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Do Prices in the EMU Converge (Non-linearly)?[§]

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Abstract

This paper examines the current state of price convergence amongst the eleven initial EMU member states. Special attention is given to possible changes in the convergence process during the euro cash changeover. We apply the σ-convergence approach using both panel estimates of changes in the deterministic time trend of a coefficient of variation and stochastic kernel-density estimates. We find that convergence took place before 2000, slowed down substantially between 2000 and 2003, and resurfaced after 2003. This points to a non-linear convergence path. We show that stronger convergence is associated with periods of positive and less-dispersed output gaps across member states. There are no big differences between the results for tradables and non-tradables, indicating that Balassa-Samuelson effects are relatively weak.

Keywords: Prices, European Monetary Union, σ-convergence, Kernel-density Estimation, Balassa-Samuelson Effect
JEL classification: C14, C33, E31, F15

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1 Introduction

This paper addresses the case for price convergence within the European monetary union. We test for price convergence using a large data set of annual price levels for 224 product groups in eleven EMU countries from 1995 to 2005. Special attention is given to possible changes due to the introduction of a common currency. In the course of the paper, we apply the σ-convergence approach to examine, whether the price dispersion has declined over the decade 1995-2005. In particular, this study applies stochastic Kernel-density estimates as suggested in Quah (1997) to capture price convergence amongst the eleven initial EMU member states. This method is especially appropriate if we observe high persistence in the underlying data, which is clearly the case for price levels (Cecchetti et al., 2002). However, in the literature on price convergence, to our knowledge, a Kernel-density approach has never been used before. This is a gap we fill with this paper. Our findings suggest that prices have converged in the EMU. However, we cannot confirm that the introduction of the common currency has fostered price convergence as the bulk of convergence has taken place before 1999.

The case for price convergence within the European monetary union can be justified in several ways. The most remarkable aspect of integration in Europe surely lies in the process of monetary integration, culminating in the creation of a single currency and the euro cash changeover in 2002. Most theoretical arguments support the view that the monetary and institutional integration process will foster price convergence. According to these arguments, falling trade barriers and increased arbitrage possibilities should speed up convergence, at least for tradable goods and services. Furthermore, the stepwise harmonization of financial and product market regulations should enforce the process (Cuaresma et al., 2007). Price setters outside the currency union will possibly set their respective prices on a unified level for the entire currency union area (Devereux et al., 2003). Increasing trade flows (Rose, 2000; Rose and Engel, 2002) will spur further price level convergence.

On the other hand, we know from empirical studies investigating convergence processes for other regions or large countries (Cecchetti et al., 2002) that price level convergence can be astonishingly slow even in the case of highly integrated currency areas (e.g. for the U.S.) due to a large share of non-traded goods. Furthermore, it can be argued that the recent changes in market-based and policy-induced adjustment mechanisms in the EMU are far from being trivial to cope with (Allsopp and Artis, 2003) after the irreversible loss of nominal exchange rate instruments. Lasting inflation differentials and diverging business cycle movements and its implications have therefore been intensively discussed over the last couple of years (Angeloni and Ehrmann, 2004; Angeloni et al., 2006; Busetti et al., 2006; Campolmi and Faia, 2006; European Central Bank, 2003; Eichengreen, 2007; Lane, 2006). It is not clear, whether the introduction of the common currency has indeed strengthened convergence pressure on individual prices. Therefore, we have to test this question empirically.

In order to do so, we rely on convergence testing methods[1] based on the notion of β- and σ-convergence. According to Barro and Sala-i-Martin (1991), β-convergence is present if different time series show a mean reverting behavior towards a cross-sectional common level. In contrast, σ-convergence measures the reduction of the overall cross-section dispersion of the time series. Islam (2003) argues that β-convergence can be seen as a necessary but not as a sufficient condition for σ-convergence. Especially, β-convergence tests regressing average growth rates on initial levels and interpreting a negative initial level coefficient as convergence, are plagued by Galton's classical fallacy of regression towards the mean (Quah, 1993).[2] The concept of σ-convergence thus defines a sufficient condition and is the underlying concept for the greater part of the more recent convergence tests.

Several empirical papers so far analyzed the impact of the single currency on the EU's σ-convergence of prices. For example, Engel and Rogers (2004) analyze a panel of price data for tightly specified items collected by the *Economist Intelligence Unit* for 18 European cities inside and outside the Eurozone. The data starts in 1990 and ends in 2003. They do find evidence of a decline in price dispersion over much of the 1990s but little evidence of a further decline since 1999. That finding applies both to cities within the Eurozone, and to European cities outside of Euroland. Hence, Engel and Rogers do not find a separate effect of the single currency. Also Rogers (2007) confirms this finding using the same data set up to 2004. In a similar vein, Lutz (2003) looks at various data sets, including the *Big Mac Index* and the *Cover Price* published by *The Economist*, and comes to a similar conclusion. Mathä (2005) analyzes data on 92 products in supermarkets in Luxembourg, Belgium, France and Germany. He finds no significant change in price dispersion since the euro introduction, either. Gil-Pareja and Sosvilla-Rivero (2008) as well as Imbs et al. (2004) look at prices for cars and TVs, respectively. Both conclude that price dispersion among EMU members has already declined before the introduction of the euro, but neither of them reports a significant role of the euro changeover in fostering the reduction of price dispersion. Summing up, there is sufficient evidence for price convergence before the launch of the euro. On the other hand, there is no marked change in price dispersion in the aftermath of the euro introduction.

[1] See Barro and Sala-i-Martin (1991) and Barro and Sala-i-Martin (1992)

[2] Islam (2003), Durlauf and Quah (1999), and Bernard and Durlauf (1996) discuss several issues in empirical convergence testing, too.

The only study finding a significant effect of the euro introduction on price convergence is Allington et al. (2005). The authors explore Eurostat data on comparative price levels for individual consumption expenditures in 200 product groups concerning the 15 EU countries over the period from 1995 to 2002. This data set stemming from the Eurostat-OECD comparison program is the most detailed data set on comparative price level information being currently available at European level. To measure price dispersion, Allington et al. (2005) compute the coefficient of variation. In contrast to a standard differences-in-differences framework merely including controls for the treatment group, the treatment period and an interaction term, Allington et al. (2005) also examine time trends. They find that the introduction of the euro has fostered price level convergence among EMU countries.

We refer to an updated version of the Allington et al. (2005) data as in Dreger et al. (2007). The new data set now covers the time span until 2005, thus giving further information on possible changes around the cash changeover. In the following, we examine the structural shifts in the price convergence process in detail. In particular, we employ two methods of investigation. First, we assume that there is a falling trend in the coefficients of variation. Using panel estimates and applying structural break tests (Chow tests and Quandt Likelihood Ratio or QLR tests) we investigate if there are any breaks in the convergence process. However, the regression approach does not give any information on the intra-distributional dynamics. Second, we use the stochastic Kernel-density approach of Quah (1997) recursively employing year-over-year estimations to examine possible shifts in the conditional distribution of prices over time.

The results of the paper can be summarized as follows: We find evidence for convergence with a substantial time-varying pattern. Both of the applied methods indicate that no progress in price convergence was made between 2000 and 2003. The results from both methods differ slightly. Structural break tests on the deterministic time trend of coefficients of variation in a panel framework suggest that the bulk of the convergence process happened between 1995 and 1999. The results from stochastic Kernel-density estimates show two periods, where significant shifts in convergence took place: 1999/2000 and 2003/2004. The results do not change when splitting the goods prices into tradables and non-tradables, indicating that Balassa-Samuelson effects only play a minor role among the eleven countries which formed the first stage of EMU. The convergence process can furthermore be associated with periods of increasing and decreasing output gaps as well as the cross-section dispersion in output gaps. This points to possible asymmetries in the convergence path which could be related to the business cycle. Convergence is stronger in periods of less-dispersed and increasing output gaps but weaker in periods of dispersed and falling output gaps.

The paper is structured as follows: In section 2, we explain the data set and discuss some properties of the data. Section 3 presents the methods and the empirical analysis, while Section 4 concludes.

2 Data

An important feature of any study of price convergence is the structure of the underlying data. Our empirical analysis is based on price level data provided by Eurostat. The price data were compiled by Eurostat, in cooperation with national statistical offices, for the Eurostat-OECD comparison program. This data set is the most detailed level of price information currently available at Eurostat. We obtained data for the period 1995-2005, which is an updated version of the data set analyzed in Allington et al. (2005), where the data was only available until 2002. As the effect of the euro introduction on price level convergence is likely to be especially evident after the the euro coins introduction in 2002, the additional years give us very valuable information.

Given its purpose of collection, the price data displays a number of notable features. First, the price information is provided for 224 product groups (labelled 'basic headings') according to the United Nations' "*C*lassification *O*f *I*ndividual *CO*nsumption according to *P*urpose"(COICOP). That is, the price levels generally refer to baskets of goods and services, not to individual products. Also, prices for some of these product groups were not collected directly, but instead imputed from other product groups for which price information was readily available (so called 'reference groups').[3] We (often) exclude those product groups with imputed prices and focus on (147) product groups that refer to 'individual consumption expenditure by households' in our empirical analysis.

Second, the data is provided as a comparative price level index. That is, annual national price levels are not given in currency terms, but harmonized relative to the (geometric) average of the EU-15 (1995-2003) and the EU-25 (2004-2005); index values larger than 100 indicate price levels above EU average, while indices below 100 indicate prices lower than the EU average. Third, the data covers the period from 1995 to 2005 on an annual basis. However, the raw price information for individual product groups is collected at much lower frequencies; prices are typically collected every three years on a rotating basis across product groups (with two collection dates in each year so that at each date about one sixth of the products are covered). Prices in between the collection dates are simply extrapolated with the respective monthly consumer price index. Fourth, the number of countries, for which price information are available, increases over time; the

[3] See the "EUROSTAT – OECD Methodological Manual on Purchasing Power Parities".

number of countries gradually increased from 18 in 1995 to 33 in 2005. In order to explore a balanced sample, we analyze price developments for the eleven countries having formed the first stage of EMU.[4]

Before turning to more sophisticated investigation methods, we will first have a look at the distribution of the coefficients of variation for different products and product groups, respectively, over time. For each year we can observe comparable price levels for a very large number of product groups for all EMU countries. One benchmark measure of price dispersion is the coefficient of variation (CV), which is defined as the standard deviation of prices (for a given group of countries) divided by its respective mean value. This measure has the advantage that it is independent from the respective price level which makes it a natural choice in convergence analysis (Friedman, 1992). Therefore, comparable price level data for for each group and across the EMU countries were used to construct a corresponding number of CVs measuring the dispersion across countries for each price (see section 2 for details).

We summarized the information about the time-shifts in the distribution of all CVs using Box-Plots.[5] Figure 2 shows the results.

The figures indicate that the decade from 1995 to 2005 can probably be decomposed into three regimes:

1. A regime of fast convergence – 1995 to 1998 – just before entering the EMU. This is not astonishing since the expectation of a monetary integration as well as the applied convergence criteria (even if they are described in growth rates and not as level convergence criteria) should have fostered convergence processes.
2. A period of increasing dispersion from 1999 to 2002.
3. A period of slightly falling price dispersion from 2003 to 2005.

3 Empirical Analysis

3.1 Panel Regressions

In a first step, we use very straightforward methods to analyze σ-convergence by testing whether or not we find a decrease of the coefficient of variation

[4]This being Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain.

[5]The Box-Plots show the median (line in the box) as well as the 25^{th} and 75^{th} percentile as the lower and upper hinge and the respective adjacent lines. Circles denote outliers.

over time. The coefficient of variation (CV) is calculated for each of the 147 product groups in our data set and then regressed on a time trend, following Dreger et al. (2007). The σ-convergence would be reflected in a negative trend coefficient. As the main focus of our study is to find whether or not the euro introduction has significantly influenced the process of σ-convergence, we interact the time trend with a dummy variable D, which is equal to one (1) after a potential break date and zero (0)before. We present results for the break dates from 1998 until 2004. An increase in the speed of σ-convergence would be reflected in a negative interaction term. To control for the presence of unobserved product heterogeneity, we include product fixed effects. Standard errors are estimated robustly. Thus, we estimate the equation for T products

$$\mathrm{CV}_{j,t} = \beta_1 D + \beta_2 \times \mathrm{trend} \times D + \beta_3 + \beta_4 \times \mathrm{trend} + \sum_{j}^{T} \mathrm{product}_j + \varepsilon_{g,t}$$

where $CV_{j,t}$ is the coefficient of variation of product j at time t, trend is the linear time trend, $\mathrm{product}_j$ is the product fixed effect, and $\varepsilon_{g,t}$ represents the error term. We run this regression seven times, once for each possible break date from 1998-2004. Results are presented in Table 1. The speed of σ-convergence should be possibly higher for tradable than for non-tradable goods. Therefore, we also estimate the same set of seven regressions separately for tradable and non-tradable goods. Results are presented in Tables 2 and 3, respectively.

Table 1 shows the results for all goods. The first column shows the results for the break date 1998, the second for the break date 1999, and so forth. Interestingly, the time trend is always negative and significant, showing that the price level dispersion amongst the EMU countries diminished during the time period 1995-2005. Turning to the detection of possible break dates, we find that the interaction term is significant for the years 1998, 1999 and 2000. However, the coefficient is positive, showing that the speed of convergence has not increased, but decreased significantly after these years. For the years 2001-2004, the interaction term is insignificant, but the coefficient estimate of the time trend in columns (4) to (7) is lower in absolute terms compared to the estimates in columns (1) to (3). These findings suggest that we do find σ-convergence for all goods, but we do not find that the speed of σ-convergence has increased since the introduction of the euro. Rather, the speed of sigma convergence has decreased after 1998. However, this result is subject to the relatively strong assumption that all goods display the same speed of convergence. As already mentioned above, we therefore split the goods into tradable and non-tradable goods. In Table 2, we show the results for tradable goods. We find evidence for σ-convergence, which is reflected in the negative coefficient on the time trend. A break in the speed of convergence is evident again before the euro introduction, in the years 1998 and 1999. However, the positive coefficients on the interaction terms show that the speed of price convergence has decreased again after 1999. For the years 2000-2004, the interaction term is insignificant. Turning to non-tradable goods, the evidence for σ-convergence is less clear-cut. According to the results presented in Table 3, we do not find strong evidence for a reduction in price dispersion over the entire time period 1995-2005. While the coefficient on the time trend is not significantly different from zero (0) in columns (1) and (7), it is significant and negative in columns (2) to (6). However, the interaction terms are positive and larger in absolute terms for the break dates 1999, 2000 and 2001, suggesting that price dispersion in non-tradable goods eased before 1999, but remained mostly unchanged or even increased slightly afterwards.

3.2 Chow tests

In order to test for a break date, we compute several Chow tests, one for each possible break date. We thus use the results obtained from the regressions above and test the hypothesis $\beta_1 = \beta_2 = 0$ using a simple F-test. Furthermore, as we test for several break dates, the Chow test has to be modified slightly. The resulting test is known as the Quandt Likelihood Ratio (QLR) statistic or the sup-Wald statistic, corresponding critical values are taken from Stock and Watson (2003).

In Figure 3 we plot the t-statistics of the two interaction terms for all goods, tradable, and non-tradable goods, respectively. In addition, we plot the Chow test statistics and the critical values for the Chow test and the QLR test in Figure 4. The results confirm the picture of our panel regressions: overall, we do not find a significant break date after 2001. The interaction terms are jointly insignificant at the 5 percent level.

3.3 Stochastic Kernel-density estimates

The literature testing the implications of growth theory empirically has an important conclusion: tests for β convergence derived from regressing average growth rates on initial levels suffer from Galton's fallacy of regression towards the mean (Friedman, 1992; Quah, 1993). This could lead to a negative and significant sign for the β-coefficient while the underlying data does not show a pattern of convergence. Therefore, most empirical growth tests rely upon the concept of σ-convergence and examine whether or not coefficients of variation decline. However, this analysis might also display misleading results. The same level of standard deviation can be associated with observations continually fluctuating around the mean, sometimes being above, sometimes being below mean. It could likewise mean that countries are persistently above or below the mean. The last case would imply that convergence would be less distinct than in the first case. To capture these intra-distributional movements stochastic Kernel-density estimates can be calculated. This method is appropriate especially if we have high persistence – as in the case of price convergence (Cecchetti et al., 2002). However, in the literature on price convergence, to our knowledge, a Kernel-density approach has never been used before. This is a gap we fill in this section. Therefore, we first give a brief description of the model. An extensive description can be found in Quah (1997).

If X $= X\left\{X_t\right\}_{t\in\aleph}$ is a continuous state Markov chain with X_t having a distribution function ϕ_t then X satisfies:

$$\Pr\left(X_{t-\tau}\in\mathbf{A}\left|X_j,j\leq t;X_t=x\right.\right)=P^{\tau}\left(x,\mathbf{A}\right) \tag{1}$$

with $\mathbf{A}\subseteq\mathbf{E}\subseteq\Re$ and $\Re$ being the state space of X. P^{τ} is a conditional distribution also called stochastic Kernel (Stockey et al., 1989, p. 226). Equation (1) states, that the probability for being in a certain state which is an element of the subset $\mathbf{A}$ in period $t+\tau$, conditional on being in state x in period t is independent of all previous periods. The probability is also independent of t. P^{τ} is than a mapping of ϕ_t into $\phi_{t+\tau}$ (Quah, 1997):

$$\phi_{t+\tau}=\int\limits_E P^{\tau}\left(x,\mathrm{A}\right)\phi_t(dx). \tag{2}$$

This can be re-written in terms of density functions:

$$f_{t+\tau}\left(y\right)=\int\limits_E f_{\tau}\left(y\left|x\right.\right)f_t\left(x\right)dx=\int\limits_E\frac{f_{\tau}\left(y\left|x\right.\right)}{f_t\left(x\right)}f_t(x)dx,$$

where $f_t\left(x\right)$ is the density function of ϕ_t, $f_{\tau}\left(y\left|x\right.\right.$ is the density function for P^{τ} and $f_{\tau}\left(y\left|x\right.\right.$ is the joint distribution of y and x. The density function for P^{τ} can be calculated by estimating the expression $\frac{f_{\tau}(y|x}{f_t(x)}$. For estimating the joint density, a product Gaussian kernel[6] will typically be used:

$$f\left(y,x\right)=\frac{1}{n}\sum_{i=1}^{n}\frac{1}{h_x\sqrt{2\pi}}e^{-0.5\left(\frac{x-x_i}{h_x}\right)^2}\frac{1}{h_y\sqrt{2\pi}}e^{-0.5\left(\frac{y-y_i}{h_y}\right)^2},$$

which implies that:

[6]For a discussion of the properties of the product Gaussian kernel see e.g. Wand and Jones (1995) or Pagan and Ullah (1999).

$$f(x) = \int_{-\infty}^{\infty} f(y,x)dy = \frac{1}{n}\sum_{i=1}^{n} \frac{1}{h_x\sqrt{2\pi}} e^{-0.5\left(\frac{x-x_i}{h_x}\right)^2},$$

the usual univariate Gaussian Kernel.[7]

When using stochastic Kernel-density estimates for testing convergence, usually the first and last available year are taken. This is in line with the notion of long-run convergence, but could be misleading if periods of convergence and divergence interchange. Using only two data points can then hide some substantial patterns in the convergence process. In particular, the dating of the change in the convergence speed can not be determined then. Therefore, the first approach in this paper is a recursive scheme, i.e. to let the initial year be constant (1995) while the final year varies. The final year is increased gradually by one year. If there is an extraordinary shift in convergence, this should be reflected in the results and, hence, a dating should be possible. The results are shown in Figure 5 to 7 for all goods, tradable goods and non-tradable goods, respectively.

To have a sound base for interpretation, the results of the three-dimensional joint density functions are illustrated using contour plots. The y-axis is the starting date and the x-axis is the final year. The plots can be read as follows (see figure 1):

- If the complete probability mass was located at a 45 degree line, *no convergence* at all would be observed, since the probability in the final year of being at the same level as in this year is 100%, regardless of the initial value.
- *Perfect convergence* would occur when all the probability mass was located at the vertical line over the point 100. This would imply that, regardless of the initial position, the probability for being at the level 100 is 100 %. Since the index used here is an index measuring the deviation from the average price, being at the value 100 implies all observations remain at the average level.
- The other extreme case is *perfect divergence*, which occurs at the horizontal line at level 100, using the same argumentation as in the previous case but reversed. Regardless of the initial position, the probability of being at level 100 is 0 %.

Keeping the extreme cases in mind, we infer that by comparing the recursive and year-over-year results, any counter-clockwise turning of the probability

[7] The bandwidth h_i is calculated according to Silverman (1986) and minimizes the mean integrated square error.

mass around the point (100, 100) would indicate increasing convergence over time. In an analogous manner, any clockwise turning would imply increasing divergence.

Panel (a) of figure 5 shows the case of non-convergence. In this figure, the transition from 1995 to 1996 is illustrated. It is obvious that the probability mass is heavily concentrated around the 45 degree line. The results changes only marginally as the final year is gradually increased from 1997 to 1999.[8] All in all, no convergence can be observed up until 1999. Panel (b) and (c) show results for years, where considerable changes took place. Panel (b) shows the transition from 1995 to 2000. The year 2000 obviously is a major step in convergence. The ridge widens significantly and is turning counter-clockwise indicating increasing convergence. Another big step in the convergence process can be observed for the transition from 1995 to 2004 (panel (c)). Panel (d) shows that no further convergence took place after 2004. Figure 6 and 7 show the results separated in tradable and non-tradable goods. It is noteworthy that there is no real difference in the results for both categories. Hence, we can summarize so far: there is a remarkable shift in convergence with steps in 2000 and 2004 for both categories.

To gain deeper insights into the convergence process, Figures 8 to 10 show the year-over-year transitions for different years for all goods and separated in tradable and non-tradable goods. In this analysis, the initial year also varies but the time period is constant. The y-axis is the initial year again while the x-axis is the final year. Figure 8, panel (a), therefore shows the same result as Figure 5, panel (a) for the transition from 1995 to 1996. Figure 8, panel (b), instead, shows the transition from 1999 to 2000. For almost every year-over-year transition the ridge is along the 45 degree line. The major exceptions and the years with the strongest changes in convergence are again shown in panels (b) and (c) here. In panel (b), showing the transition from 1999 to 2000, it can be seen, that although most of the probability mass is still concentrated along the 45 degree line, a significant proportion moves counter-clockwise, hence showing a tendency for convergence. Panel (c) illustrates the period 2003/2004. Here, the complete ridge has moved counter-clockwise indicating a marked tendency of price level convergence. The final year graphed in panel (d) in turn shows no sign of further convergence anew. This result holds for tradable as well as for non-tradable goods again.

The analysis indicates so far that a price convergence process happened after the fixing of the exchange rates between EMU member states in 1998. The process was strong in 2000, was interrupted in the following years and is showing no further gains until 2003-2004, when a marked increase in price level convergence could be observed again.

[8] Those results are not shown here but are available upon request.

3.4 Convergence and the State of the Business Cycle

There have been different episodes of business cycle and inflation rate convergence in EMU member states during the period under investigation (Dullien and Fritsche, 2009; Eichengreen, 2007). One of the interesting findings of our research is, that the convergence process can be related to periods of increasing (decreasing) output gaps, pointing to possible asymmetries in the convergence path. Convergence is obviously stronger in periods of less-dispersed and increasing output gaps but weaker in periods of dispersed and falling output gaps. Nominal inertia might play a role here. We used the output gap data and inflation rates as published in the AMECO data base of the European commission to illustrate the point. Once more, we use the technique of Box-plots as in figure 2 to present tendencies and distributional aspects.[9]

As can be seen from figure 11, periods of increasing/ stagnating convergence (marked by shaded areas) coincide perfectly with periods of increasing/ decreasing output gaps in the investigated countries. Furthermore, progress in convergence seems to happen in periods when inflation rates are below or at least close to the inflation target of the EMU, but not in periods of generally higher and dispersed inflation. Boom periods as well as low, stable and less dispersed inflation rates are associated with periods of stronger price convergence in the EMU. This suggests that the convergence process in itself might be non-linear and a function of the business cycle. However, a longer time period with different business cycle periods would be necessary to assess whether or not there is indeed a causality between the state of the business cycle and price convergence.

A prominent reason for interrupting the convergence process could hence be the business cycle downturn which affected the EMU member states in markedly different ways. This could be in line with arguments in Alesina and Barro (2002) as well as Tenreyro and Barro (2007) who argue that entering a common currency area on the one hand enhances trade (Rose, 2000), increases price co-movement across the member states in itself but on the other hand decreases the co-movement of shocks to real GDP. The resulting asynchrony in the national business cycles may have caused a tendency price divergence that was stronger than the convergence forces resulting from entering the monetary union. Only after the ending of the business cycle downturn at the start of this millennium, the process of convergence could continue.

[9] Again, the Box-Plots show the median (line in the box), the mean (point) as well as the 25th and 75th percentile as the upper and lower hinge, respectively. Circles denote outliers.

4 Discussion and Conclusion

The results stemming from both test procedures can be summarized as follows:

- We find evidence for convergence in general.
- Both methods indicate that between 2000 and 2003 no further progress in price convergence was made.
- Results from structural break tests on deterministic time trends using the coefficients of variation suggest that the bulk of the convergence process happened between 1995 and 1999.
- Results from the stochastic Kernel-density exercise reveal that two major shifts occurred, taking place in 2000 and 2004.
- The results are independent from the classification of goods into tradables and non-tradables. This suggests that a possible "Balassa-Samuelson" effect is not an important driving force among the eleven initial EMU member states.
- Furthermore, we found that periods of increasing (stagnating) convergence coincide well with periods of increasing (decreasing) output gaps. Progress in convergence seems to happen in periods in which inflation rates are below or close to the inflation target. This suggests that the convergence process might by non-linear in itself.

Further research should concentrate on the underlying reasons for the observed non-linearity. Possible candidates are found in the theoretical contributions of Alesina and Barro (2002) and Tenreyro and Barro (2007) – something which has to be tested using either longer time spans or/ and other episodes of currency union forming.

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Appendix

Figure 1: Convergence interpretation with Stochastic Kernel-density estimates

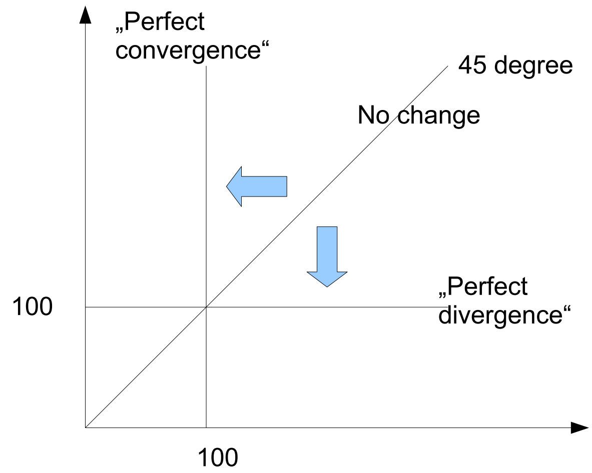
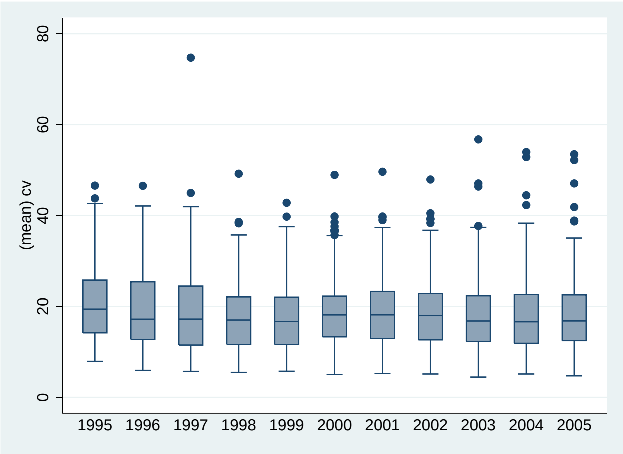
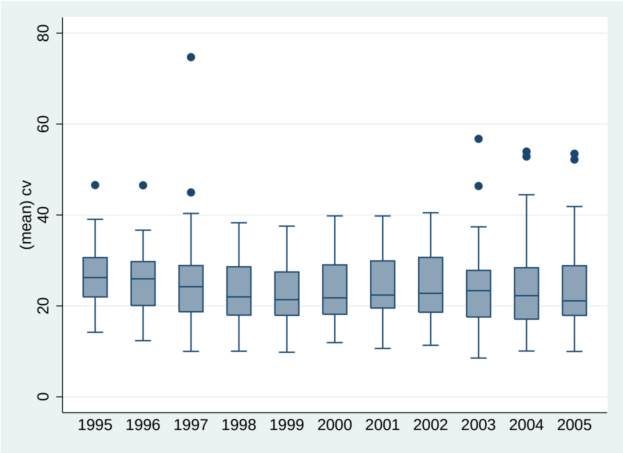


Figure 2: Box-Plots: distribution of CV's

(a) All goods



(b) Tradable goods



(c) Non-tradable goods

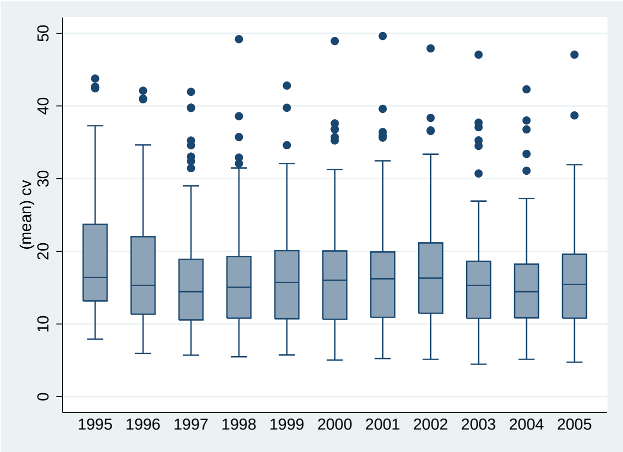


Figure 3: Recursive Chow Tests (T-statistics)

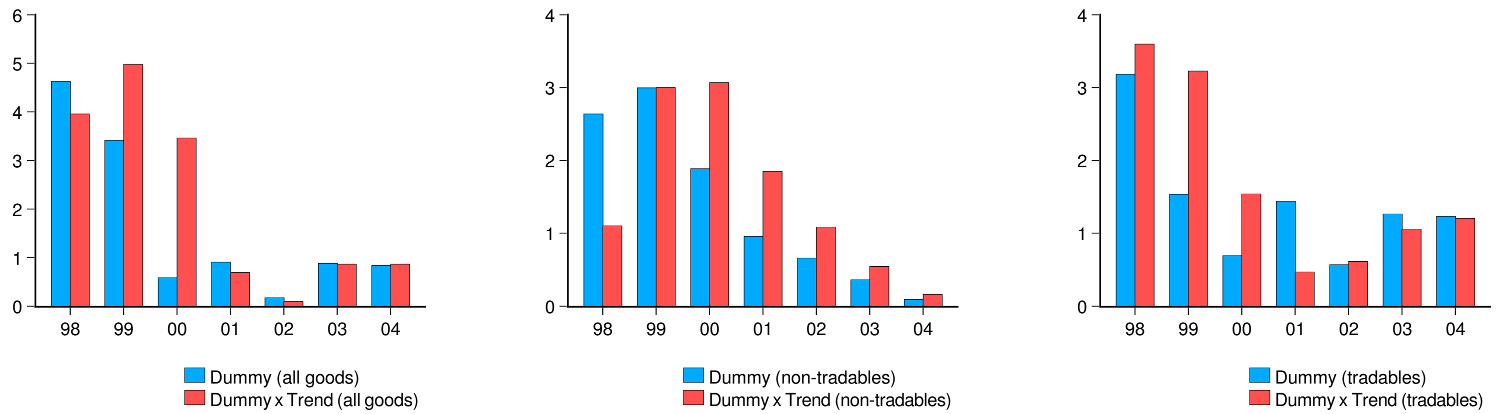


Table 1: Structural break test in CV's, all goods

		Specification						
Year		1	2	3	4	5	6	7
	Constant	21.92***	21.63***	21.24***	20.58***	20.06***	19.90***	19.95***
	Trend	-1.054***	-0.884***	-0.686***	-0.405***	-0.210***	-0.155***	-0.170***
1998	Dummy (D)	-3.106***						
	D*Trend	1.029***						
1999	Dummy (D)		-2.250***					
	D*Trend		0.796***					
2000	Dummy (D)			-0.469				
	D*Trend			0.450***				
2001	Dummy (D)				0.942			
	D*Trend				0.090			
2002	Dummy (D)					0.258		
	D*Trend					0.016		
2003	Dummy (D)						-2.484	
	D*Trend						0.242	
2004	Dummy (D)							-5.126
	D*Trend							0.500
	Observations	1617	1617	1617	1617	1617	1617	1617
	R-squared	0.029	0.031	0.034	0.025	0.016	0.016	0.016

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 2: Structural break test in CV's, tradable goods

		Specification						
Year		1	2	3	4	5	6	7
	Constant	19.89***	19.31***	18.82***	18.20***	17.82***	17.70***	17.87***
	Trend	-1.163***	-0.813***	-0.568***	-0.304***	-0.160**	-0.119*	-0.171***
1998	Dummy (D)	-2.450***						
	D*Trend	1.043***						
1999	Dummy (D)		-1.156					
	D*Trend		0.613***					
2000	Dummy (D)			0.614				
	D*Trend			0.231				
2001	Dummy (D)				1.67			
	D*Trend				-0.0786			
2002	Dummy (D)					0.939		
	D*Trend					-0.111		
2003	Dummy (D)						-3.448	
	D*Trend						0.285	
2004	Dummy (D)							-7.099
	D*Trend							0.663
	Observations	1001	1001	1001	1001	1001	1001	1001
	R-squared	0.042	0.043	0.045	0.033	0.027	0.031	0.028

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 3: Structural break test in CV's, non-tradable goods

		Specification						
Year		1	2	3	4	5	6	7
	Constant	26.51***	27.24***	27.10***	26.41***	25.76***	25.41***	25.18***
	Trend	-0.552	-0.988***	-0.920***	-0.625***	-0.381***	-0.265**	-0.195
1998	Dummy (D)	-4.590***						
	D*Trend	0.804						
1999	Dummy (D)		-5.215***					
	D*Trend		1.229***					
2000	Dummy (D)			-3.980*				
	D*Trend			1.043***				
2001	Dummy (D)				-2.673			
	D*Trend				0.684*			
2002	Dummy (D)					-2.837		
	D*Trend					0.521		
2003	Dummy (D)						-3.067	
	D*Trend						0.461	
2004	Dummy (D)							-1.657
	D*Trend							0.281
	Observations	418	418	418	418	418	418	418
	R-squared	0.025	0.023	0.025	0.020	0.012	0.009	0.007

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Figure 4: Chow/QLR Test (F-statistics)

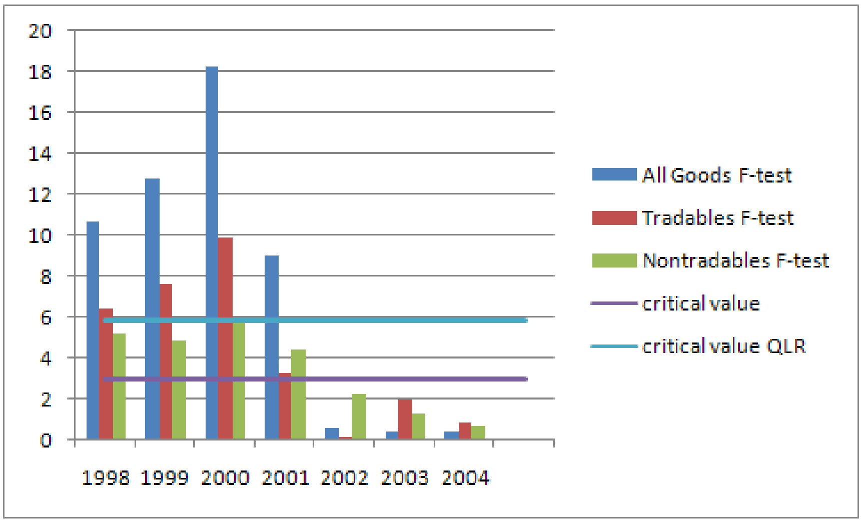


Figure 5: Kernel density estimates, all goods, recursive, base year 1995

(a) 1996

(b) 2000

(c) 2004

(d) 2005

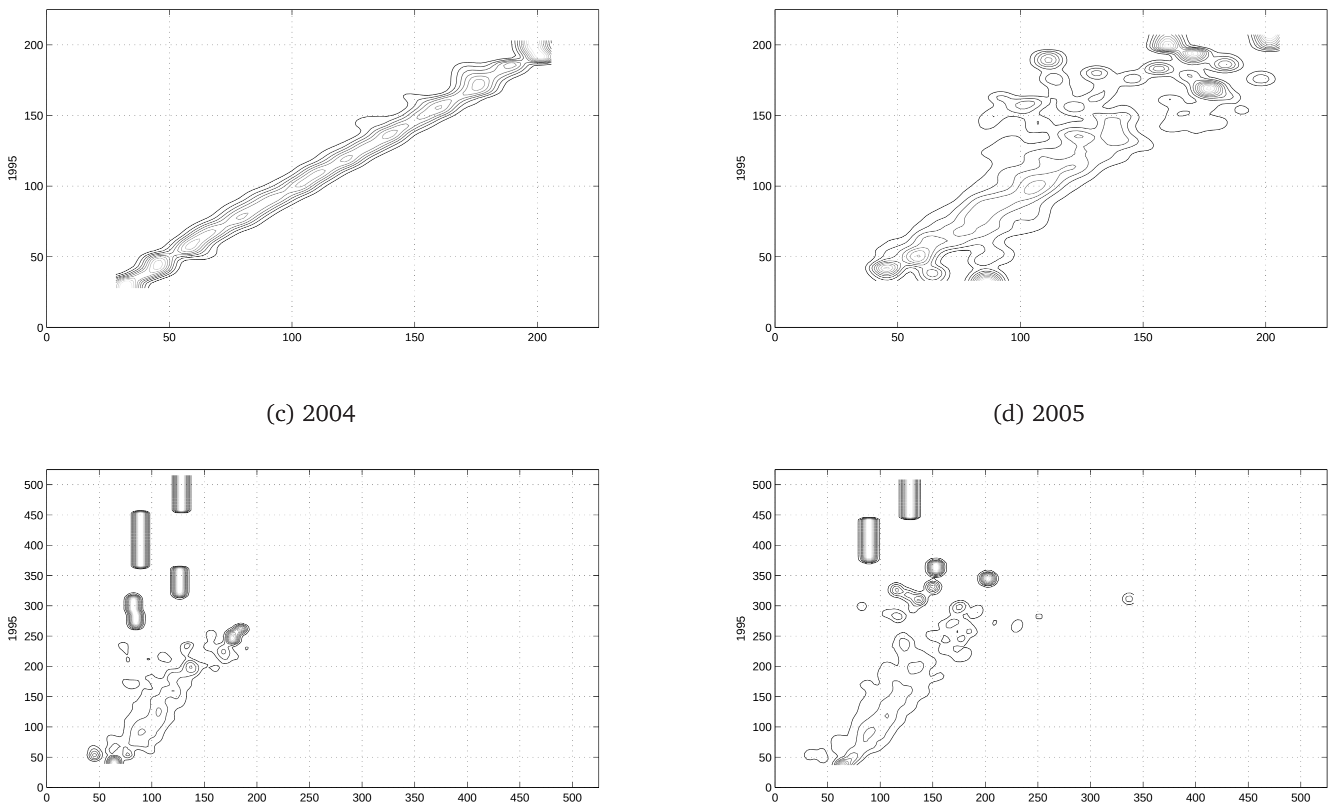
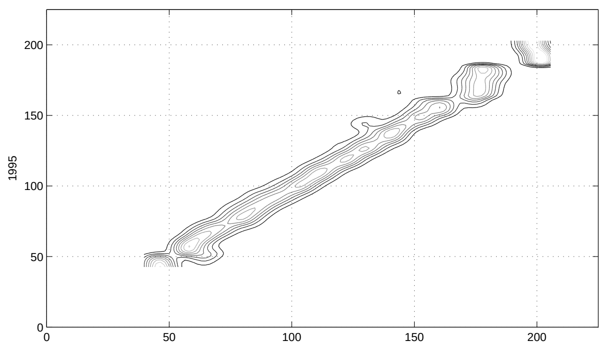
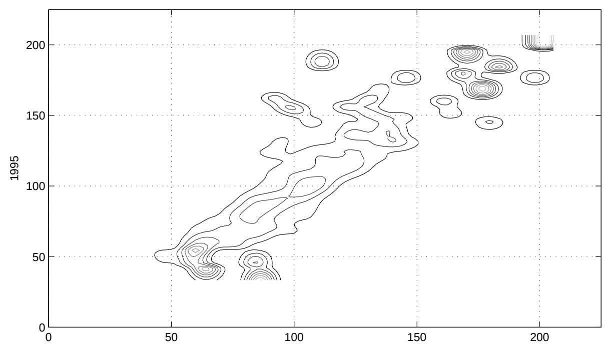


Figure 6: Kernel density estimates, tradable goods, recursive, base year 1995

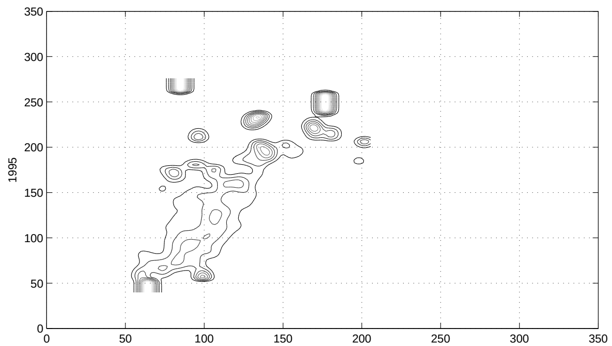
(a) 1996



(b) 2000



(c) 2004



(d) 2005

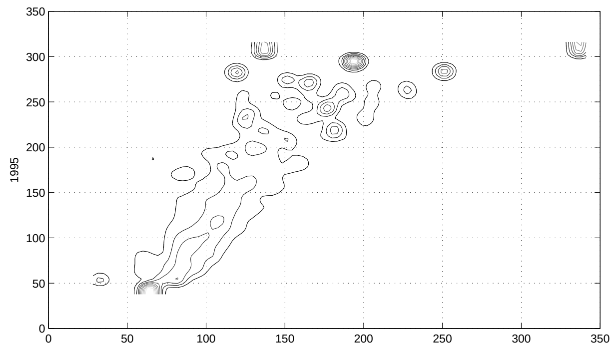
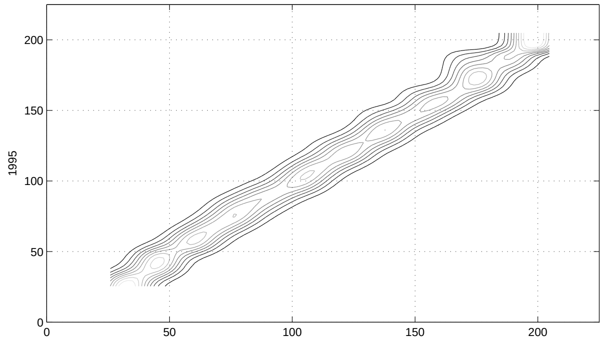
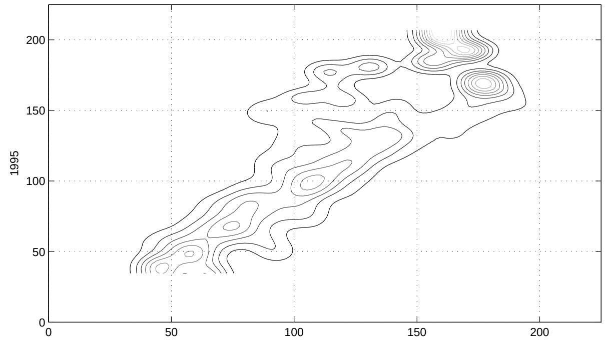


Figure 7: Kernel density estimates, non-tradable goods, recursive, base year 1995

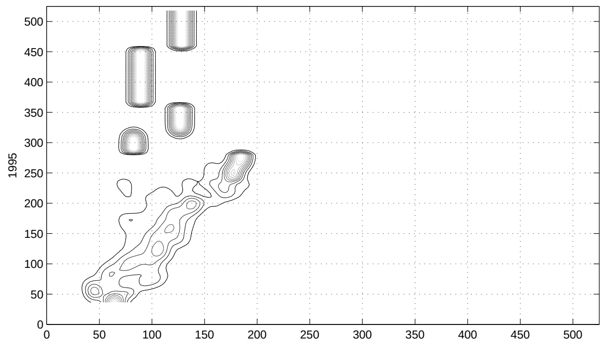
(a) 1996



(b) 2000



(c) 2004



(d) 2005

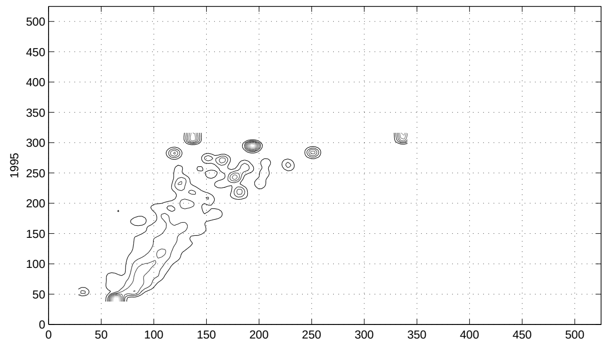
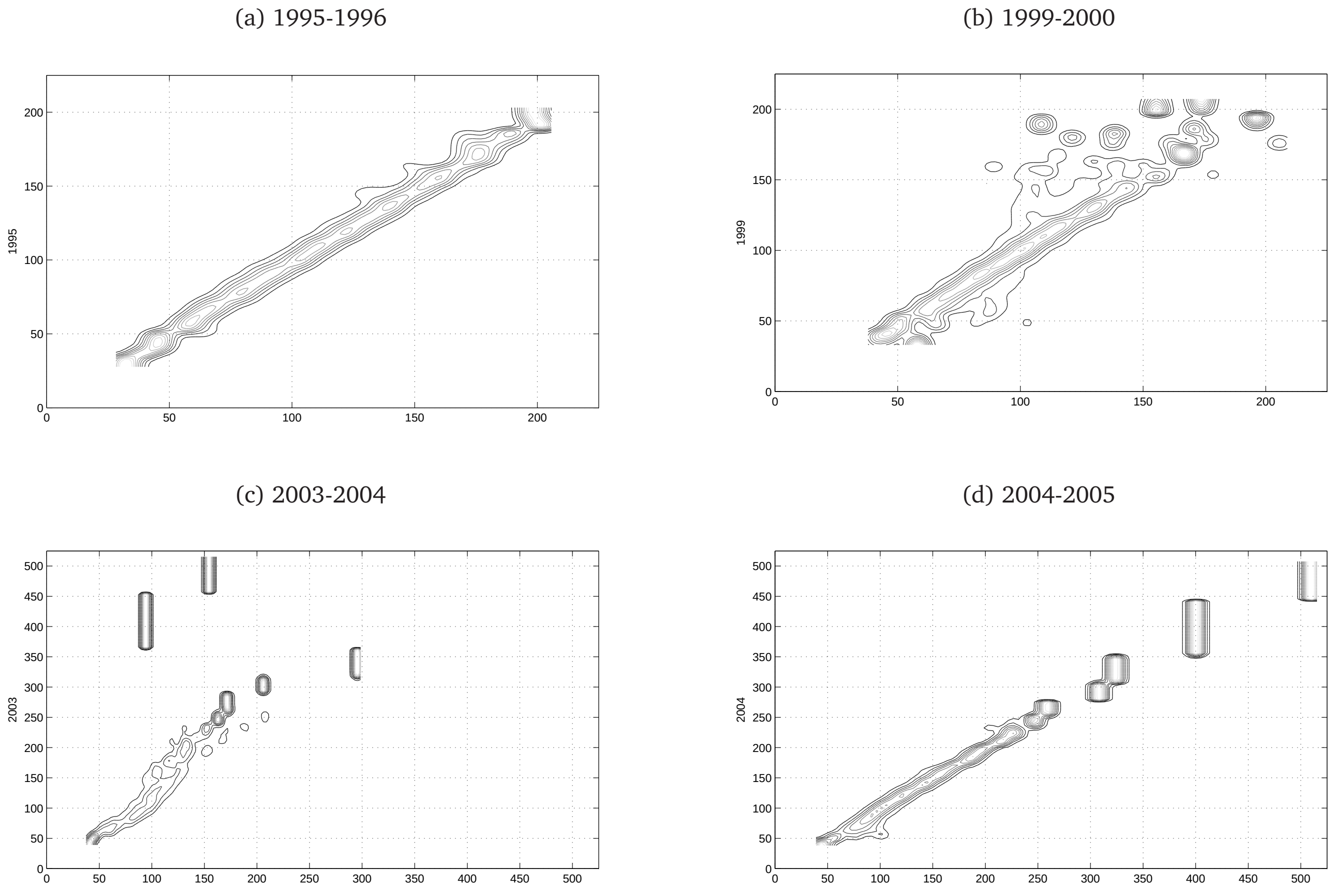


Figure 8: Kernel density estimates, all goods, y-o-y



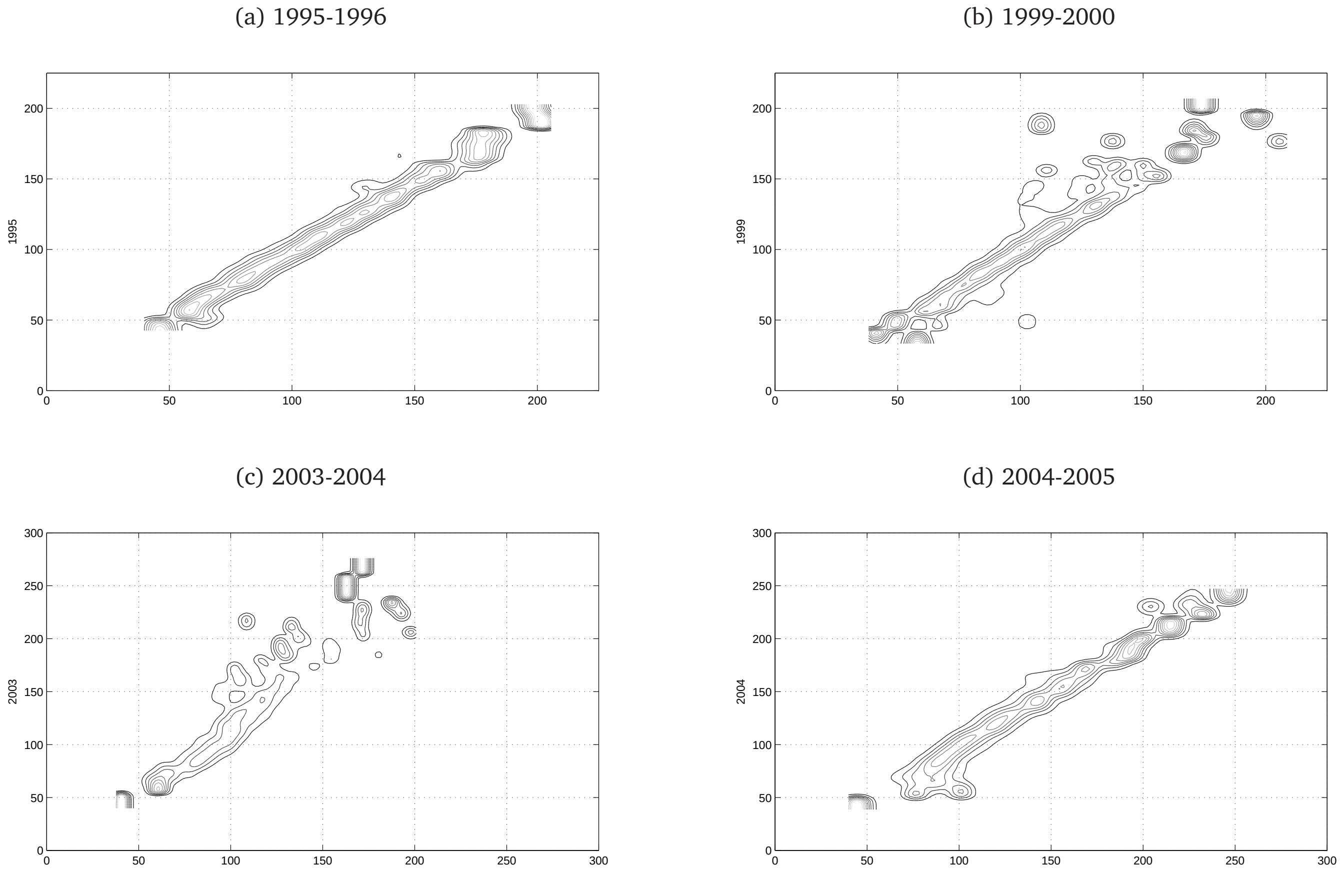
(a) 1995-1996

(b) 1999-2000

(c) 2003-2004

(d) 2004-2005

Figure 9: Kernel density estimates, tradable goods, y-o-y



(a) 1995-1996

(b) 1999-2000

(c) 2003-2004

(d) 2004-2005

Figure 10: Kernel density estimates, non-tradable goods, y-o-y

(a) 1995-1996

(b) 1999-2000

(c) 2003-2004

(d) 2004-2005

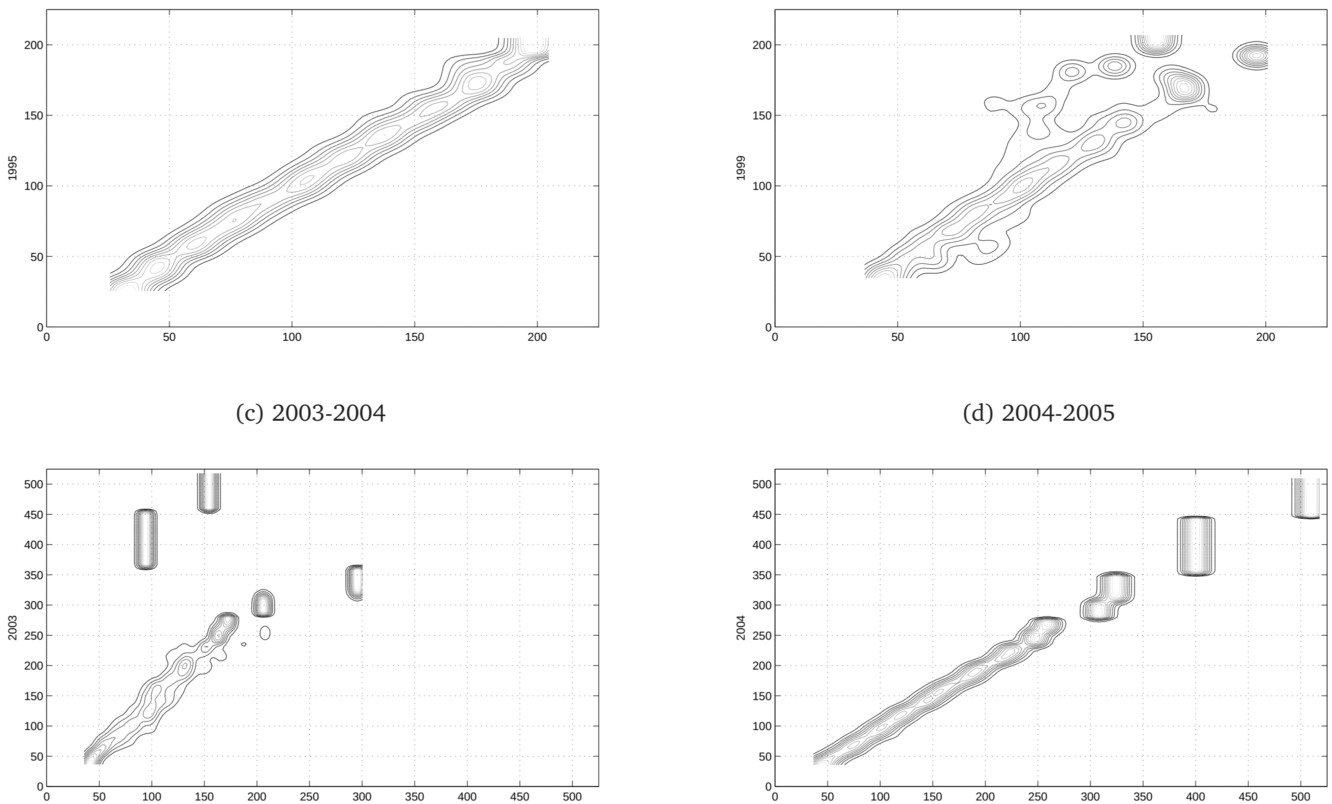


Figure 11: Level and Dispersion of Selected Macroeconomic Variables