperiod examined, while they show almost no discernable change in the second one. We have also tested the statistical significance of the difference in these measures for

[6]See *e.g.* Coulter (1989) for a careful review and exposition of inequality measures.

Table 4 Results on price dispersion prior to and after the introduction of the euro using data on Big Mac prices for 11 Eurozone countries over the 1986–2009 period[1]

Statistics

	First period of observation[2]	2002[2]	2002[3]	2009[3]
N	10	10	11	11
Mean	2.012	2.578	2.607	3.339
St. dev.	0.359	0.237	0.245	0.330

Measures of dispersion[4]

	First period of observation[2]					2002[2]					2002[3]					2009[3]				
	Value	St. err.	95% conf. int.[5]			Value	St. err.	95% conf. int.[5]			Value	St. err.	95% conf. int.[5]			Value	St. err.	95% conf. int.[5]		
			0.074	0.136	(N)			0.028	0.074	(N)			0.032	0.073	(N)			0.038	0.077	(N)
G	0.096	0.016	0.053	0.113	(P)	0.046	0.012	0.019	0.062	(P)	0.048	0.010	0.022	0.063	(P)	0.053	0.010	0.030	0.068	(P)
			0.073	0.122	(BC)			0.027	0.073	(BC)			0.033	0.074	(BC)			0.039	0.073	(BC)
			0.008	0.024	(N)			0.001	0.007	(N)			0.001	0.007	(N)			0.002	0.008	(N)
MLD	0.015	0.004	0.005	0.022	(P)	0.004	0.002	0.001	0.006	(P)	0.004	0.001	0.001	0.007	(P)	0.005	0.002	0.002	0.008	(P)
			0.008	0.025	(BC)			0.001	0.009	(BC)			0.002	0.009	(BC)			0.002	0.009	(BC)
			0.007	0.024	(N)			0.001	0.007	(N)			0.002	0.007	(N)			0.002	0.008	(N)
T	0.014	0.004	0.005	0.022	(P)	0.004	0.002	0.001	0.006	(P)	0.004	0.001	0.001	0.007	(P)	0.004	0.002	0.002	0.008	(P)
			0.008	0.025	(BC)			0.001	0.009	(BC)			0.002	0.009	(BC)			0.002	0.009	(BC)

EDF tests for normality[6]

	First period of observation[2]			2002[2]			2002[3]			2009[3]		
	Value	Adj. value	p-value	Value	Adj. value	p-value	Value	Adj. value	p-value	Value	Adj. value	p-value
W^2	0.037	0.039	0.698	0.098	0.103	0.103	0.089	0.093	0.141	0.029	0.030	0.843
A^2	0.253	0.278	0.652	0.564	0.619	0.107	0.528	0.574	0.136	0.211	0.229	0.809

Tests for homogeneity of variances

	First period of observation vs. 2002[2]		2002 vs. 2009[3]	
	Value	p-value	Value	p-value
W_0	3.346	0.084	1.268	0.273
W_{50}	3.117	0.094	1.147	0.297

t-test for equality of dispersion measures[7]

	First period of observation vs. 2002[2]									2002 vs. 2009[3]									
	G			MLD			T				G			MLD			T		
	Value	DF	p-value	Value	DF	p-value	Value	DF	p-value		Value	DF	p-value	Value	DF	p-value	Value	DF	p-value
Two-tail	2.558	18	0.020*	2.440	18	0.025*	2.393	18	0.028*	Two-tail	-0.339	20	0.738	-0.222	20	0.826	-0.217	20	0.830
Right-tail			0.010**			0.013*			0.014*	Left-tail			0.369			0.413			0.415

Lichtenberg test[8]

	First period of observation vs. 2002[2]		2002 vs. 2009[3]	
	Value	p-value	Value	p-value
	3.966	0.026*	0.892	0.570

[1] Finland was not surveyed before 2002. When excluded from the analysis, a footnote signals the fact
[2] Excluding Finland
[3] Including Finland
[4] The estimated standard errors and confidence intervals are based on 1000 bootstrap replications
[5] N = normal, P = percentile, BC = bias-corrected
[6] "Value" indicates the asymptotic test statistic, while "Adj. value" indicates the test statistic with finite sample correction. The p-value is computed from the latter according to Table 4.9 in Stephens (1986)
[7] "DF" denotes the total number of degrees of freedom, calculated as $2N - 2$
[8] Test performed using logarithmic transformation of prices
Star codes for significance: $***$ = 0.1%, $**$ = 1%, $*$ = 5%

both the subperiods by means of a straightforward t-test whose statistic is defined as

$$\frac{I_1 - I_T}{\sqrt{SE_{I_1}^2 + SE_{I_T}^2}}, \tag{4}$$

where I_t denotes the dispersion index, SE_{I_t} its standard error, and $t = 1, T$ the extremes of each subperiod. The results of the test, stored in the same table, confirm at the 5% level the findings that point to a narrowing price dispersion in the Eurozone up to around the time of the euro cash changeover and the absence of a perceptible price convergence since then.[7]

As a further check, we consider the absolute value of the relative distance from the mean of *logarithm* transformed Big Mac prices,[8] i.e.

$$\left| 1 - \frac{p_{i,t}}{\bar{p}_{.,t}} \right|, \tag{5}$$

where $p_{i,t} = \ln(P_{i,t})$, $\bar{p}_{.,t} = \frac{1}{N_t} \sum_{i=1}^{N_t} p_{it}$ is the log-average across the i countries, and N_t is the number of countries at time t. The values returned by (5) for each country and for each of the extremes of the two subperiods under study are plotted on the axes of Figure 5, where the 45 degree line represents the case in which there is no change in the departure from the average. Thus, a point above the line represents an increase in the distance from the average at the later point in time than before, whereas a point below denotes a decline. It is clear from the figure that prices in all countries moved closer to the Eurozone average at the time of the euro introduction, but for a distinct majority of countries they have departed noticeably from the average as recently as 2009. In particular, according to this measure, it is in Austria, Ireland, Netherlands, Portugal, and, to a lesser extent, in Germany and Italy, that prices in 2009 have increased their distance from the average since the time of changeover compared with the other Eurozone countries.

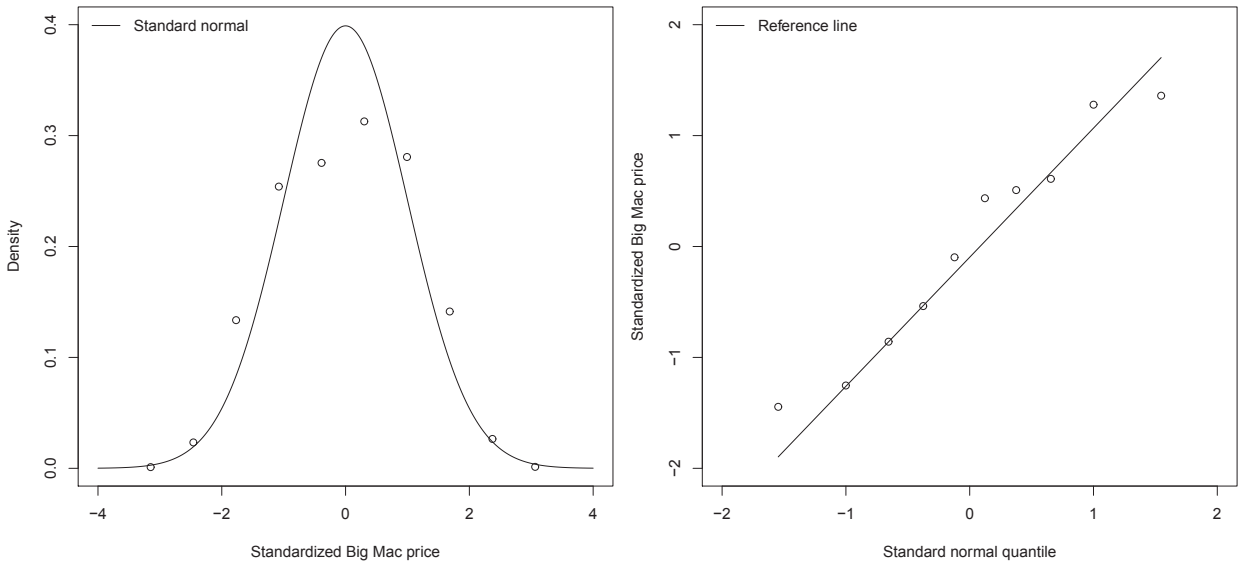
The finding of distinct developments in price dispersion before and after the introduction of the euro is also confirmed by computing the traditional Lichtenberg (1994) test statistic of the ratio between the variances at two different points in time, i.e. $\hat{\sigma}_1^2/\hat{\sigma}_T^2$, which is $F(N_1 - 1, N_T - 1)$-distributed, where N is the number of countries and 1 and T denotes, respectively, the beginning and the end of the period of investigation (see *e.g.* Carree and Klomp 1997). Indeed, as reported in the last section of Table 4, the null hypothesis of equality of variances (i.e., no convergence) was rejected only for the period up to the introduction of the euro.

4. Concluding remarks

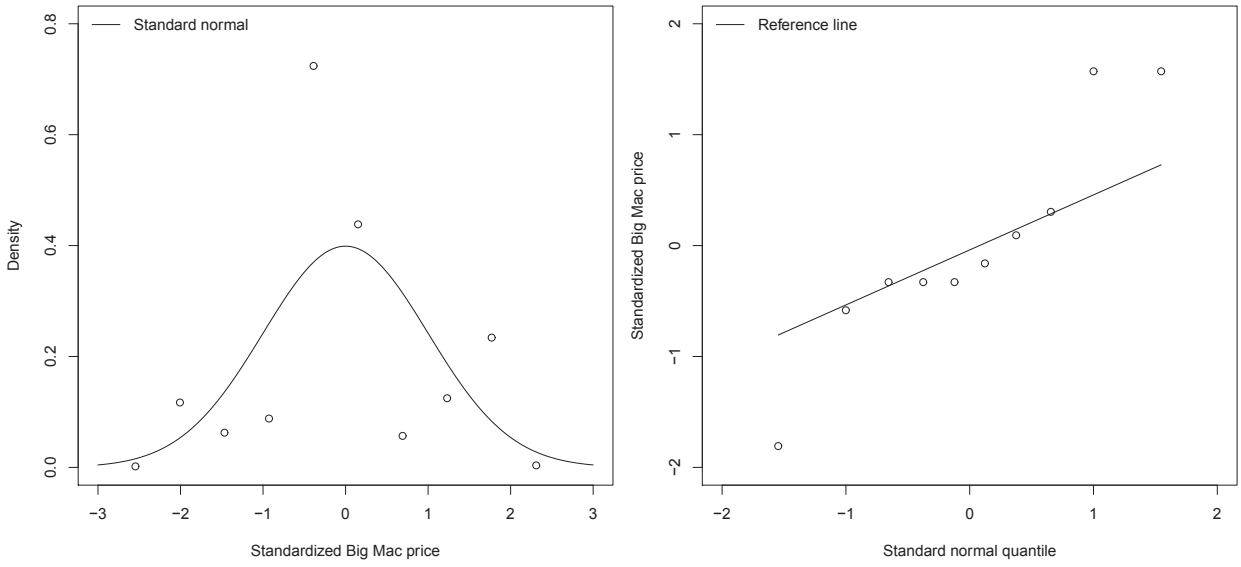
In this article we have addressed two questions. The first is whether the adoption of the euro was accompanied by an increase in inflation. Using information on the prices of McDonald's Big Mac hamburger in 11 Eurozone countries over the 1986–2009 period, we have performed a

[7] Similarly with the "inflationary" issue already discussed, the two assumptions of normality and equal variances underpinning the t procedure have been explicitly checked on. The results of statistical and graphical tests, which validate them, are presented in Table 4 and Figures 3 and 4.

[8] The logarithmic transformation is taken in order to remove heteroskedasticity.



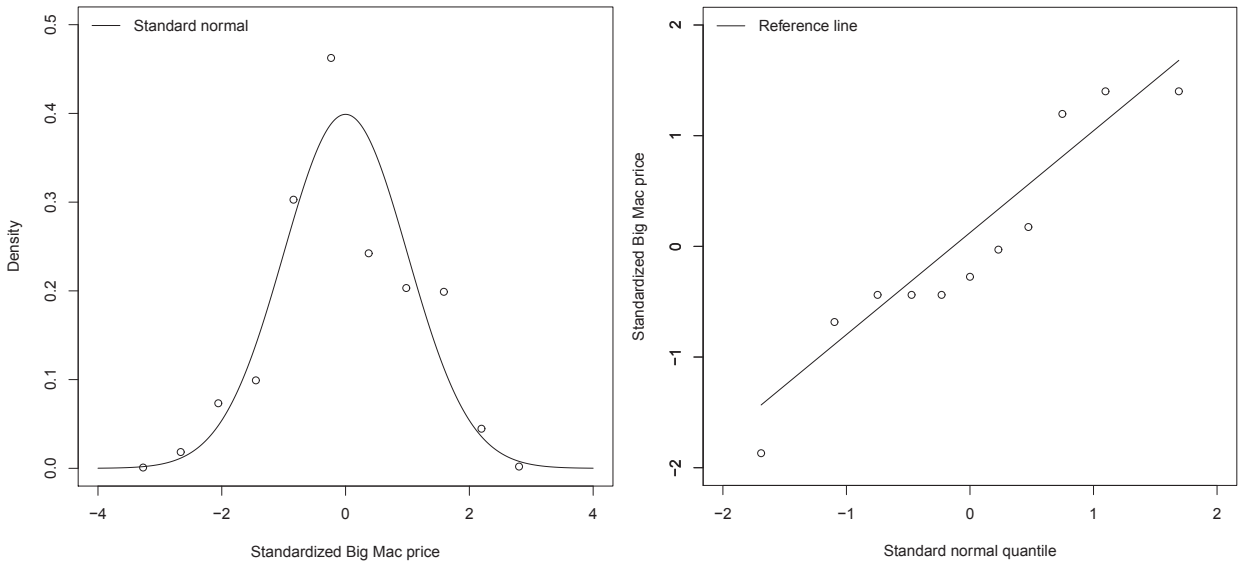
[a] First period of observation (excluding Finland)



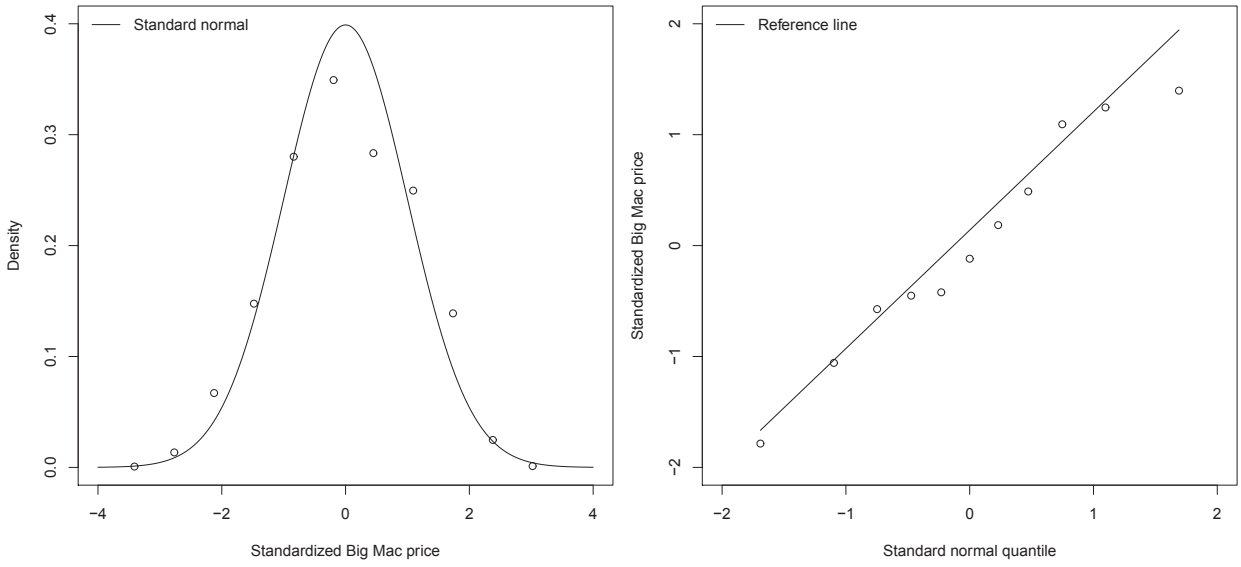
[b] 2002 (excluding Finland)

Fig. 3 Empirical density plot with normal curve overlay (*left*) and normal Q-Q plot (*right*) of Big Mac prices. For each country, except for Finland that was not surveyed up to 2002, the data include observations from the first period available and 2002. The empirical density has been estimated using a Gaussian kernel function after standardization

statistical test of this hypothesis and conclude that after the single currency was introduced in 2002 the mean inflation in the Eurozone rose significantly from the pre-euro period. Secondly, we asked whether the euro has promoted a widespread narrowing of price differences in the Eurozone since its introduction. We have used various uncomplicated methods for analyzing price dispersion in connection with the introduction of the euro, but in all cases we find no evidence of a significant impact on price disparity since the euro cash changeover compared



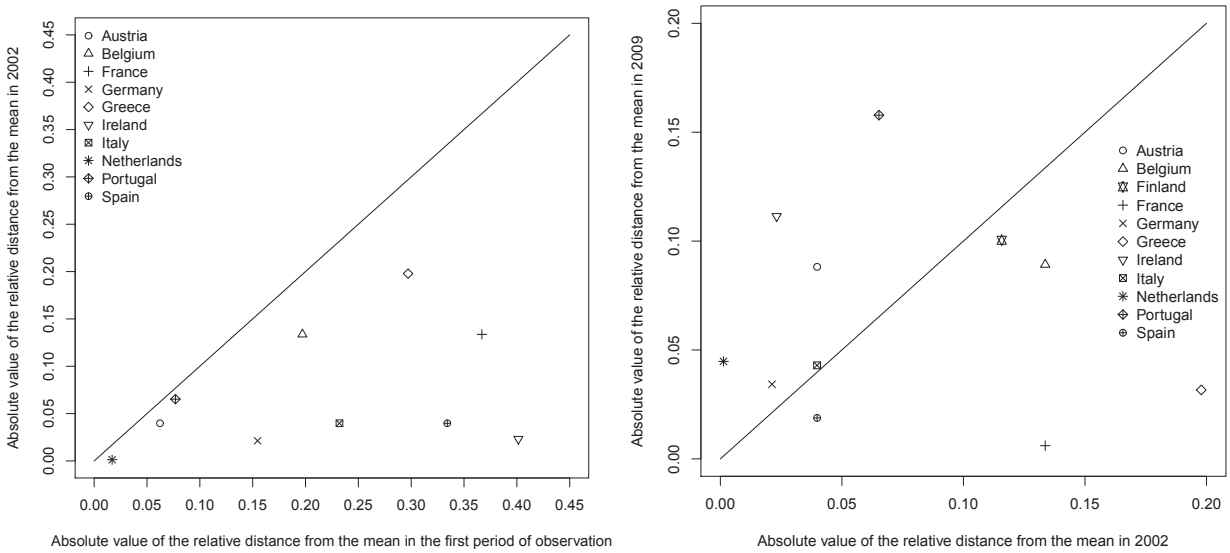
[a] 2002 (including Finland)



[b] 2009 (including Finland)

Fig. 4 Empirical density plot with normal curve overlay (*left*) and normal Q-Q plot (*right*) of Big Mac prices. For each country, the data include observations from 2002 and 2009. The empirical density has been estimated using a Gaussian kernel function after standardization

with marked progress towards convergence earlier. This suggests that monetary union's contributions to inflationary pressures and price convergence should not be overestimated. Of course, the adoption of the euro may have other benefits (or costs) that are outside the scope of this work.



[a] First period of observation vs. 2002 (excluding Finland)

[b] 2002 vs. 2009 (including Finland)

Fig. 5 Absolute value of the relative distance from the mean of (logarithmic) Big Mac prices for each country at two different points in time

References

Angelini, P. and F. Lippi (2007) "Did Prices Really Soar After the Euro Cash Changeover? Evidence from ATM Withdrawals" *International Journal of Central Banking* **3**, 1–22.

Annaert, J. and M.J.K. De Ceuster (1997) "The Big Mac: More Than a Junk Asset Allocator?" *International Review of Financial Analysis* **6**, 179–192.

Ashenfelter, O. and S. Jurajda (2001) "Cross-Country Comparisons of Wage Rates: The Big Mac Index" unpublished manuscript, Princeton University and CERGE-EI/Charles University. Available at: `http://economics.uchicago.edu/download/bigmac.pdf`.

Barro, R.J. and X. Sala-i-Martin (1995) *Economic Growth*, MIT Press: Cambridge MA.

Breitung, J. (2000) "The Local Power of Some Unit Root Tests for Panel Data" in *Nonstationary Panels, Panel Cointegration, and Dynamic Panels* by B. Baltagi, Ed., JAI Press: Amsterdam, 161–178.

Brown, M.B. and A.B. Forsythe (1974) "Robust Tests for the Equality of Variances" *Journal of the American Statistical Association* **69**, 364–367.

Caetano, S., Moura, G. and S. Da Silva (2004) "BigMac Parity, Income, and Trade" *Economics Bulletin* **6**, 1–8.

Carree, M. and L. Klomp (1997) "Testing the Convergence Hypothesis: A Comment" *Review of Economics and Statistics* **79**, 683–686.

Chen, C.-F., Shen, C.-H. and C.-A. Wang (2007) "Does PPP Hold for Big Mac Price or Consumer Price Index? Evidence From Panel Cointegration" *Economics Bulletin* **6**, 1–15.

Choi, I. (2001) "Unit Root Tests for Panel Data" *Journal of International Money and Finance* **20**, 249–272.

Clements, K.W., Lan, Y. and S.P. Seah (2010) "The Big Mac Index Two Decades on: An Evaluation of Burgernomics" available at SSRN: `http://ssrn.com/abstract=1081843`.

Click, R.W. (1996) "Contrarian MacParity" *Economics Letters* **53**, 209–212.

Coulter, P.B. (1989) *Measuring Inequality: A Methodological Handbook*, Westview Press: Boulder.

Cumby, R.E. (1996) "Forecasting Exchange Rates and Relative Prices with the Hamburger Standard: Is What You Want What You Get with McParity?" NBER Working Paper number 5675. Available at: `http://www.nber.org/papers/w5675`.

Deutsche Bundesbank (2004) "The Euro and Prices Two Years on" Monthly Report January 2004. Available at: `http://www.bundesbank.de/download/volkswirtschaft/mba/2004/200401_en_prices.pdf`.

Dziuda, W. and G. Mastrobuoni (2009) "The Euro Changeover and its Effects on Price Transparency and Inflation" *Journal of Money, Credit, and Banking* **41**, 101–129.

Engel, C. and J.H. Rogers (2004) "European Product Market Integration After the Euro" *Economic Policy* **19**, 347–384.

European Central Bank (2002) "Annual Report" available at: `http://www.ecb.int/pub/pdf/annrep/ar2002en.pdf`.

European Central Bank (2003) "Annual Report" available at: `http://www.ecb.int/pub/pdf/annrep/ar2003en.pdf`.

European Commission (2002) "The Euro, One Year Later" Flash Eurobarometer number 139. Available at: `http://ec.europa.eu/publicopinion/flash/fl139en.pdf`.

European Commission (2003) "The Euro, Two Years Later" Flash Eurobarometer number 153. Available at: `http://ec.europa.eu/publicopinion/flash/fl153en.pdf`.

European Commission (2005) "The Euro, Four Years After the Introduction of the Banknotes and Coins" Flash Eurobarometer number 175. Available at: `http://ec.europa.eu/publicopinion/flash/fl175en.pdf`.

Fujiki, H. and Y. Kitamura (2003) "The Big Mac Standard: A Statistical Illustration" Discussion Paper number 446, Hitotsubashi University. Available at: `www.ier.hit-u.ac.jp/Common/publication/DP/DP446.pdf`.

Haskel, J. and H. Wolf (2000) "From Big Macs to iMacs: What Do International Price Comparisons Tell Us?" *World Economics* **1**, 167–178.

Hobijn, B., Ravenna, F. and A. Tambalotti (2006) "Menu Costs at Work: Restaurant Prices and the Introduction of Euro" *Quarterly Journal of Economics* **121**, 1103–1131.

Im, K.S., Pesaran, M.H. and Y. Shin (2003) "Testing for Unit Roots in Heterogeneous Panels" *Journal of Econometrics* **115**, 53–74.

Lan, Y. (2001) "The Long-Run Value of Currencies: A Big Mac Perspective" Economics Discussion Paper number 01–17, University of Western Australia. Available at: `http://www.rbnz.govt.nz/research/workshops/112040/5apr02lan.pdf`.

Levene, H. (1960) "Robust Tests for Equality of Variances" in *Contributions to Probability and Statistics: Essays in Honor of Harold Hotelling* by I. Olkin, S.G. Ghurye, W. Hoeffding, W.G. Madow and H.B. Mann, Eds., Stanford University Press: Stanford, 278–292.

Levin, A., Lin, C.-F. and C.-S.J. Chu (2002) "Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties" *Journal of Econometrics* **108**, 1–24.

Lichtenberg, F.R. (1994) "Testing the Convergence Hypothesis" *Review of Economics and Statistics* **76**, 576–579.

Lutz, M. (2001) "Beyond Burgernomics and MacParity: Exchange Rate Forecasts Based on the Law of One Price" unpublished manuscript, University of St. Gallen. Available at: `http://econpapers.repec.org/cpd/2002/45\_Lutz.pdf`.

Lutz, M. (2004) "Price Convergence Under EMU? First Estimates" in *The Past, Present and Future of the European Union* by A.V. Deardoff, Ed., Palgrave MacMillan: London, 48–73.

Maddala, G.S. and S. Wu (1999) "A Comparative Study of Unit Root Tests with Panel Data and a New Simple Test" *Oxford Bulletin of Economics and Statistics* **61**, 631–652.

Mann, H.B. and D.R. Whitney (1947) "On a Test of Whether One of Two Random Variables is Stochastically Larger Than the Other" *Annals of Mathematical Statistics* **18**, 50–60.

Ong, L.L. (1997) "Burgernomics: The Economics of the Big Mac Standard" *Journal of International Money and Finance* **16**, 865–878.

Ong, L.L. (1998*a*) "Big Mac and Wages to Go, Please: Comparing the Purchasing Power of Earnings Around the World" *Australian Journal of Labor Economics* **2**, 53–68.

Ong, L.L. (1998*b*) "Burgernomics and the ASEAN Currency Crisis" *Journal of the Australian Society of Security Analysts* **1**, 15–16.

Ong, L.L. (2003) *The Big Mac Index: Applications of Purchasing Power Parity*, Palgrave MacMillan: London.

Ong, L.L. and J.D. Mitchell (2000) "Professors and Hamburgers: An International Comparison of Real Academic Salaries" *Applied Economics* **32**, 869–876.

Pakko, M.R. and P.S. Pollard (1996) "For Here or to Go? Purchasing Power Parity and the Big Mac" *Federal Reserve Bank of St. Louis Review* **78**, 3–22.

Pakko, M.R. and P.S. Pollard (2003) "Burgernomics: A Big Mac^{TM} Guide to Purchasing Power Parity" *Federal Reserve Bank of St. Louis Review* **85**, 9–28.

Parsley, D.C. and S.-J. Wei (2007) "A Prism into the PPP Puzzles: The Micro-Foundations of Big Mac Real Exchange Rates" *The Economic Journal* **117**, 1336–1356.

Parsley, D.C. and S.-J. Wei (2008) "In Search of a Euro Effect: Big Lessons from a Big Mac Meal?" *Journal of International Money and Finance* **27**, 260–276.

Sala-i-Martin, X. (1996) "Regional Cohesion: Evidence and Theories of Regional Growth and Convergence" *European Economic Review* **40**, 1325–1352.

Satterthwaite, F.E. (1946) "An Approximate Distribution of Estimates of Variance Components" *Biometrics Bulletin* **2**, 110–114.

Schwarz, G. (1978) "Estimating the Dimension of a Model" *The Annals of Statistics* **6**, 461–464.

Shiamptanis, C. (2009) "Did the Euro Give Us a Break in Inflation?" *Empirical Economics*, doi: 10.1007/s00181-009-0309-3.

Stephens, M.A. (1986) "Tests Based on EDF Statistics" in *Goodness-of-Fit Techniques* by R.B. D'Agostino and M.A. Stephens, Eds., Marcel Dekker: New York, 97–194.

Welch, B.L. (1947) "The Generalization of 'Student's' Problem when Several Different Population Variances are Involved" *Biometrika* **34**, 28–35.