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The Maastricht Inflation Criterion: What is the Effect of Expansion of the European Union?[*]

John Lewis

De Nederlandsche Bank (Netherlands Central Bank), the Netherlands
Tallinn University of Technology, Estonia

Karsten Staehr[**]

Bank of Estonia, Estonia
Tallinn University of Technology, Estonia

Abstract: Following the Maastricht criteria, a country seeking to join the European Monetary Union cannot have an inflation rate in excess of 1.5 percent plus the average inflation rates in the three "best performing" EU countries. This inflation reference value is a non-increasing function of the number of EU members. Looking backwards, the effect of increasing the number of EU countries from 15 to 27 was sizeable in 2003 and 2004, but has been relatively modest since 2005. Monte Carlo simulations show that the expansion of the EU from 15 to 27 members reduces the expected inflation reference value by 0.15-0.2 percentage points, and with a considerable probability of a larger reduction. The treatment of countries with negative inflation rates in the calculation of the reference value has a major impact on the results.

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[**] Corresponding author: Eesti Pank (Bank of Estonia), Research Department, Estonia Blvd. 13, 15095 Tallinn, Estonia. E-mail: karsten.staehr@epbe.ee. Phone: +372 668 0716.

1. Introduction

Countries seeking to join the European Monetary Union must be members of the EU and in addition satisfy the convergence criteria of the Maastricht Treaty. The exchange rate and fiscal criteria are phased in terms of fixed reference values.[1] The reference values for the inflation criterion and the interest rate criterion are, however, defined *relative* to the performance of other member states of the European Union.[2] In particular, the inflation reference value is defined as the average of the lowest three inflation rates in the EU, plus 1.5 percentage points.

One notable feature of such a relative criterion is how it changes as the number of EU members increases. More EU members means a greater pool of potential reference group members. Adding a new member could lower the reference value (if the new member has an inflation rate low enough to be in the reference group), but it could never raise it. Thus, the expansion of the EU from 15 to 27 members has on average resulted in a lower reference value. The potential importance of this effect was underlined in May 2006, when two non-EMU members, Sweden and Poland, were included in the reference group for the calculation of the reference value, which Lithuania missed by 0.1 percentage points (ECB 2006, p. 26). Had the membership of the reference group been restricted to the 15 "old" EU members or the EMU members, Lithuania would have met the reference value.

The fulfilment of the inflation criterion is challenging for the new EU countries from Central and Eastern Europe for two disparate reasons. First, price convergence and the Balassa-Samuelson effect exert upward pressure on the inflation rate, in particular in the countries with fixed parities towards the euro (Dobrinsky 2006, Lewis 2007). Second, the expansion of the European Union from 15 to first 25 and later 27 member countries has expectedly lowered the reference value of the inflation criterion. The lower the reference value, the less likely it is that a country will comply with the criterion.

The inflation criterion and the challenges it raises for the new EU countries from Central and Eastern Europe have been subject to much academic debate (Buiter 2005, Buiter & Siebert 2006, Jonas 2006, Calmfors *et al.* 2007). The quantitative importance of the Balassa-Samuelson and price convergence effects have been thoroughly investigated although the interval of estimates obtained is rather wide (Egert *et al.* 2003, Dobrinsky 2006). The fact that more EU countries leads to a lowering of the inflation reference value has been noted previously (Kenen & Meade 2003, Gros 2005, Tuma 2007), but to our knowledge, no study has presented *quantitative* estimates of this enlargement effect.

The main contribution of this paper is to quantify numerically the size of the enlargement effect, i.e. effect on the inflation reference value resulting from the expansion of EU from 15 to 27 member countries. One approach comprises a counterfactual analysis based on historical data where the reference value is computed assuming respectively 15 and 27 EU countries. This backward-looking approach is intuitive and straightforward, but the results will depend on specific events and shocks during the period considered. The second approach seeks to es-

[1] A country must have participated in the ERM II for at least two years without devaluation or exchange rate severe tensions; the deficit to GDP ratio must be below 3 percent; the debt to GDP ratio must be below 60 percent or converging at "a satisfactory pace".

[2] The relative inflation criterion may not imply convergence to the average inflation rate in the eurozone. The choice of a relative criterion may be linked to the fact that when the Maastricht Treaty was penned, the future members of the eurozone were unknown (Kenen & Meade 2003). See also Buiter & Sibert (2006) and Wyplosz (2006).

tablish the effect of EU enlargement on the inflation reference value by using Monte Carlo simulations where the inflation rate in each country is modelled as a draw from a distribution with country-specific distribution parameters. This forward-looking approach provides an estimate of the enlargement effect outside the standard forecasting horizon of one or two years.

The rest of the paper is organised as follows: Section 2 sets out and discusses the inflation criterion. Section 3 shows the importance on the inflation threshold of 27 instead of 15 over the period 1999-2007. Section 4 comprises simulations of the reduction in the reference value subject to different assumptions concerning the inflation distributions in the EU countries. Section 5 concludes with a discussion of the implications of the findings in the paper.

2. The inflation criterion

This section discusses the inflation criterion and the computation of the inflation reference value (cf. also Buiter & Sibert 2006). [3] Under the provisions of the Maastricht Treaty the final decision on euro entry is taken by the Council of Ministers.[4] The decision is made based on Convergence Reports from the European Central Bank (ECB) – or its predecessor the European Monetary Institute (EMI) – and from the European Commission (EC). The inflation criterion is formally set out in Article 1 of the Protocol on Convergence Criteria of the Maastricht Treaty (European Union 1992b, p. 29-30):

> [A] Member State has a price performance that is sustainable and an average rate of inflation, observed over a period of one year before the examination, that does not exceed by more than 1½ percentage points that of, at most, the three best performing Member States in terms of price stability.

This entails two requirements, namely that inflation is lower than or equal to the reference value, and that the inflation performance is expected to be sustained over a period of time.

The relevant inflation measure is the *annual HICP inflation* calculated on a monthly basis. For any particular month, the annual HICP inflation rate is found as the percentage change of the 12-month average HICP index relative to the same index one year earlier. This calculation method ensures that the time series of the annual HICP inflation are relatively smooth.

The annual HICP inflation for each country is rounded to one decimal place in accordance with the publication standards of Eurostat. The average of the inflation rates in the three best performing countries, (and hence the reference value), is similarly rounded to one decimal place (EC 2006, p. 37; Buiter & Sibert 2006, p. 2006).[5]

Technically, the Maastricht Treaty states that the reference group should consist of "at most" the three best performing members. In practice, however, this value has always been calculated on the basis of a reference group comprising three countries.

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[3] The inflation criterion is termed the "price stability criterion" in the Maastricht Treaty, cf. below. Since the criterion is evaluated with reference to rates of inflation, it has become common in the academic and policy-oriented literature to label it the "inflation criterion".

[4] See European Union (1992a) for full texts of the Maastricht Treaty and its protocols.

[5] When identifying the three countries with the lowest inflation, unrounded inflation figures may be used in case of ties (EMI 1996, p. 11). This use of unrounded figures, however, will not affect the calculation of the reference value.

The "best performing" countries "in terms of price stability" has in recent Convergence Report by both the European Commission and the European Central Bank been taken to mean the countries with the *lowest non-negative inflation rates*. The first country to be excluded from the reference group on this basis was Lithuania in the reports published in 2004 (EC 2004a, pp. 3, 20; ECB 2004, p. 8). The exclusion by the EC is based on the argument that "countries with negative inflation rates are not considered to be best performers in terms of price stability" (EC 2004a, p. 20). The exclusion by the ECB is based on the argument that extraordinary factors influenced the Lithuanian inflation rate in the period prior to the assessment. It is noticeable, however, that the ECB has not ruled out including countries with negative inflation rates in the future, as explicitly stated in the 2004 Convergence Report (ECB 2004, p. 8): [6]

> The price developments in Lithuania over the reference period, which resulted in a 12-month average rate of –0.2% due to the accumulation of specific factors, have been judged to be an outlier. This figure has consequently been excluded from the calculation of the reference value as it might otherwise have given rise to a distortion in the reference value and reduced the usefulness of the reference value as an economically meaningful benchmark. It does not imply any mechanical approach to the exclusion of certain inflation rates but was introduced in the 1998 EMI Convergence Report to appropriately deal with potential significant distortions in individual countries' inflation developments.

Clearly, while the European Central Bank has explicitly chosen to exclude countries with negative inflation, it has not committed itself to continue this practice. The effect of different rules concerning countries with negative inflation rates is considered explicitly in subsequent sections.

It follows explicitly from the Treaty text that the reference group is drawn from all member states of the EU. The Convergence Reports prior to 2004 (including the 1998 reports on the first wave of entrants and the 2000 reports assessing Greece and Sweden) calculated the inflation reference value based on 15 EU countries. Lithuania and Slovenia were assessed in May 2006 on the basis of 25 members, and the assessments of Malta and Cyprus in May 2007 were based on 27 members. Baring withdrawals from the EU, future assessments will be based on 27 or more member countries.

The Treaty does not contain an explicit definition of the sustainability component of the inflation criterion, but the practice in the Convergence Reports might provide some guidance. In the May 2006 Convergence Report from the European Central Bank, the detailed assessment of the sustainability of the recent inflation performance comprises both a backward-looking and a forward-looking part (ECB 2006, p. 14). The backward-looking part consists of a review of the recent inflation performance in light of developments during the preceding 10 years. The forward-looking part entails an assessment of the inflation forecasts for the immediate future (ECB 2006, p. 21, 36).

3. Looking backward

The enlargement of the EU affects the reference value through two channels. First, adding more countries will tend to reduce the average inflation rates of the three countries with the

[6] The possibility of exclusion of countries with negative inflation was brought up already in the 1998 convergence report of the European Monetary Institute (EMI 1998, p. 33).

lowest inflation even if the distributional characteristics of the inflation processes in the new member countries are identical to existing members. Second, the inflation processes in the new countries may exhibit different distributional characteristics than observed in the old members.

Table 1 shows the means and standard deviations (S.D.) for the monthly tally of annual HICP inflation rates in the 27 EU countries for three time samples starting respectively in January 1999 (the start of EMU), January 2001 (the entry of Greece) and January 2004 (the year of the first eastward expansion of the EU), and all ending in June 2007.

Table 1: Summary statistics for HICP inflation in 27 EU countries, different sample periods (percent)

	1999:01-2007:06		**2001:01-2007:06**		**2004:01-2007:06**	
	Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
Belgium	1.94	0.62	2.11	0.53	2.14	0.39
Bulgaria	6.02	2.47	6.21	2.20	6.09	1.29
Czech Republic	2.56	1.72	2.18	1.42	1.85	0.57
Denmark	1.94	0.56	1.91	0.54	1.50	0.40
Germany	1.44	0.50	1.63	0.36	1.75	0.33
Estonia	3.87	1.41	3.78	1.34	3.55	1.22
Ireland	3.39	1.05	3.46	1.03	2.56	0.36
Greece	3.29	0.54	3.44	0.28	3.27	0.16
Spain	3.06	0.55	3.28	0.32	3.25	0.35
France	1.73	0.55	1.99	0.19	2.05	0.22
Italy	2.31	0.32	2.42	0.23	2.30	0.18
Cyprus	2.58	0.94	2.63	0.77	2.22	0.38
Latvia	4.01	2.03	4.41	2.15	6.20	1.19
Lithuania	1.56	1.60	1.41	1.64	2.10	1.69
Luxembourg	2.62	0.98	2.92	0.69	3.18	0.60
Hungary	7.01	2.77	5.92	2.15	4.90	1.36
Malta	2.56	0.45	2.47	0.40	2.49	0.41
Netherlands	2.46	1.17	2.62	1.29	1.58	0.18
Austria	1.64	0.56	1.86	0.32	1.58	0.18
Poland	4.39	3.28	3.02	2.38	1.83	1.03
Portugal	2.97	0.73	3.18	0.71	2.60	0.32
Romania	25.13	15.86	18.41	11.50	9.83	2.96
Slovenia	5.76	2.38	5.34	2.51	3.21	0.90
Slovakia	6.95	3.11	5.87	2.20	5.28	2.18
Finland	1.53	0.85	1.48	0.90	0.80	0.43
Sweden	1.46	0.69	1.69	0.61	1.25	0.34
United Kingdom	1.47	0.46	1.55	0.48	1.84	0.46
Average EU15	2.22	0.68	2.37	0.57	2.13	0.33
Average CEE10	6.73	3.66	5.66	2.95	4.52	1.44
Average EU27	3.91	1.78	3.60	1.45	3.03	0.75

Notes: Averages are unweighted country averages. CEE10 denotes the 10 Central and Eastern European countries acceding to the EU in 2004 and 2007.

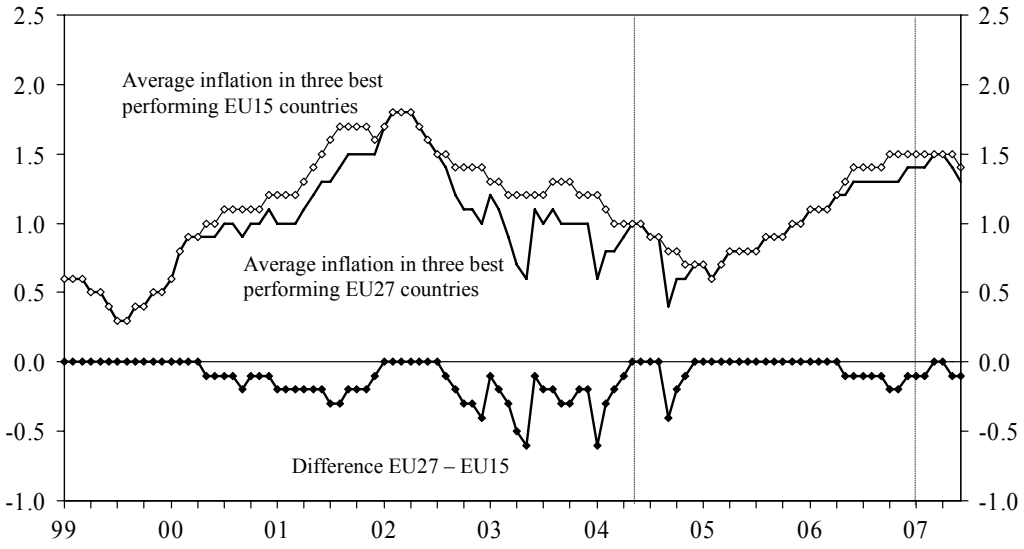
Source: Eurostat (2007), own calculations.

Several observations follow from Table 1. First, the average HICP inflation in all EU27 countries is relatively stable over time. The new EU members from Central and Eastern Europe (Romania excepted) also exhibit relatively stable inflation. Second, the average inflation rate in the EU15 countries is lower than the inflation in the countries that acceded to the Union in 2004 and 2007, but the difference is declining over time – mostly as a result of Romanian inflation falling during the period. Third, the variability or standard deviation of the inflation rate is larger for the CEE10 accession countries than for the old EU15 countries, but the variability is decreasing over time for both groups of countries.

The EU expansions brought in countries with on average higher inflation rates, but also much larger variability. A higher mean inflation rate in these countries implies that the newcomers are less likely than the old countries to be among the three best performing countries, but the higher variability has the opposite effect. It is thus an empirical question as to how strong the effect of enlargement is on the inflation reference value.

Figure 1 shows for the period 1999:01-2007:06 the average inflation rate of the three best performing countries, assuming 15 and 27 EU members respectively, as well as the difference between the EU27 and EU15 measures. The latter difference is also the effect on the inflation reference value of increasing the number of member countries from 15 to 27. Countries with negative inflation have been excluded from the reference group.

Figure 1: Average inflation rate of three best performing countries, EU15 and EU27, percent per year. Difference of reference values between EU27 and EU15, percentage points



Note: Countries with inflation below 0 are excluded from the reference group of the three best performing countries.
Source: Eurostat (2007), own calculations.

Several key points stand out from this counterfactual experiment. First, the average inflation of the three best performing countries varies substantially over time spanning an interval from 0.3 percent to 1.8 percent. The reference value is not a stable numerical policy target. Second, the graph depicting the average inflation in the three best performing EU27 countries is very "spiky" with variation from month to month of up to 0.5 percentage points. This is partly re-

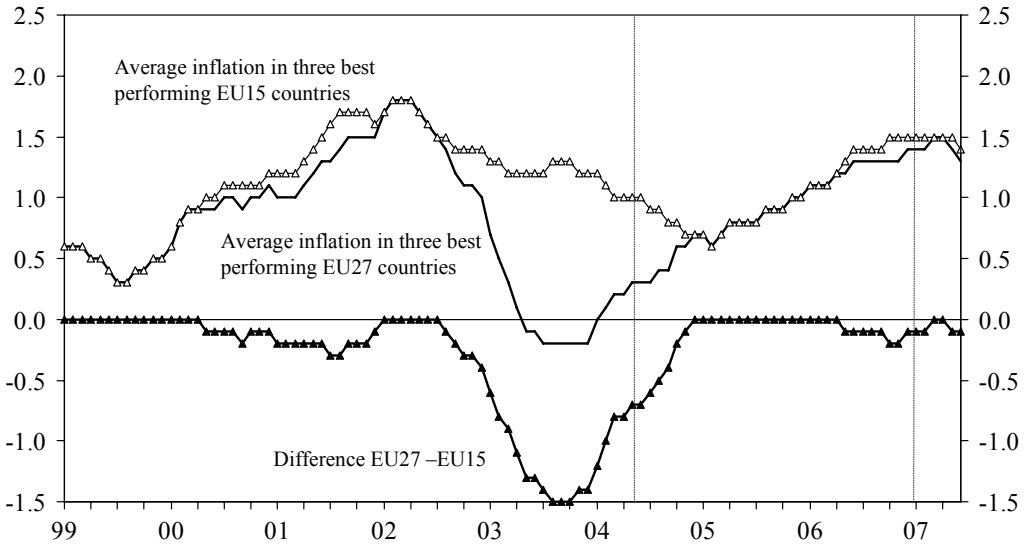
sulting from countries with inflation rates close to 0 jumping in and out of the reference group.

Third, the difference between the 15 member case and the 27 member case varies substantially over time. The two curves coincide in 1999 and again in 2005, but for other periods, the EU15 and EU27 reference values diverge by between 0.1 and 0.6 percentage points. For the entire sample 1999:01-2007:06 the average difference between the reference values in the two cases is –0.11 percentage points.

Bulgaria and Romania exhibit considerable inflation variability, but also comparatively high average inflation. Incidentally, neither country enters the reference group during the entire period 1999:01-2007:06. In other words, the difference between the EU15 and EU25 inflation reference values is the same as the difference between the EU15 and EU27 reference values.

As discussed in Section 2, it cannot be ruled out that future convergence assessments may retain countries with negative inflation in the group of countries with the best performance when the inflation reference value is calculated. We have therefore calculated the average inflation of the three best performing countries under the assumption that countries with negative inflation rates are retained. Figure 2 shows the effect of allowing countries with negative inflation in the reference group.

Figure 2: Average inflation rate of three best performing countries, EU15 and EU27 (percent per year). Difference of reference values between EU15 and EU27 (percentage points)



Note: Countries with inflation below 0 are retained in the reference group of the three best performing countries.
Source: Eurostat (2007), own calculations.

A comparison of Figures 1 and 2 shows the importance of the treatment of countries with negative inflation. While the average of the three best performing EU15 countries remain unchanged for the entire sample, the EU27-based measure changes substantially from mid-2002 to the end of 2004 (as both Lithuania and the Czech Republic experience negative inflation rates in parts of this period). Consequently, from mid-2002 to the end of 2004 the difference between the reference values based on respectively 15 and 27 EU countries is much smaller

when countries with negative inflation are retained than if they are excluded. The average difference between the reference values is –0.27 percentage points for the sample 1999:01-2007:06.

4. Looking forward

A counterfactual analysis on historical data such as the one above has a number of drawbacks. First, the effect of more EU countries will depend on specific events during the period considered. Second, some potentially important information may be discarded. For countries outside the reference group in any particular month the inflation rate data are not utilised, beyond the fact that their inflation rate was too high for them to be in the reference group. Such monthly inflation data is of value because it contains information about the statistical properties of the distribution of the rate of inflation in each country and the correlation of inflation rates across countries.

This section complements the analysis in Section 3 by undertaking Monte Carlo simulations in order to estimate the distribution of the average inflation rate in the three best performing countries for any given set of EU countries. By comparing the distributions with respectively 15 and 27 EU members, the change in the inflation reference value stemming from the enlargement effect can be ascertained.

The chief assumption underlying the Monte Carlo simulations is that the inflation rate for each of the 27 countries can be drawn from a *jointly distributed* and *stationary* random variable. The simulated inflation distributions are thus not conditioned on any economic information such as inflation expectations, unemployment or import price inflation. The resulting characterisations of inflation are the *unconditional* distributions – in the sense that no economic data is used to explain the inflation rate. If the goal was to forecast the inflation a few months ahead, this procedure would clearly be inappropriate, since currently available information would substantially aid the forecast process. However, since the goal is to estimate the enlargement effect for periods so far into the future that current data has no or negligible predictive power, the *unconditional* distribution of the inflation in each country is the appropriate starting point.[7]

A related justification is any attempt to model the reference value needs to explicitly consider the behaviour of inflation in the lower end (i.e. below the mean) of the distribution. Longer term model-based forecasts are predicated on a baseline scenario which is based on the "most likely" path of key variables. However, countries in the reference group are often those who are experiencing extremely low because they have departed from the baseline scenario envisaged in the forecasts. This is especially true when mean inflation rates across countries are similar.

To illustrate this, consider the following example. Suppose that a modeller forecasts that for all countries, inflation two years from now will be 2 percent. Any inflation forecast comes with an error: for some countries the eventual outturn of inflation will be above 2 percent, for some countries it will be below 2 percent. In other words when the forecast is made, we expect that *some* countries will have end up having inflation below 2 percent even if it is impossible to know which ones. It follows that the average of the lowest three countries inflation

[7] Throughout the paper, we use the term *unconditional* to signify unconditional with respect to economic variables.

rates in all likelihood will be below 2 percent, even though the forecast for each individual country is 2 percent.

In this paper, we derive numerical as opposed to analytical measures of the distribution function of the reference value because the formula used to calculate the reference value cannot be easily analysed in closed form. Specifically, because the formula makes use of the average of the lowest three countries, but then excludes negative inflation, this is cumbersome to express in terms of standard mathematical operators; and when issues such as the correlation between countries inflation rates, or the functional forms of inflation distributions are added in, formal analysis becomes unworkable. Accordingly, since the ultimate goal of the paper is to quantify the enlargement effect numerically, we use numerical methods.

The main assumption behind our use of Monte Carlo simulations is that the inflation outturn in a randomly specified month is being generated by a draw from a *jointly distributed* and *stationary* random variable. The assumption that the cross section of inflation rates is jointly distributed implies that the covariances (or correlations) between the inflation rates between countries must be taken explicitly into account. In our baseline case, we assume the underlying marginal distribution of inflation for each country is normal (this assumption is relaxed later on), and estimate the population parameters from the sample observations. If the inflation generating process does not change over time, then the population parameters can be estimated using data from the sampling distribution.

The process of Monte Carlo simulations works as follows: We make a draw from each the specified marginal inflation distributions incorporating the covariances across the inflation rates. The average inflation rate in the three best performing countries, rounded to one decimal place, is calculated for each draw, for both the EU15 and EU27 case. The difference between the two figures is the enlargement effect (i.e. the effect on the reference value of expansion of the EU from 15 to 27 members) for that particular draw. This procedure is repeated 10,000 times. Based on the 10,000 draws we obtain the unconditional probability density function of the enlargement effect and can also calculate e.g. the unconditional mean and standard deviation.

The results will depend on the assumed marginal distribution of the inflation rates and the correlations between national inflation rates. The challenge is to devise distributions, which are empirically substantiated and which can reasonably be expected to govern inflation in the 27 EU countries within the relevant time horizon (Charnes 2007, ch. 4). In addition, the correlation of each country's inflation rate with inflation rates in the other EU countries needs to be specified, as e.g. synchronisation of business cycles, common external shocks and/or a joint monetary policy imply that the inflation rates in different EU countries are likely to co-vary. In sum, we need to specify for the marginal distribution functions, their sufficient statistics and the inflation correlation matrix.

Our strategy is to devise a baseline scenario and subsequently undertake a number of robustness checks to examine to what extent the results rely on the specific choices of assumptions and estimation sample. It is generally difficult to ascertain the underlying inflation processes in the 27 EU countries, especially as the processes may change over time, and it is therefore expedient to undertake a number of robustness checks employing different assumptions. The chief objectives of the robustness checks are to rein in a likely interval of the inflation reference value in the case of 27 EU members as well as an interval the enlargement effect on the reference value.

The *baseline simulation* assumes that the inflation rates in the 27 countries are drawn from normal distributions with country-specific means and standard deviations estimated on the sample 1999:01-2007:06 (see Table 1), while conforming to a correlation matrix as observed during the same period.[8]

The choice of the normal distribution rests on two factors. First, tests show that the normal distribution in many cases provides a reasonable fit to the inflation series of different data samples since 1999. (Appendix A shows the results of Jarque-Bera tests of the normality assumption based on different sample assumptions.) Second, conceptually the HICP inflation rate comprises the sum of price changes of numerous products, and the central limit theorem would accordingly suggest that the distribution of the resulting sum would converge to a normal distribution. To examine the importance of the assumption that the inflation rate in each country follows a normal distribution, we undertake a number of simulations assuming that the inflation variables are drawn from other distributions than the normal distribution.

The inflation processes in the EU countries are reasonably stable across time, but there are still countries where the inflation process is likely to have changed since the start of the EMU in 1999:01 (with Romania being the prime example). In addition to estimating the population parameters on the full sample 1999:01-2007:06, we also undertake simulations where the means, standard deviations and correlations are estimated on two shorter samples, namely 2001:01-2007:06 and 2004:01-2007:06.

For some countries there was a switch in the fixity of the exchange rate or the currency to which it was fixed. The Visegrad countries (Hungary, Czech Republic, Slovakia and Hungary) pursued a form of inflation targeting throughout, but the inflation targets themselves changed. We therefore also examine whether the downward revisions of these inflation targets may affect the results.

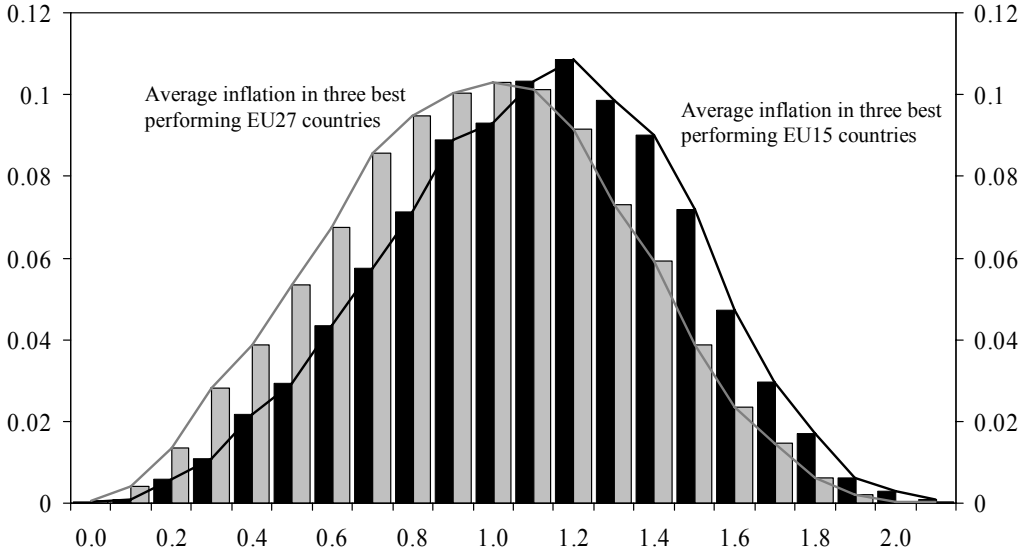
The correlation matrix between inflation rates in the EU is rather unstable across different sample periods. Thus, estimating the matrix based on the sample 1999:01-2007:06 yields quite different results compared to those obtained using the sample 2001:01-2007:06. Some of the patterns of correlation coefficients are also difficult to interpret.[9] It is therefore expedient to examine the sensitivity of the results to changes in the correlation matrix.

Figure 3 shows the unconditional probability distributions of the average inflation rate in the three best performing countries with respectively 15 (black) and 27 EU countries (grey), derived from the baseline scenario. It follows that the distribution shifts to the left when the number of countries increases. The unconditional average of the inflation rates in the three best performing countries is 1.14 percentage points with 15 EU countries and 0.98 percentage points with 27 EU countries. (The respective inflation reference values are calculated by adding 1.5 percentage points to these values.)

[8] The correlation coefficients used in the simulations are adjusted relative to the estimated coefficients in order to avoid inconsistencies between the correlation matrix and the assumptions concerning the country-specific inflation distributions. The adjustments are generally small.

[9] By means of example, based on the sample 1999:01-2007:06 the Spearman correlation coefficient between inflation in Belgium and Bulgaria is 0.78, while it is only 0.18 between the two EMU members Belgium and Italy.

Figure 3: Probability distributions of average inflation rates in the three best performing countries with respectively 15 and 27 EU countries (percent)



Note: Based on Simulation 1 using empirical means, S.D. and correlations for the sample 1999:01-2007:06. Countries with inflation below 0 are excluded from the reference group of the three best performing countries.

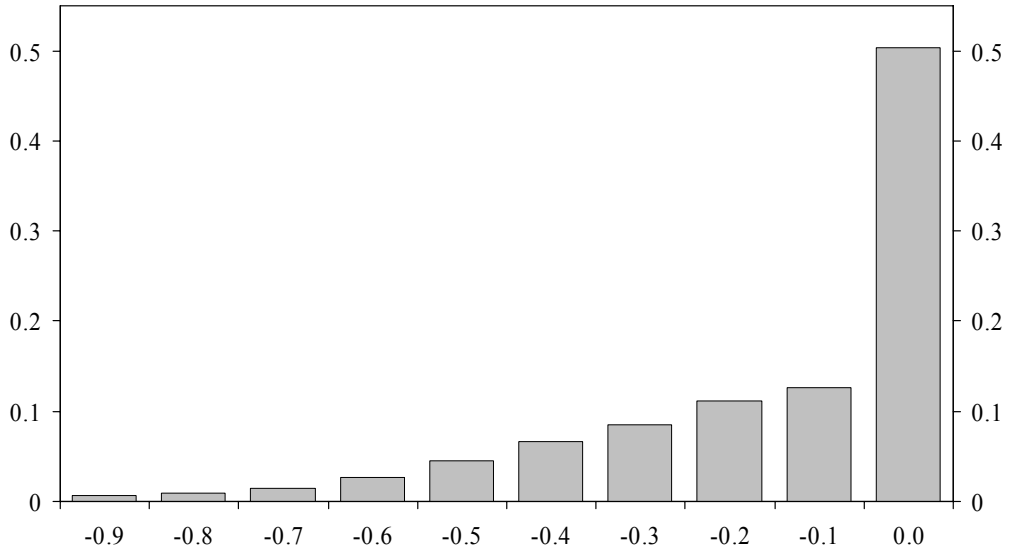
Source: Eurostat (2007), own calculations.

A noticeable feature following from Figure 3 is the substantial dispersion of the average inflation in the three best performing countries. Thus, after expansion of the EU to 27 member countries, there is a 29 percent probability that the average inflation rate in the three best performing countries is at most 0.5 percentage points resulting in a reference value less than or equal to 2 percentage points. The finding that there is substantial variability in the average of the inflation rates in the three best performing countries is in accordance with the findings of the counter-factual experiments in Section 3.

Figure 4 shows the probability distribution of the difference between the reference values with 15 and 27 countries respectively. It is evident that the probability distribution has a highly asymmetric shape, due to the fact that the upper bound of the difference is by construction zero. Around half of the time, the enlargement effect is zero. In about 25 percent of the cases, the enlargement effect is more than 0.3 percentage points, and in just under 10 percent of cases the enlargement effect is more than 0.5 percentage points. In other words, it is not unconceivable that an applicant country in a particular month could find the reference value 0.3 or 0.5 percentage points lower due to the expansion of the EU from 15 to 27 members.

Table 2 shows the results of a large number of simulations addressing the robustness of the baseline results. Simulation 1x uses the empirical means and standard deviations based on the sample 1999:01-2007:06, but all correlation coefficients between countries inflation rates are set equal to 0. The means of the inflation rates in the three best performing countries drop slightly relative to the cases with the empirical correlations, but the difference of the reference values remain unchanged. As robustness checks, all of the subsequent simulations were also run with the correlations set equal to zero. In all cases, running the simulations with correlations set to zero yields very similar results. For details of these simulations, see Appendix B.

Figure 4: Probability distribution of difference between inflation reference values with 15 and 27 EU countries (percentage points)



Notes: Based on Simulation 1 using empirical means, S.D. and correlations for the sample 1999:01-2007:06. Countries with inflation below 0 are excluded from the reference group of the three best performing countries.

Source: Eurostat (2007), own calculations.

Table 2: Inflation rates in the three best performing countries based on simulations with 27 and 15 EU countries. Difference of inflation reference values using respectively 27 and 15 EU countries

	Assumptions concerning inflation processes	**Inflation in three best performing EU15 countries, percent**		**Inflation in three best performing EU27 countries, percent**		**Enlargement effect EU27 – EU15, percentage points**	
		Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
1	Empirical means, S.D. and correlations for sample 1999:01-2007:06	1.10	(0.36)	0.95	(0.35)	–0.15	(0.21)
1x	Empirical means and S.D. for sample 1999:01-2007:06, correlations = 0	1.04	(0.26)	0.89	(0.27)	–0.15	(0.19)
2	Empirical means, S.D. and correlations for sample 2001:01-2007:06	1.25	(0.33)	1.06	(0.38)	–0.19	(0.21)
3	Empirical means, S.D. and correlations for sample 2004:01-2007:06	1.10	(0.26)	0.99	(0.27)	–0.11	(0.16)
4	Empirical mean, *doubled S.D.* and correlations for sample 1999:01-2007:06	0.90	(0.46)	0.73	(0.39)	–0.19	(0.26)
5	Empirical means, S.D. and correlations for sample 1999:01-2007:06; *uniform distributions*	1.06	(0.36)	0.93	(0.34)	–0.15	(0.22)
6	Empirical means, S.D. and correlations for sample 1999:01-2007:06; *"best fit" distributions*	1.12	(0.34)	0.99	(0.33)	–0.13	(0.19)
7	Empirical means, S.D. and correlations for sample 1999:01-2007:06, for 23 nations; *inflation target adjustments* for CZ, HU, PL and SK	1.10	(0.35)	0.92	(0.34)	-0.18	(0.19)

Notes: Inflation rates below 0 are excluded from the reference group of the three best performing countries. All inflation rates are assumed to follow normal distributions if not otherwise indicated.

Source: Eurostat (2007), own calculations.

The next robustness check considers how the effect of enlargement varies when different sample periods are used for estimating the means, standard deviations and correlation coefficients of the inflation rates. Simulation 2 uses the empirical means, standard deviations and correlations estimated on the sample 2001:01-2007:06. The mean difference between the reference values with 27 and 15 EU countries is 0.19.

Simulation 3 is parameterised based on the recent sample 2004:01-2007:06. The mean difference between the reference values is 0.11 (Simulation 3). The relatively small difference reflects the unusually low variability of inflation in many countries in this short period.

Simulation 4 employs the same assumptions as Simulation 1, but with the assumption that the standard deviation is twice the values estimated for the period 1999:01-2007:06. When comparing the two results, it is clear that the increased inflation variability brings about a substantial lowering of the mean inflation rate of the three best performing countries (0.22 percentage points), but has a rather modest impact on the enlargement effect (0.04 percentage points).

Up to this point, it has been assumed that the inflation in each country is drawn from a normal distribution. To examine the importance of the distributional assumption, the next two sets of robustness checks employ alternative assumptions concerning the distributions of the inflation process.

Simulation 5 repeats Simulation 1 under the alternative assumption that inflation follows a uniform (as opposed to a normal) distribution. The uniform distribution is chosen because it has fat tails and the simulations thus provide information concerning the importance of extreme observations on the results. For each country, the country-specific parameters a and b of the uniform density function $1/(b - a)$ as defined on the interval $[a, b]$ are estimated using the Method of Moments, where a is the mean minus $\sqrt{3}$ times the standard deviation and b is the mean plus $\sqrt{3}$ times the standard deviation. The expected inflation rates in the three best performing countries are slightly smaller when uniform distributions are used instead of normal distributions. This finding is the result of the uniform distribution having thicker tails than the normal distribution. The results show that the effect of enlargement on the reference value is very similar irrespective of whether the inflation follows a normal or a uniform distribution.

Simulation 6 allows the distribution functions to vary across the countries in order to for the individual distributions to provide the best possible fit to the observed inflation rate in the sample period 1999:01-2007:06. Specifically, for each country the continuous distribution function and parameterisation are chosen, which yields the best fit as measured by the test statistic of the Chi-Square goodness-of-fit test.[10] Comparing with Simulation 1, it follows that allowing the distributions to vary across the countries has a very limited effect on the results. In sum, the robustness checks reveal that the specific choice of distribution function is rather unimportant as is frequently the case in Monte Carlo simulations (Charnes 2007, ch. 4).

The last simulation, Simulation 7, explicitly allows for the effect of steadily declining inflation targets in the Czech Republic, Hungary, Poland and Slovakia. The reduction in the targeted rate of inflation suggests that future inflation will have a lower mean than that observed

[10] The distributions are chosen from the following possibilities: triangular, normal, uniform, lognormal, beta, gamma, Weibull, max extreme, min extreme, logistic, student's *t*, exponential and Pareto.

during our historical sample.[11] In these simulations, the data is first transformed by taking the deviation of inflation from its target value at the time, and dividing by the target value.[12] Then, this relative deviation is multiplied by 1 plus the current target value. The enlargement effect on the mean change in the reference value obtained from these simulations is 0.18, a slight increase on the figure from Simulation 1.

The results of the simulations presented in Table 2 are straightforward to summarise. The expansion of the EU from 15 to 27 members reduces the expected inflation reference value by 0.11-0.21 percentage points depending on the sample period used to estimate the means, standard deviations and correlations of the inflation processes. In the case with 27 EU countries, most of the simulations suggest that the *expected* average inflation rate in the three best performing countries is 1 percent or slightly below, but the relatively large standard deviation indicates that the measure is likely to fluctuate considerably. The results are relatively robust to the specific choice of distribution function, the exact degree of inflation variability and to changes in the correlations across the inflation rates.[13]

The simulations shown hitherto are all based on the assumption that countries with negative inflation rates are dropped from the sample when the three best performing countries are selected. This follows the practice in recent Convergence Reports, but as noted earlier this may not be the case in future assessments. We proceed by examining the effect of expansion of the EU when countries with negative inflation rates are retained. Table 3 shows the results using the same assumptions concerning the distributions and parameterisations as in Simulations 1-3 in Table 2.

Table 3: Inflation rates in the three best performing countries based on simulations with 27 and 15 EU countries. Difference of inflation reference values using respectively 27 and 15 EU countries

	Assumptions concerning inflation processes	Inflation in three best performing EU15 countries, percent		Inflation in three best performing EU27 countries, percent		Enlargement effect EU27 – EU15, percentage points	
		Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
8	Empirical means, S.D. and correlations for sample 1999:01-2007:06	1.07	(0.41)	0.55	(1.10)	–0.52	(1.04)
9	Empirical means, S.D. and correlations for sample 2001:01-2007:06	1.22	(0.40)	0.70	(0.98)	–0.53	(0.76)
10	Empirical means, S.D. and correlations for sample 2004:01-2007:06	1.09	(0.28)	0.89	(0.40)	–0.19	(0.26)

Notes: Inflation rates below 0 are retained in the reference group of the three best performing countries. All inflation rates are assumed to follow normal distributions.

Source: Eurostat (2007), own calculations.

[11] For the Czech Republic, Hungary and Poland, these numbers are taken from the websites of the central bank. Where a band is specified, we treat the midpoint as the target value. For Slovakia, prior to the advent of inflation targeting we follow the EC (2004b) in treating the future inflation path published in the Monetary Plan of the National Bank of Slovakia as its implicit target value.

[12] For these countries, inflation targeting was adopted after January 1999 and the sample period for these countries is therefore shortened, while the full sample is retained for all other countries.

[13] Appendix C shows the simulation results when the inflation rates in all countries are assumed to follow identical normal distributions. The effect of enlargement stemming solely from an increased number of countries can be pinned downed from these results.

Comparing the results in Table 3 with the results of Simulations 1-3, it is apparent that retaining countries with negative inflation in the reference group has a large impact on the average inflation rate in the three best performing countries when there are 27 EU member countries. Simulation 8 uses the empirical means, standard deviations and correlations based on the sample 1999:01-2007:06. The enlargement effect reduces the average inflation rate in the three best performing countries by 0.52 percentage points, which is substantially more than the 0.15 in the case where countries with negative inflation are excluded (Simulation 1). This is due to the lengthening of the left hand tail in the distribution. Intuitively, the treatment of countries with negative inflation has little effect when no new member states are included in the reference group and hence the EU15 and EU27 figures are identical. However, in a subset of cases where new members figure in the reference group and they have negative inflation, they do exert an influence on the enlargement effect.

The differences between the reference values with respectively 15 and 27 EU members are particularly large when the standard deviations are large relative to the means of inflation. The intuition is straightforward: A larger sample of countries implies that very low inflation rates – and indeed negative rates – are more likely especially when the standard deviations (relative to the means) are large for the additional countries. This effect particularly influences the inflation reference value when countries with negative inflation rates are not excluded from the reference group. Another interesting result is that the correlation pattern of inflation rates across countries is of more importance when countries with negative inflation are retained in the sample. The reason is that inflation variability and hence also co-variability become more important as the countries with negative observations are retained.

5. Conclusions

This paper has quantified the effect on the inflation reference value resulting from the expansion of the EU from 15 to 27 member countries. In this sense the paper has sought to quantify how much harder it has become to fulfil (the first part of) the inflation criterion effective from 2007 when the EU has 27 members, as compared to 1998 and 2000 when there were 15 member countries.

The backward looking counterfactual analysis showed that had the EU comprised of 27 member countries instead of 15, the reference value would have been substantially lower in extended periods 1999-2004 and again from mid-2006. The Monte Carlo simulations showed that the expected reference value has decreased by 0.15-0.2 percentage points after the expansion of the EU from 15 to 27 members. This result is robust to a wide variety of alternative assumptions. Equally important is the distribution of this enlargement effect which is highly skewed. In around 25 percent of the cases the effect is 0.3 percentage points or more; and in around 10 percent of the cases the effect is 0.5 percent or more.

The paper also highlighted the implications of the practice of excluding countries with negative inflation from the group of the three best performing countries. Both the counterfactual experiments and the simulations indicated that this choice has a major impact on the inflation reference value as well as the expected lowering of the reference value when the number of EU countries increases from 15 to 27. If countries with negative inflation are included in a future assessment, the resulting reference value could be much lower if negative inflation figures were observed.

The exclusion of negative inflation rates also means that the inflation reference value is likely to fluctuate markedly from month to month. This implies that there may be months in which an applicant country by luck will satisfy the inflation criterion because of relatively large realisations of the reference value. The implication for compliance with the criterion is difficult to assess because of the sustainability component of the criterion. Sustainability is assessed by comparing current inflation rates with both past and future expected levels, but the expected future value of the reference value is also likely to play a role in this context.

The simulations also showed that with 27 EU countries the expected average inflation in the three countries with the best performance is around 1 percentage point for a broad range of distributions and parameter specifications. This implies that the unconditional expectation of the reference value would be around 2.5 percent with a 95 percent confidence interval spanning ranging from 1.8 to 3.2 percent. These estimates may provide useful yardsticks of the inflation reference value and its likely dispersion within a time horizon of two years or more.

A lower reference value may also have an indirect effect on the sustainability component of the criterion. In previous Convergence Reports, one of the tools used to assess sustainable inflation was a comparison of a country's inflation performance over a spell of months or years with respect to the reference value (as opposed to simply comparing inflation performance and reference value for the latest month for which data is available). In this sense, a lowering of the reference value constitutes a tightening of the standard by which sustainable inflation performance is assessed.

Appendix A: Test of normality of inflation rates in historical sample periods

Table A.1: Jarque-Bera test of normality of HICP inflation in 27 EU countries, different sample periods

	1999:01-2007:06		2001:01-2007:06		2004:01-2007:06	
	Jarque-Bera	**Prob.**[a)]	**Jarque-Bera**	**Prob.**[a)]	**Jarque-Bera**	**Prob.**[a)]
Belgium	5.42	0.066	4.54	0.103	3.43	0.180
Bulgaria	1.99	0.370	0.17	0.920	0.88	0.644
Czech Republic	27.67	0.000	2.14	0.344	19.22	0.000
Denmark	6.96	0.031	6.57	0.037	4.28	0.117
Germany	7.22	0.027	6.96	0.031	8.63	0.013
Estonia	0.43	0.807	5.74	0.057	8.14	0.017
Ireland	11.70	0.003	9.19	0.010	31.09	0.000
Greece	11.51	0.003	4.69	0.096	2.03	0.362
Spain	16.63	0.000	4.24	0.120	2.06	0.358
France	33.09	0.000	1.29	0.526	1.03	0.597
Italy	3.26	0.196	4.59	0.101	11.04	0.004
Cyprus	9.41	0.009	15.04	0.001	93.21	0.000
Latvia	13.82	0.001	10.34	0.006	14.87	0.001
Lithuania	2.48	0.290	4.03	0.133	4.53	0.104
Luxembourg	6.54	0.038	5.32	0.070	3.86	0.145
Hungary	7.41	0.025	7.03	0.030	3.47	0.177
Malta	0.85	0.653	5.53	0.063	18.89	0.000
Netherlands	19.37	0.000	9.80	0.007	3.12	0.210
Austria	14.18	0.001	3.54	0.171	1.61	0.448
Poland	11.29	0.004	26.84	0.000	4.62	0.099
Portugal	8.02	0.018	5.28	0.071	1.98	0.371
Romania	11.19	0.004	10.38	0.006	1.63	0.443
Slovenia	9.24	0.010	8.42	0.015	7.64	0.022
Slovakia	10.18	0.006	4.45	0.108	5.37	0.068
Finland	5.01	0.082	4.65	0.098	3.62	0.164
Sweden	3.80	0.149	3.85	0.146	1.36	0.507
United Kingdom	11.88	0.003	8.00	0.018	3.46	0.177

[a)] Probability that the null hypothesis of normality cannot be rejected.

Source: Eurostat (2007), own calculations.

Appendix B: Results from simulations where correlations are set to zero

Table B.1 shows the results of the simulations in Table 2 in Section 4 but with the correlation coefficients between the inflation rates are set to zero. Table B.2 shows the results of the simulations in Table 3 in Section 4, when countries with negative inflation are retained in the groups of the best performing countries), but with the correlation coefficients between the inflation rates are set to zero. The simulations with zero correlations are numbered as in Section 4 but with a post-positioned x.

Table B.1: Inflation rates in the three best performing countries based on simulations with 27 and 15 EU countries. Difference of inflation reference values with respectively 27 and 15 EU countries.

	Assumptions concerning inflation processes	**Inflation in three best performing EU15 countries, percent**		**Inflation in three best performing EU27 countries, percent**		**Enlargement effect EU27 – EU15, percentage points**	
		Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
1x	Empirical means and S.D. for sample 1999:01-2007:06, correlations = 0	1.04	(0.26)	0.89	(0.27)	–0.15	(0.19)
2x	Empirical means and S.D. for sample 2001:01-2007:06, correlations = 0	1.23	(0.27)	1.01	(0.30)	–0.21	(0.23)
3x	Empirical means and S.D. for sample 2004:01-2007:06, correlations = 0	1.07	(0.20)	0.96	(0.22)	–0.11	(0.15)
4x	Empirical mean and *doubled* S.D. for sample 1999:01-2007:06, correlations = 0	0.84	(0.34)	0.67	(0.31)	–0.17	(0.21)
5x	Empirical means and S.D. for sample 1999:01-2007:06, correlations = 0; *uniform distributions*	0.99	(0.24)	0.85	(0.26)	–0.14	(0.19)
6x	Empirical means and S.D. for sample 1999:01-2007:06, correlations = 0; *"best fit" distributions*	1.06	(0.25)	0.94	(0.25)	–0.12	(0.16)
7x	Empirical means, S.D. 1999:01-2007:06, for 23 nations; *inflation target adjustment* for CZ, HU, PL, and SK; correlations = 0	1.04	(0.26)	0.85	(0.26)	-0.19	(0.20)

Notes: Inflation rates below 0 are excluded from the reference group of the three best performing countries. All correlation coefficients set equal to 0. All inflation rates are assumed to follow normal distributions if not otherwise indicated.

Source: Eurostat (2007), own calculations.

Table B.2: Inflation in the three best performing countries based on simulations with 27 and 15 EU countries. Difference of inflation reference values with respectively 27 and 15 EU countries.

	Assumptions concerning inflation processes	**Inflation in three best performing EU15 countries, percent**		**Inflation in three best performing EU27 countries, percent**		**Enlargement effect EU27 – EU15, percentage points**	
8x	Empirical means and S.D. for sample 1999:01-2007:06, correlations = 0	1.00	(0.29)	0.45	(0.89)	–0.55	(0.87)
9x	Empirical means and S.D. for sample 2001:01-2007:06, correlations = 0	1.18	(0.30)	0.57	(0.78)	–0.61	(0.75)
10x	Empirical means and S.D. for sample 2004:01-2007:06, correlations = 0	1.06	(0.20)	0.86	(0.32)	–0.20	(0.28)

Notes: Inflation rates below 0 are retained in the reference group of the three best performing countries. All correlation coefficients set equal to 0. All inflation rates are assumed to follow normal distributions if not otherwise indicated.

Source: Eurostat (2007), own calculations.

Appendix C: Results from simulation experiments with identical distributions

This appendix reports the results from simulation experiments, where the inflation rate is assumed to follow the same normal distribution for all countries. The purpose of using the same "artificial" distribution for all counties is to pin down the enlargement effect when the effect stems solely from the increased number of countries. The chosen means and standard deviations are motivated by the empirical moments reported in Table 1 in Section 3.

Table C.1 shows the results when countries with inflation rates below zero are excluded from the reference group. Simulation 11 assumes that inflation in all countries has a mean of 2 percent, a standard deviation of 1 percent and no correlation with inflation in other countries. With 15 EU countries the mean inflation of the three best performing countries is 0.86 percent, while it is 0.60 percent with 27 EU countries, implying an expected drop in the reference value of 0.26 percentage points.

Table C.1: Inflation rates in the three best performing countries based on simulations with 27 and 15 EU countries. Difference of inflation reference values with respectively 27 and 15 EU countries

	Assumptions concerning inflation processes	Inflation in three best performing EU15 countries, percent		Inflation in three best performing EU27 countries, percent		Enlargement effect EU27 – EU15 , percentage points	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
11	Means = 2, S.D. = 1, correlations = 0 for all countries	0.86	(0.31)	0.60	(0.25)	–0.26	(0.23)
12	Means = 2, S.D. = 0.5, correlations = 0 for all countries	1.33	(0.20)	1.17	(0.18)	–0.15	(0.15)
13	Means = 2.5, S.D. = 1, correlations = 0 for all countries	1.23	(0.34)	0.95	(0.30)	–0.28	(0.26)
14	Means = 2.22, S.D. = 0.68, correlations = 0 for all countries	1.31	(0.26)	1.11	(0.23)	–0.20	(0.19)
15	Means = 2.37, S.D. = 0.57, correlations = 0 for all countries	1.57	(0.23)	1.41	(0.21)	–0.16	(0.16)
16	Means = 2.13, S.D. = 0.33, correlations = 0 for all countries	1.64	(0.16)	1.55	(0.15)	–0.09	(0.10)

Notes: Inflation rates below 0 are excluded from the reference group of the three best performing countries. The inflation is assumed to follow the same normal distribution in all countries.

Source: Own calculations.

Simulation 12 retains the previous assumptions with the exception that standard deviation is now reduced to 0.5 percent. The mean inflation in the three best performing countries is now 1.33 with 15 countries and 1.17 with 27 countries, resulting in an enlargement effect equal to 0.15 percentage points; the reduced inflation variability leads to a lower difference between the two reference values in absolute terms. Simulation 13 retains the assumptions from Simulation 11, but assumes a higher mean inflation rate. The mean of the inflation rates of the three best performing countries increases markedly regardless of the number of EU members, but the difference between the reference values change only little when compared to Simulation 11. The extent of inflation variability affects greatly the expected reference values as well as the enlargement effect. Simulations 14-16 assumes that the means and standard deviations of all countries take the average value for EU15 for, respectively, 1999:01-2007:06, 2001:01-

2007:06 and 2004:01-2007:06. The results are commensurate to Simulations 1-3 in Table 2 in the main text.

Table C.2 shows the results of the Monte Carlo simulations when countries with negative inflation rates are retained in the group of the three best performing countries. In the simulation exercises where identical parameterisations are employed, the average inflation rate is relatively large relative to the variability of inflation, and the inflation rate will therefore seldom be negative. This implies that the differences between the results with and without exclusion of countries with negative inflation rates (Tables 4 and 5) are relatively small. In the case where the standard deviation is 0.5, the results are essentially identical.

Table C.2: Inflation rates in the three best performing countries based on simulations with 27 and 15 EU countries. Difference of inflation reference values with respectively 27 and 15 EU countries

	Assumptions concerning inflation processes	**Inflation in three best performing EU15 countries, percent**		**Inflation in three best performing EU27 countries, percent**		**Enlargement effect EU27 – EU15, percentage points**	
		Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
17	Means = 2, S.D. = 1, correlations = 0 for all countries	0.72	(0.38)	0.39	(0.35)	–0.33	(0.30)
18	Means = 2, S.D. = 0.5, correlations = 0 for all countries	1.33	(0.20)	1.18	(0.18)	–0.15	(0.15)
19	Means = 2.5, S.D. = 1, correlations = 0 for all countries	1.18	(0.38)	0.88	(0.35)	–0.30	(0.29)

Notes: Inflation rates below 0 are retained in the reference group of the three best performing countries. The inflation is assumed to follow the same normal distribution in all countries.

Source: Own calculations.

Overall, the results of the simulations using identical parameterisations show two important results. First, the enlargement effect is substantial even when all countries have inflation with the same distributional characteristics. Thus, the enlargement effects found in Section 4 do not hinge on the newcomers having higher inflation variability than the old EU countries. Second, higher inflation variability relative to the average inflation rate leads to relatively low reference values and also implies that EU expansion leads to a relatively marked decrease in the reference value.

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