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

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Abstract

Following the Maastricht criteria, a country seeking to join the European Monetary Union cannot have inflation in excess of 1.5 percent plus the average inflation 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 would have been sizeable in 2003 and 2004, but 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, but with a considerable probability of a larger reduction. The treatment of countries with negative inflation in the calculation of the reference value has a major impact on the results.

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Non-technical summary

The inflation criterion of the Maastricht Treaty stipulates that a country seeking to join the European Monetary Union (EMU) must have an inflation rate lower than or equal to a reference value defined as the average inflation rate in the three EU countries with the best performance in terms of price stability, plus 1.5 percentage points. The reference group of the three best performing countries has been taken to comprise the three EU countries with the lowest non-negative inflation, i.e. countries experiencing negative inflation are excluded from the reference group.

The inflation reference value is a non-increasing function of the number of EU members, so the expansions of the EU from 15 countries in 2003 to 27 countries in 2007 has in all likelihood lowered the reference value and made it more difficult to satisfy the inflation criterion. This paper quantifies the effect on the inflation reference value resulting from the expansion of the EU from 15 to 27 Member States. The reference value is of importance for current and future EU members seeking to satisfy the conditions for membership of the EMU.

The paper assesses the effect of EU enlargement on the inflation reference value using two different approaches. The first approach is a counterfactual analysis using inflation data for the period 1999:01–2007:06 for the 27 countries that have been EU members since 2007. The average inflation in the three best performing countries (and hence the reference value) is calculated assuming 15 and 27 EU members respectively.

The analysis on historical data shows that if the EU had comprised of 27 Member States instead of 15, the reference value would have been substantially lower (up to 0.5 percentage points) in extended periods during the years 1999–2004 and again from mid-2006. The analysis also shows that the inflation reference value fluctuates considerably from month to month as countries with inflation around zero shift in and out of the reference group. If countries with negative inflation rates are assumed to be retained in the reference group, the enlargement effect on the reference value would be even larger.

The second approach consists of Monte Carlo simulations which are used to ascertain the distribution of the average inflation in the three best performing countries (and hence the reference value) for a given set of EU countries. Previous inflation data is used to parameterise assumed inflation distributions for the 27 countries. The enlargement effect is found by comparing the estimated distributions of the reference value with 15 and 27 EU countries respectively.

The simulations show that the distribution of the average inflation in the three best performing countries is shifted to the left after the increase of the

number of EU members from 15 to 27. The *expected* reference value has decreased by 0.15–0.2 percentage points depending on the specific assumptions employed. There is around a 25 percent change that the gap is 0.3 percentage points or larger.

Our Monte Carlo simulations for 27 countries estimate that the expected average inflation in the three best performing countries is around 1 percentage point for a broad range of distributions and parameter specifications. This implies that the unconditional expectation of the inflation reference value would be around 2.5 percent which suggests that this is a useful yardstick for the likely value of the actual reference value. The standard deviation of the reference value is substantial as a result of the exclusion of countries with negative inflation from the reference group.

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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.[1] The exchange rate and fiscal criteria are phased in terms of fixed reference values.[2] 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.[3] The reference value for the inflation criterion 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 inflation 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 2006:26). 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 reference value of the inflation criterion is of importance for current and future EU members seeking membership of the eurozone. 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 most recently 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 scrutiny (Buiter, 2005; Buiter and Siebert, 2006; Jonas, 2006). The quantitative impor-

[1] Full texts of the Maastricht Treaty and its protocols are available from European Union (1992a).

[2] A country must have participated in the ERM II for at least two years without devaluation or 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".

[3] We adopt the commonly used term "inflation criterion" instead of what is termed the "price stability criterion" in the Treaty itself.

tance 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 is also well known (e.g. Kenen and Meade, 2003), but no studies have to our knowledge presented quantitative estimates of this "enlargement effect".

This paper seeks to quantify the enlargement 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 past data where the reference value is computed under different assumptions concerning the number of EU countries and the composition of the reference group. Such an approach has the advantage of requiring few assumptions, but may potentially discard important information. For example, the monthly inflation rates for countries outside the reference group in any particular month are essentially discarded, beyond the fact that their inflation was too high for them to be in the reference group. Such monthly inflation data is of value. For this reason, we also deploy a more sophisticated approach, using Monte Carlo simulations based on our estimates of the population distribution parameters of each country's inflation rate.

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

2. The inflation criterion

The Maastricht Treaty appointed the Council of Ministers to make the decision whether or not a country applying to join the EMU satisfies the five convergence criteria. 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). This section discusses the inflation criterion and the computation of the inflation reference value. The main sources are the Treaty and the practice established in the Convergence Reports (see also Buiter and Sibert, 2006).

The inflation criterion is formally set out in Article 1 of the Protocol on Convergence Criteria of the Maastricht Treaty (European Union, 1992b: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 1 1/2 percentage points that of, at most, the three best performing Member States in terms of price stability.

This entails two requirements, namely that the 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 a chosen month, the annual HICP inflation 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 become 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 is similarly rounded to one decimal place, implying that the inflation reference value comes out with one decimal (EC, 2006:37; Buiter and Sibert, 2006).[4]

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.

The "best performing" countries "in terms of price stability" has been taken by both the European Commission and the European Central Bank to mean the countries with the lowest non-negative inflation rates (EC, 2004:3; ECB, 2004:8).[5] Countries with inflation below zero are excluded based on the reasoning that negative inflation is incompatible with price stability.[6] Lithuania became the first country to be excluded from the reference group because of rule. It is noticeable, however, that the EC and the ECB have not committed themselves to exclude countries with negative inflation rates in the future. This is stated explicitly in the 2004 Convergence Report of the European Central Bank (ECB, 2004:8):

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

[5]The exclusion of countries with negative inflation was stipulated already in the 1998 convergence report of the European Monetary Institute (EMI, 1998:33).

[6]The asymmetric exclusion suggests a lexicographic ordering of "inflation preferences": lower inflation is associated with better performance until the inflation reaches 0, while all levels of negative inflation rates are equally (un)preferable.

> 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 the "Member States" of the EU, not the member states of the Monetary Union. All Convergence Reports prior to 2004 (including the 1998 reports on the first wave of entrants and the 2000 reports assessing Greece and Sweden) used 15 EU countries when calculating the reference values of the inflation (and interest) criteria. 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 2006:14). 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 following year or two (ECB 2006:21, 36).

The Maastricht convergence criteria and/or the application of the criteria have been widely debated and frequently criticised. It has been argued that the criteria were hastily put together and with little emphasis on the underlying objectives of the criteria (Buiter and Sibert, 2006; Wyplosz, 2006). The inflation criterion in particular has been criticised for not entailing convergence to the eurozone inflation rate, for the reason that the inflation rates of all EU countries are employed in the convergence calculations. Keren and Meade (2003:4) states:

> When EMU was not yet in being, it made sense to base the inflation-rate and interest-rate criteria on the track records of the three EU countries with the lowest inflation rates. Now that EMU is in being, it would make far more sense to base those criteria on the average inflation rate and average long-term interest rate in the whole euro area.

The inflation criterion has been criticised for not taking into account the underlying reason for the inflation developments in the applicant countries. In particular, it has been argued that the reference value should be raised for countries experiencing very high trend growth bringing about inflation pressure because of the Balassa-Samuelson effect (Buiter and Sibert, 2006; Calmfors et al., 2007). Another peculiarity stemming from the formulation of the inflation criterion is that an applicant country may be among the three best performing countries and thus itself enter the reference group. This can *theoretically* entail that a country has an inflation rate being among the three lowest inflation rates in the EU, while still having inflation above the reference value.[7]

3. Looking backward

The enlargement effect works through two channels. First, adding more countries will tend to reduce the average inflation of the three countries with the 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 for the monthly tally of annual HICP inflation 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 EU's first eastward expansion), and all ending in June 2007.

A number of insights follow from Table 1. First, the average HICP inflation in all EU27 countries is relatively stable over time. This is hardly surprising for the EMU countries as the monetary policy in the eurozone targets the inflation rate. Nevertheless, the new EU members from Central and Eastern Europe also exhibit relatively stable inflation developments with Romania as the prime exception. Second, the average inflation in the EU15 countries is lower than the inflation in the countries that acceded to the Union in 2004 and 2007, but

[7] This would be the case, for instance, if the country in question has inflation equal to 2.4 percent, two countries have zero inflation and the rest all have inflations rates equal to 2.5 percent.

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: S.D. denotes the standard deviation. 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.

the difference is declining over time — mostly as a result of the Romanian inflation falling during the period. Third, the variability or standard deviation of the inflation 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 main conclusion is that the EU expansions brought in countries with on average higher inflation rates, but also much larger variability. A higher mean inflation 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. In other words, it is expedient to examine the effect on the

Maastricht inflation reference value of adding 12 new member countries.

Figure 1 shows the average inflation of the three best performing countries for the period 1999:01–2007:06, assuming respectively 15 and 27 EU members in addition to 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 not been included in the reference group (which therefore consists of the three countries with the lowest non-negative inflation rates).

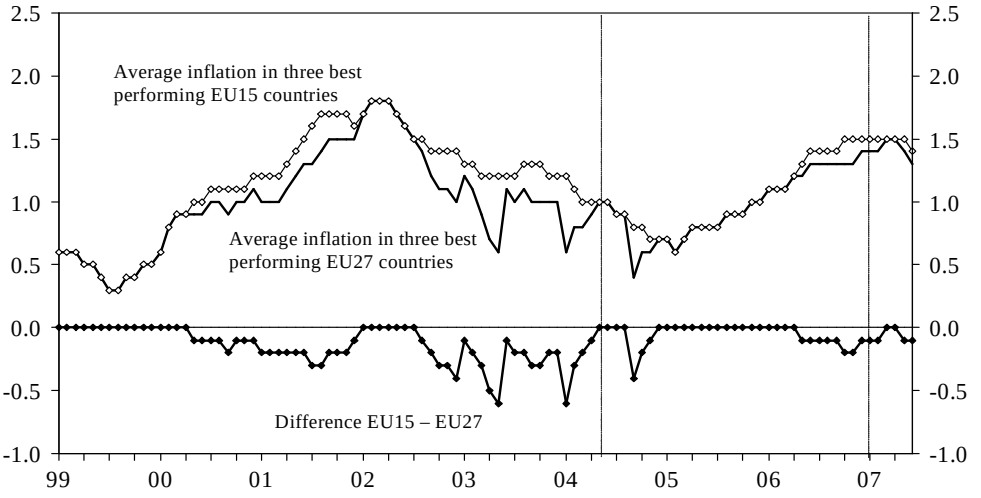

Figure 1: Average inflation of three best performing countries, EU15 and EU27 (percent per year). Difference of reference values between EU15 and EU27 (percentage points)

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

Several key things stand out from the counterfactual experiment. First, the average inflation of the three best performing countries (whether EU15 or EU27) varies substantially over time and spans an interval from 0.3 percent to 1.8 percent. The Maastricht inflation criterion is not providing a stable target towards which to direct policies. 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 caused by countries with inflation rates close to 0 shifting 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 average of the inflation in the three best performing countries in the EU15 coincides with the corresponding measure

EU27 in 1999 and again in 2005, is around 0.3 percentage points higher during much of 2003 and 2004, and 0.1–0.2 percentage points higher in 2006 and 2007. The average difference between the reference values in the two cases is –0.11 percentage points for the entire sample 1999:01–2007:06.

Bulgaria and Romania exhibit large inflation variability, but also comparatively high average inflation. Incidentally, neither country enters the group of the three best performing countries during the entire period 1999:01–2007:06. This implies that the average of the inflation in the three best performing EU25 countries, i.e. the countries being members of the EU from May 2004 to December 2006, coincides with the average of the inflation in the best performing EU27 countries. 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 also countries with negative inflation rates are retained. Figure 2 shows the results for both EU27 and EU15 from 1999:01 to 2007:06, as well as the difference between the two measures.

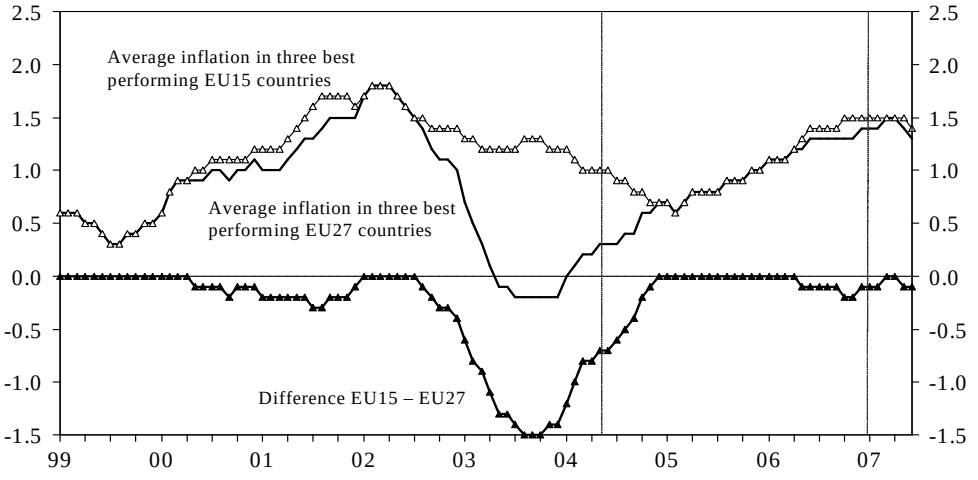

Figure 2: Average inflation of three best performing countries, EU15 and EU27 (percent per year). Difference of reference values between EU15 and EU27 (percentage points)

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

Comparing Figures 1 and 2, it is evident that the treatment of countries with

negative inflation is important. 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).[8] 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 lower 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.

The Maastricht Treaty stipulates that the inflation criterion is based on the average inflation in the three best performing *EU countries*. As discussed in Section 2, the criterion has been criticised on the grounds that it does not necessarily imply convergence to the EMU average inflation. In the spirit of the inflation criterion being a convergence criterion, we compare the average inflation in the three best performing EU27 countries with the hypothetical case where the inflation reference value is based on the average inflation in the three best performing EMU countries. The EMU comprises the original 11 countries until the end of 2000, and includes Greece from January 2001 and Slovenia from January 2007. Figure 3 shows the results.

The average inflation of the three best performing countries in the EMU is above the corresponding measure for the EU27 countries for every month in the sample except in most of 1999, two months in 2000 and two months in 2007. The difference between the reference values based on respectively the EU27 countries and the EMU countries is –0.33 percentage points for the entire sample. When the EMU applications of Lithuania and Slovenia were assessed in May 2006 the observance of the inflation criterion was based on HICP inflation for March 2006 and the difference was –0.4 percentage points. In sum, a convergence criterion in the spirit of the Maastricht Treaty criterion but based on the actual EMU countries would have implied a substantial loosening of the criterion relative to the case where 27 EU countries enter the sample.

4. Monte Carlo simulations

When employing counterfactual experiments using historical data, the effect of more EU countries will depend on specific events and shocks during the period considered. This section extends the analysis by estimating the inflation reference value independent of specific inflation realisations. Monte

[8]The average inflation of the three best performing EU27 countries is much smoother when negative inflation rates are included, because the non-linearity around zero is removed.

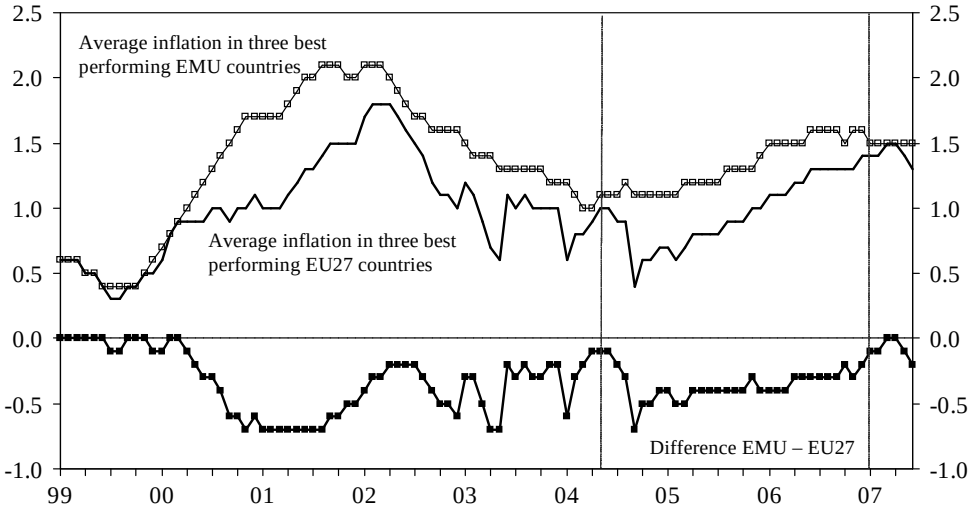

Figure 3: Average inflation of three best performing countries, EMU and EU27 (percent per year). Difference of reference values between EMU and EU27 countries (percentage points)

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

Carlo simulations are undertaken in order to estimate the distribution of the average inflation in the three best performing countries with a given set of EU countries, which makes it possible to uncover the change in the inflation reference value stemming from the enlargement effect. Previous inflation data is used to parameterise an assumed inflation distribution for each country.

The simulation analysis has two key advantages over the counterfactual analysis on historical data in Section 3. First, computations of the reference value based on past data effectively discard a large portion of the data. For countries that are not in the reference group, no information is utilised beyond the fact that inflation was too high for them to be in the lowest three. Important information about the variance and functional form of the inflation distribution is lost. Monte Carlo methods, by contrast, utilise all such data. Second, Monte Carlo simulations permit the examination of a far larger sample size than the 120 or so monthly observations currently available for the counterfactual experiments using historical data.

For each EU country the HICP inflation rate is modelled as a random variable with a given continuous distribution, which subsequently is rounded to one decimal point. As shown in Section 3, in most countries the inflation rate has been relatively stable since 1999. It seems reasonable to assume that the inflation in all EU countries will remain stable within the considered time-

frame, so we have specified the inflation process in each country to be time-invariant.[9] Each particular draw is treated as a distinct occurrence independent of previous draws or other factors. This implies that the draw in an individual country can be thought of as originating from the *unconditional distribution* of the inflation variable, absent any information about its value in preceding months or the cyclical position of the economy, import price inflation, etc.

The simulations are undertaken by randomly drawing 10,000 observations from the specified inflation distributions in the chosen sample of countries (using the *Crystal Ball* software package). The average inflation in the three best performing countries, rounded to one decimal, is calculated for each draw, and its distribution is computed based on the 10,000 draws. From this distribution we calculate the *unconditional* expectation to the average inflation in the three best performing countries, i.e. the expected value in the absence of any information about inflation realisations in preceding months. (The unconditional expectation to the inflation reference value is obtained by adding 1.5 percentage points.)

The Monte Carlo simulations described above can be carried out for any given set of countries. The distribution of the inflation reference value — and in particular the expected reference value — with 27 EU countries in the simulations may provide guidance for policymakers in countries aiming to satisfy the inflation criterion in coming times.

The simulations can also produce the distribution of the *difference* between the inflation rates of the three best performing countries with two different country samples. This difference is also the difference between the reference values in the two cases. The mean — and more generally the distribution — of the difference between the inflation reference values using respectively the 15 old EU countries and the 27 countries being members since 2007 captures the implicit tightening of the Maastricht inflation criterion resulting from the expansions of the EU in 2004 and 2007.

The results will depend on the assumed distribution of the 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 frame (Charnes, 2007:Ch.4). Furthermore, the inflation rates in different EU countries are likely to covary. The covariation can e.g. be the result of synchronisation of business cycles, common external shocks and/or a joint monetary policy. Thus, in addition to specifying for each country a distribution function and its sufficient statistics, also the correlation

[9]The assumption also implies that the prediction of future inflation is not improved by knowing previous realisations of the inflation rate (as long as the sufficient statistics of the distributions are known).

of the inflation rate with inflation rates in the other EU countries need to be specified.

Our modelling strategy is to devise a baseline scenario and subsequently undertake a number of robustness checks to examine to which extent the results rely on the specific choices concerning 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.[10]

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 generating a correlation matrix as observed during the same period.[11]

The choice of the normal distribution is based 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. 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 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 mean and variability have changed markedly since the start of the EMU in 1991:01 (with Romania being the prime example). In addition to the full sample 1999:01–2007:06, we also undertake simulations where the means, standard deviations and correlations are estimated based on two shorter samples, namely 2001:01–2007:06 and 2004:01–2007:06.

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 compared to the results obtained

[10] Appendix 1 shows the results when the inflation rates in all countries are assumed to follow *identical* normal distribution. The purpose is to pin down the enlargement effect when the effect stems solely from the increased number of countries.

[11] 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 minor.

using the sample 2001:01–2007:06. Some of the patterns of correlation coefficients are also difficult to interpret.[12] It is useful to examine the sensitivity of the results to changes in the correlation matrix. Specifically, a number of robustness tests are undertaken where all correlation coefficients are set equal to 0.

As stated, the *baseline simulation*, Simulation 1a, uses the empirical means, standard deviations and correlations estimated on the sample 1999:01–2007:06. Figure 4 shows the unconditional probability distributions of the average inflation in the three best performing countries with respectively 15 (black) and 27 EU countries (grey), based on 10,000 draws. 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.)

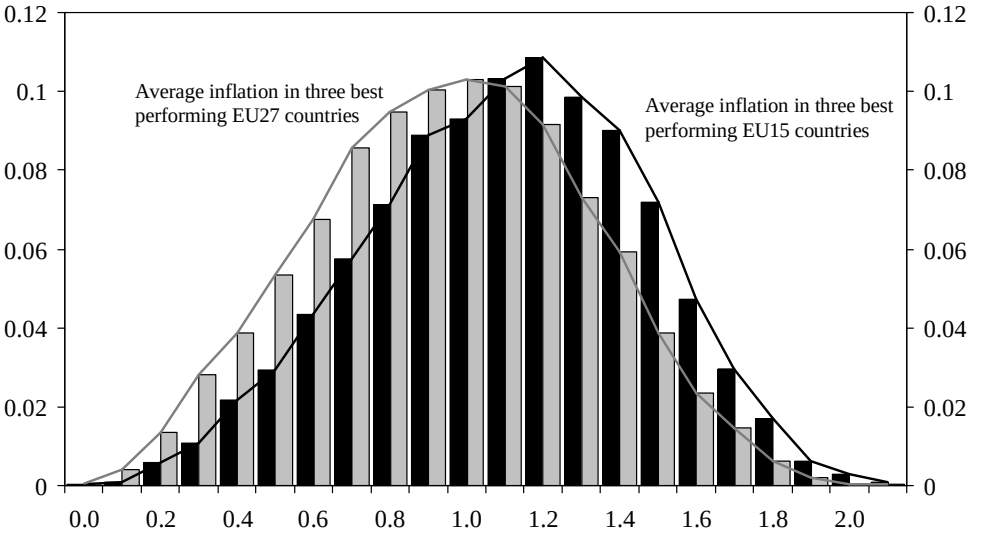

Figure 4: Probability distributions of average inflation in the three best performing countries with respectively 15 and 27 EU countries (percent)
Note: Based on Simulation 1a using empirical means, S.D. and correlations for the sample 1999:01–2007:06. Countries with inflation below 0 are excluded from the reference group of the three best performing countries.
Source: Eurostat (2007), own calculations.

A noticeable feature following from Figure 4 is the substantial dispersion of the average inflation of the inflation in the three best performing countries.

[12] 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.

Thus, after expansion of the EU to 27 member countries, there is a 29 percent probability that the average inflation 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 in the counter-factual experiments in Section 3.

Figure 5 shows the probability distribution of the difference between the reference values under the 15 and 27 country cases. This probability distribution has a highly asymmetric shape, as the upper bound of the difference is by construction zero. There is a 50% probability that the reference value will remain the same when the EU expands from 15 to 27 countries, and below this a long tail to the left. On average, the difference in the inflation reference value is 0.15 percentage points. The probability of the reference value falling by 0.3 percentage points or more is 25 percent. The standard deviation is 0.21 percent. The main statistics describing the results of the baseline simulation, Simulation 1a are presented in Table 2.

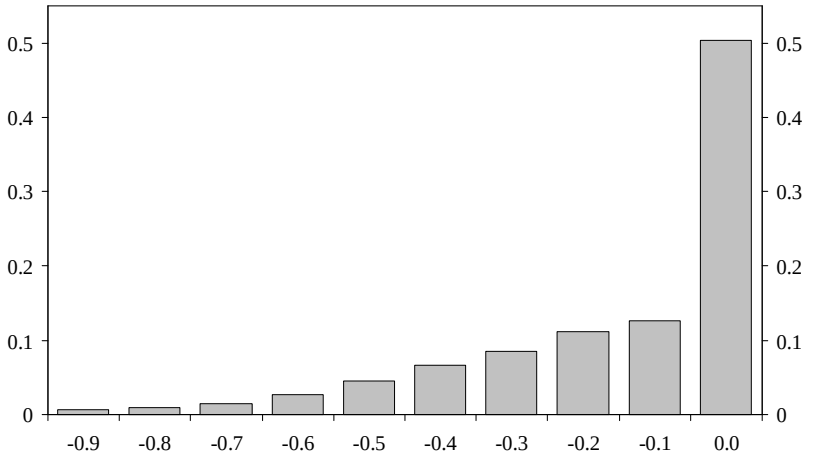

Figure 5: Probability distribution of the difference between inflation reference values with 15 and 27 EU countries (percentage points)

Notes: Based on Simulation 1a 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 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 EU15 – EU27, percentage points	
		Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
1a	Empirical means, S.D. and correlations for sample 1999:01–2007:06	1.10	(0.36)	0.95	(0.35)	-0.15	(0.21)
1b	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)
2a	Empirical means, S.D. and correlations for sample 2001:01–2007:06	1.25	(0.33)	1.06	(0.38)	-0.19	(0.21)
2b	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)
3a	Empirical means, S.D. and correlations for sample 2004:01–2007:06	1.10	(0.26)	0.99	(0.27)	-0.11	(0.16)
3b	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)
4a	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)
4b	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)
5a	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)
5b	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)
6a	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)
6b	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)

Notes: S.D. denotes the standard deviation. 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. See text for additional explanation of the simulation experiments.
Source: Eurostat (2007), own calculations.

Table 2 also shows the results of the large number of simulations addressing the robustness of the baseline results. Simulation 1b uses — as Simulation 1a — 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. Thus, the results in the baseline simulation are relatively insensitive to the changes in the correlations across the inflation rates.

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 2a 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. When setting the correlations equal to 0 in Simulation 2b, the difference is slightly larger.

Simulations 3a and 3b are parameterised based on the recent sample 2004:01–2007:06. The mean difference between the reference values is 0.11, irrespective the choice of correlation matrix, reflecting the lower variability of inflation in many countries in this period (Simulations 3a and 3b).

The next set of simulations (4a and 4b) analyse the effect of higher variance in the distribution of individual countries inflation rates. The simulations employ the same assumptions as Simulations 1a and 1b, but with the assumption that the standard deviation is twice the values estimated for the period 1999:01–2007:06. When comparing with the results from Simulations 1a and 1b, it is clear that the increased inflation variability brings about a substantial lowering of the mean inflation of the three best performing countries (and hence the reference value), but has a rather modest effect on the change in the reference value stemming from enlargement.

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.

Simulations 5a and 5b repeat simulations 1a and 1b under the alternative assumption that inflation follows a uniform (as opposed to 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 $1/(b-a)$ 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 result 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 essentially the same irrespective of whether the inflation follows a normal or a uniform distribution.

Simulations 6a and 6b allow 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 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.[13] Comparing with Simulations 1a and 1b, 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 results from the simulations in Table 2 are easily summarised. 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 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.

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 convergence assessments. We proceed by examining the effect of increasing the number of EU countries when it is assumed that countries with negative inflation rates are retained. Table 3 shows the results using the same assumptions concerning the distributions and parameterisations as in Simulations 1a–3b in Table 2.

Comparing the results in Table 3 with the results of Simulations 1a–3b, it is apparent that retaining countries with negative inflation in the reference group has a large impact on the average inflation in the three best performing countries when there are 27 EU member countries. Simulation 7a uses the empirical means, standard deviations and correlations based on the sample 1999:01–2007:06. The enlargement effect reduces the average inflation 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 1a). 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 do figure in the reference group, and they

[13]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.

Table 3: Inflation 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 EU15 – EU27, percentage points	
		Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
7a	Empirical means, S.D. and correlations for sample 1999:01–2007:06	1.07	(0.41)	0.55	(1.10)	-0.52	(1.04)
7b	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)
8a	Empirical means, S.D. and correlations for sample 2001:01–2007:06	1.22	(0.40)	0.70	(0.98)	-0.53	(0.76)
8b	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)
9a	Empirical means, S.D. and correlations for sample 2004:01–2007:06	1.09	(0.28)	0.89	(0.40)	-0.19	(0.26)
9b	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: S.D. denotes the standard deviation. 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. See text for additional explanation of the simulation experiments.
Source: Eurostat (2007), own calculations.

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 inflation means. 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 inflation criterion effective from 2007 when the EU has 27 members, as

compared to 1998 and 2000 when there were 15 (and 12 of these qualified for EMU membership).

The counterfactual experiments 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 increase of the number of EU members from 15 to 27 and with a substantial probability of a larger reduction.

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 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. However, the expected future value of the reference value is 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 suggesting that this is a useful yardstick for the likely value of the actual reference value.

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Appendix 1. Results from simulation experiments with identical distributions

This appendix reports the results from simulation experiments, where the inflation 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 4 shows the results when countries with inflation rates below zero are excluded from the reference group. Simulation 10 assumes that the 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 4: Inflation in the three best performing countries based on simulations with 27 and 15 EU countries. Difference of inflation reference values with respectively 15 and 27 EU countries

	Assumptions concerning inflation processes	**Inflation in three best performing EU15 countries, percent**		**Inflation in three best performing EU27 countries, percent**		**Enlargement effect EU15 – EU27, percentage points**	
		Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
10	Means = 2, S.D. = 1, correlations = 0 for all countries	0.86	(0.31)	0.60	(0.25)	-0.26	(0.23)
11	Means = 2, S.D. = 0.5, correlations = 0 for all countries	1.33	(0.20)	1.17	(0.18)	-0.15	(0.15)
12	Means = 2.5, S.D. = 1, correlations = 0 for all countries	1.23	(0.34)	0.95	(0.30)	-0.28	(0.26)

Notes: S.D. denotes the standard deviation. 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. See text for additional explanation of the simulation experiments.
Source: Own calculations.

Simulation 11 retains the assumptions of Simulation 10 with the exception that standard deviation of the inflation rate 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 on the average inflation in the three best performing countries equal to 0.15 percentage points; the reduced inflation variably leads to a lower difference between the two reference values in absolute terms. Simulation 12 assumes a higher mean inflation, but otherwise retains the assumptions from Simulation

10. The mean of the inflation rates of the three best performing countries increase markedly regardless of the number of EU members, but the difference between the reference values change only little when compared to Simulation 10. The conclusion is that the extent of inflation variability greatly affected the expected reference values as well as the enlargement effect.

Table 5 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 inflation average is relatively large relative to the inflation variability, and the inflation 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 5: Inflation in the three best performing countries based on simulations with 27 and 15 EU countries. Difference of inflation reference values with respectively 15 and 27 EU countries

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

Notes: S.D. denotes the standard deviation. 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. See text for additional explanation of the simulation experiments.
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 largely hinge on the newcomers having higher inflation variability than the old EU countries. Second, higher inflation variability relative to the average inflation leads to relatively low reference values and also implies that EU expansion leads to a relatively marked decrease in the reference value.