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Explaining the Persistent Effect of the Euro-Changeover on German Restaurant Prices

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Abstract

This paper studies the long-run effect of the 2002 changeover on restaurant prices in Germany. German restaurant prices increased significantly when the euro was introduced as a new currency but rather than returning to their pre-changeover trend, restaurant prices appear to have stabilized on a higher path. This stands in contrast to the prediction of menu costs models or models of confusion-induced price increases as these models can only account for a transitory effect. The persistence of the increase suggests the existence of more than one price equilibrium. This multiplicity of price equilibria is a central part of the explanation proposed in the paper.

Keywords: currency changeover, euro, price setting, restaurant prices

JEL classification: D43, E31, L13, L89

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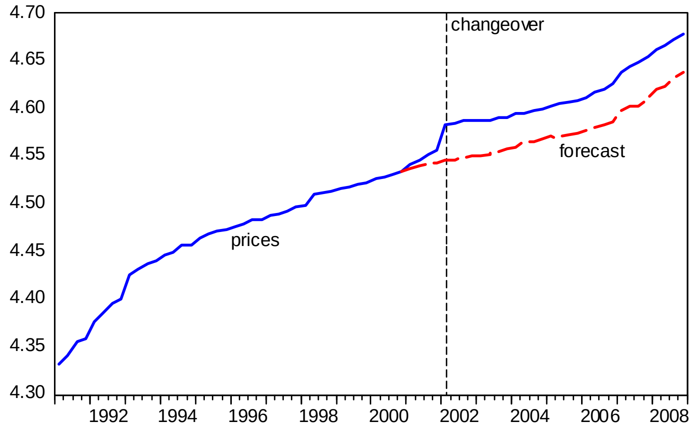


Figure 1: Restaurant prices around changeover, log scale, German data. The forecast is based on model (mv-1) of section 2.2.

1 Introduction

This paper studies the long-run effect of the 2002 changeover on German restaurant prices. The changeover's impact is estimated by forecasting the pre-changeover trend taking into account input prices and other variables that may affect the output price over the business cycle. Overall, restaurant prices are fairly predictable and the forecast is robust to various specifications so that an extrapolation of several years appears permissible. Figure 1 shows the actual price index and the forecast of the paper's baseline model over the period from 1991 to 2008.

At the changeover (denoted by the vertical line), the index leaps up by around 3.5 percent. The stability of the gap between actual and predicted series is puzzling and documenting the gap and suggesting an explanation is subject of this paper. Somewhat overshadowed by the leap in January 2002, restaurant price inflation in the year before the changeover is unusually high. This and the persistence make the menu costs explanation unlikely. Menu costs would appear a natural explanation for the restaurant sector (Hobijn, Ravenna, Tambalotti, 2006) but menu costs are neutral in the sense that they can only explain a jump in prices if the jump is accompanied by periods of reduced inflation. This neutrality is not observed in the data.

A second type of explanation for the high inflation at the changeover is that firms took advantage of buyers' "confusion" with the new currency and with the new nominal prices.[1] This explanation is able to explain some of the patterns in the data but cannot explain the persistence of the increase because after some time, buyers should be familiar with the new prices.

A third type of explanation was suggested by Adriani, Marini, and Scaramozzino (2009) who argue that the changeover allowed firms to coordinate on a higher price equilibrium. In their model, restaurants and customers are matched stochastically. The stochastic matching implies that restaurants do not compete and that there are multiple price equilibria.

The existence of multiple equilibria would provide an explanation for the persistence but they also raise the question why restaurants have not coordinated on the higher price before and why there should be multiple price equilibria in the restaurant sector. Below I will argue that there are several features of the restaurant pricing game that make multiple equilibria likely and that the answer to the question why restaurants have not coordinated on the higher equilibrium before is almost obvious once we are familiar with the peculiarities of restaurant pricing.

The paper contributes to the existing literature (1) by estimating the long-run effect of a currency changeover on the price of a particular sector (2) by suggesting an explanation for why changeovers may have a persistent impact on prices.

Two words of caution are in order. First, in this paper, I study one particular sector of one particular country and figure 1 is not necessarily representative for the European restaurant sector as a whole. Second, estimating the long-run effect of the changeover requires a long sample and for that reason, I use a price index. Aggregation, however, disguises the underlying heterogeneity. Evaluating their argument about consumers' reaction to rounding, Berardi et al. (2011) find that in France around a fifth of restaurants rounded down. For Germany, a similar pattern is probably to be expected. By analyzing a price index, the paper studies the effect of the changeover on the "average" German restaurant. The reason why I focus on Germany is that the German statistical office publishes detailed data on the restaurant sector (including restaurant specific wages).

[1] See for example Dziuda and Mastrobuoni (2009), Gaiotti and Lippi (2008), and Berardi, Eife, and Gautier (2011).

2 Forecasting Restaurant Prices

How would the restaurant price index look like had the changeover not taken place? We cannot answer this question directly but we can construct hypothetical paths using pre-changeover data - similar to an event study. As always, there remains uncertainty about these forecasts and we have to be careful when interpreting the results but we will see that restaurant prices are fairly predictable and the projections are quite robust so that an extrapolation of four or five years seems permissible.

Following the event study literature, I define the event window to be larger than the actual event (the changeover). The reason for this is that firms may alter their normal price setting in the months around the changeover. In order to reduce the influence of any unusual behavior, the estimation window (the subsample I use to forecast) is restricted to the period up to December 2000 (one year before the changeover). Expanding the event window further, affects the estimation results only slightly.

I proceed in two steps. First, following the Box-Jenkins methodology, I use only past values of restaurant prices to construct the forecasts. Besides providing an easy way to produce fast and often reliable forecasts, this univariate approach has the advantage that we can use monthly data. In a second step (subsection 2.2), I include additional explanatory variables such as wages or producer prices. These variables are often available only quarterly. Subsection 2.3 summarizes the findings.

2.1 Univariate Forecast

The German statistical office publishes a monthly index of restaurant prices starting in January 1991. Visual inspection of the data (see figure 1) suggests that the (logged) index is not stationary which is confirmed by an augmented Dickey Fuller (ADF) test. An ADF test indicates that the differenced data are stationary. One key assumption of the Box-Jenkins methodology is that the structure of the data generating process does not change. That is, the model's parameters should be constant over time. Figure 1 suggests, however, a possible break around 1993. The index is significantly steeper before 1993 than in the rest of the estimation sample. To test for an unknown structural break point, I start with an ARMA(1,1) model and run a Quandt-Andrews test with 15 percent trimming. This test indicates that May 1993 is the most likely break-point location. The variance of inflation in both subsamples is similar.

Regarding taxes, Germany raised VAT rates three times during our sample: January 1993 (by one percentage point), April 1998 (one percentage point) and January 2007 (three percentage points). The first two VAT increases fall into the estimation period and will be controlled for by two dummy variables that take the value one at the appropriate date and zero otherwise. Firms may not be able to pass on all the tax increase immediately so I have added more dummies covering the months after the tax increases. These turned out to be insignificant. The third VAT change in 2007 falls into the post-event window and needs to be taken into account when we construct the forecasts. This is discussed in the next subsection. The dummy for the break in May 1993 takes the value zero up to this point and one afterwards.

Table 1 presents the baseline model (uv-1) and five other models for the robustness analysis. The baseline model, an ARMA$((1,12),1)$-model, provides a reasonable fit. As all other models in the table, this model includes two tax dummies (1993:01 and 1998:04) and a dummy for the break in 1993:05. It is possible to improve the Akaike information criterion and the Schwarz criterion by adding other lags but in order not to overfit I have chosen the more parsimonious model.

The correlograms and the Ljung-Box Q-statistics point to no autocorrelation in the residuals but due to outliers, the residuals of the first five models of table 1 do not appear normally distributed. Using the studentized residual ($\bar{e}_i$) as a measure, two observations appear influential: 1992:02 and 1994:09. In both cases $|\bar{e}_i| > 3$.[2] Model uv-6 adds two outlier dummies that take the value one at these influential dates and zero otherwise. After adding the two outlier dummies, the residuals appear normally distributed.

[2]The studentized residual is the residual at that observation divided by an estimate of its standard deviation, $\bar{e}_i = \frac{e_i}{s(i)\sqrt{1-h_i}}$, where e_i is the original residual for that observation, $s(i)$ is the variance of the residual that would have resulted had observation i not been included in the estimation and h_i is the $i-$th diagonal element of $x_i (X'X)^{-1} x_i$ (hat matrix).

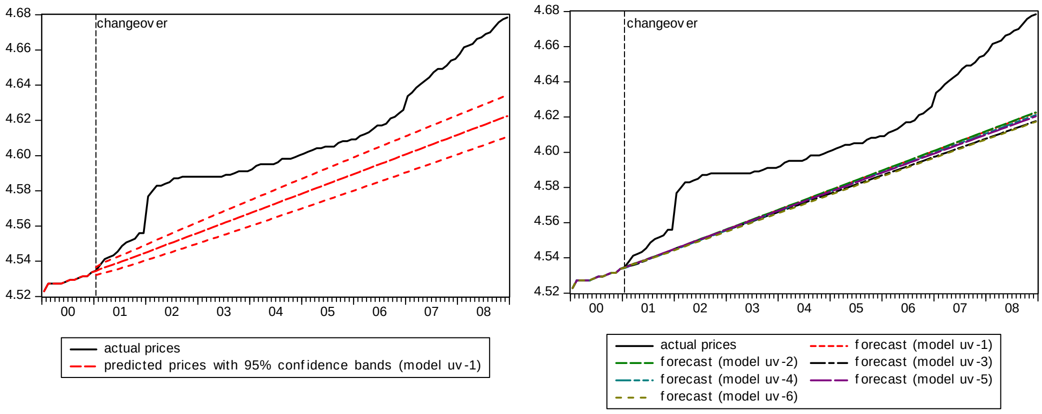


Figure 2: Left hand panel: forecast based on baseline model (uv-1) of univariate forecasts with 95% confidence bands. Right hand panel: forecasts of all six models shown in table 1. The forecasts do not take into account the VAT increase in 2007.

With $\bar{R}^2 = 0.68$, the baseline model explains the evolution of restaurant prices over the 10-year period before the changeover reasonably well. Figure 2 shows that the six univariate forecasts are almost identical. Figure 2 also plots confidence bands around the baseline forecast. Adding outlier dummies in model uv-6, affects the point estimates and the forecasts only slightly but it does improve the model's fit. The confidence bands around the forecast of model uv-6 are significantly narrower than the confidence bands shown in figure 2.

2.2 Multivariate Forecast

In this section, I include additional explanatory variables to construct the forecasts. These are mainly costs factors such as wages, rents, and producer prices but also other variables that may affect restaurants' price setting over the business cycle. The goal of the section is, again, to understand how restaurant prices would have evolved had the changeover not taken place. Cost factors are important as it may well be that the gap between actual and predicted prices we found in the univariate analysis closes once these variables are included.

An index of restaurant wages is available for Germany but unfortunately, the series starts only in 1996 so that the sample is rather short. The German statistical

	uv-1	uv-2	uv-3	uv-4	uv-5	uv-6
constant	0.001*** (0.000)	0.001*** (0.000)	0.001** (0.000)	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)
AR(1)	0.409*** (0.035)	0.387*** (0.066)	0.423** (0.164)	0.450*** (0.057)	0.416*** (0.054)	0.443*** (0.032)
AR(2)		0.064 (0.086)	0.041 (0.221)			
AR(3)		0.003 (0.095)	−0.00 (0.128)			
AR(4)		−0.076 (0.056)	−0.081 (0.050)	−0.071 (0.059)		
AR(5)		0.023 (0.052)	0.047 (0.054)	0.066 (0.055)	0.029 (0.028)	
AR(6)		0.063 (0.069)	0.046 (0.069)			
AR(7)		0.029 (0.076)	0.010 (0.075)			
AR(8)		−0.131 (0.085)	−0.101 (0.074)			
AR(9)		0.056 (0.071)	0.046 (0.070)			
AR(10)		−0.027 (0.067)	0.008 (0.085)			
AR(11)		0.102 (0.084)	0.019 (0.094)			
AR(12)	0.106*** (0.025)	0.034 (0.055)	0.134* (0.070)	0.094*** (0.033)	0.153*** (0.043)	0.098*** (0.018)
MA(1)	−0.744*** (0.108)	−0.730*** (0.116)	−0.880*** (0.271)	−0.910*** (0.118)	−0.779*** (0.073)	−0.835*** (0.047)
MA(2)			0.122 (0.394)	0.207* (0.109)		
MA(3)			−0.00 (0.200)			
MA(12)			−0.220** (0.089)		−0.221*** (0.069)	
outlier dummies	no	no	no	no	no	yes
$Q\,(4)$	1.895 [0.595]	0.931 [0.818]	0.883 –	1.600 [0.449]	1.530 [0.465]	4.025 [0.259]
$Q\,(8)$	6.707 [0.460]	3.212 [0.865]	2.071 [0.723]	5.361 [0.498]	4.533 [0.605]	6.917 [0.438]
$Q\,(12)$	11.180 [0.428]	3.754 [0.977]	2.753 [0.949]	9.497 [0.486]	6.254 [0.794]	11.348 [0.415]
Jarque Bera	28.85 [0.000]	18.52 [0.000]	22.77 [0.000]	20.89 [0.000]	18.25 [0.000]	2.307 [0.315]
$\bar{R}^2$	0.68	0.67	0.68	0.69	0.70	0.74
AIC	−10.66	−10.54	−10.57	−10.66	−10.71	−10.76
SI	−10.48	−10.12	−10.07	−10.41	−10.49	−10.54
n. obs.	119	119	119	119	119	119

Table 1: Univariate models. Dependent variable: first difference of logged restaurant price (rp). Newey West standard errors in parenthesis (2 lags). ***, **, and * indicate significance at 1 percent, 5 percent, and 10 percent. All models include two tax dummies (1993:01, 1998:04) and a dummy for the break in 1993:05. Q(n) are the Ljung-Box Q-statistics of the residual autocorrelations, p-value in brackets. Jarque-Bera: test for normality of the residuals, p-value in brackets. Outlier dummies for 1992:03, 1994:09. Sample 1991:01 - 2000:12.

office recommends using barber wages instead. The office's argument here is that both wages are for relatively low-skilled work in a services sector. The variable "$wage1$" in the model below is barber wage. The series is quarterly and ends in 2008.

As robustness check, I also use wages paid in the food-processing industry ($wage2$). The variable "$wage3$" is the short series of restaurant wage. Regarding restaurant wages, the sample is too short to provide reliable estimates. Nonetheless, the data still provide information about the question whether the gap between actual and predicted prices closes once additional explanatory variables are included. The answer is likely to be negative. Restaurant wage inflation during the sample is around 1 percent per year, similar to barber wage inflation so that wages do not appear to be the driving force between the increases in the output price.

The second and third input factors considered are rents and producer prices. For both factors, no restaurant specific data are available. Bulwien, a market research company, publishes a yearly index of commercial rents in Germany. An interpolation of this series is used as regressor. Note that unlike in many other countries, rents have been declining in Germany over the past two decades. For producer prices, the index used is an aggregate index of German producer prices that includes food and energy.

Firms' pricing behavior may change over the business cycle. To account for this, gross domestic product (gdp) is included as explaining variable. Using national income or workers' compensation instead of gdp gives similar results. Again, two dummies for the VAT increases in 1993 and 1998 are added. The break dummy included in the univariate analysis is dropped as the break that occurs around 1993 is well explained by the additional variables.

Table 2 shows the estimation output of six models. All models include two tax dummies (1993q1 and 1998q4). After adding an MA(1)-term, the residuals of the models appear normally distributed and the correlograms and the Ljung-Box Q-statistics point to no autocorrelation in the residuals.

Model mv-1 is the baseline model. The signs are as expected. An increase in wage inflation increases output price inflation after some lags. A similar effect is observed for producer prices. Pricing behavior seems to change over the course of the business cycle with higher inflation during expansionary periods. I also added the dependent variable lagged one and two periods to proxy for unobserved factors whose omission may bias estimation. The dependent variable lagged two periods is significant. Adding Δrp lagged one period leaves the point estimates of the other variables almost unchanged. The forecasts are similar.

Model mv-4 includes rents. As mentioned above, housing rents decrease during the estimation period explaining the negative sign. Even though rents turn out to be significant at 10 percent, I dropped the variable from the baseline model because of the unreasonable sign. Model mv-5 replaces barber wage with wages paid in the food-processing sector and model mv-6 shows the estimates with restaurant wages. Note the low F-statistic in model mv-6.

When forecasting beyond 2007, we have to take into account the 3-percent VAT increase in January 2007. Not doing so would lead to a considerably wider gap between actual and predicted index towards the end of the sample (see figure 2). In the long run, we should expect firms to pass on the entire tax increase but the data suggest that firms were not able to do so immediately. In order to estimate the VAT increase's impact, I run the baseline model over the entire sample adding dummies for the event window (2001:01 - 2002:04) and dummies for the eight quarters following the tax increase (2007:01 - 2008:04). The point estimates of the latter dummies indicate firms' ability to pass on the tax. The estimates (see appendix), show that in the first quarter following the tax increase, firms were able to pass on almost a third of the tax. After eight quarters, 98 percent of the tax increase was passed on. The point estimates of the VAT dummies are then added to the forecasts.

Overall, with coefficients of determination of around 0.9, the models explain the evolution of restaurants in the estimation period reasonably well. Compared to the univariate models in the previous section, including additional explanatory variables significantly improves the fit. The forecasts appear robust across different model specifications. The left hand panel of figure 3 plots confidence bands around the forecast based on model mv-1. The right hand panel of the figure shows the forecasts of all six models of table 2 in addition to the forecast of model uv-1 of the previous section. The forecasts are multi-step, that is, the forecasts are constructed using only information about the explanatory variables (e.g., wages or producer

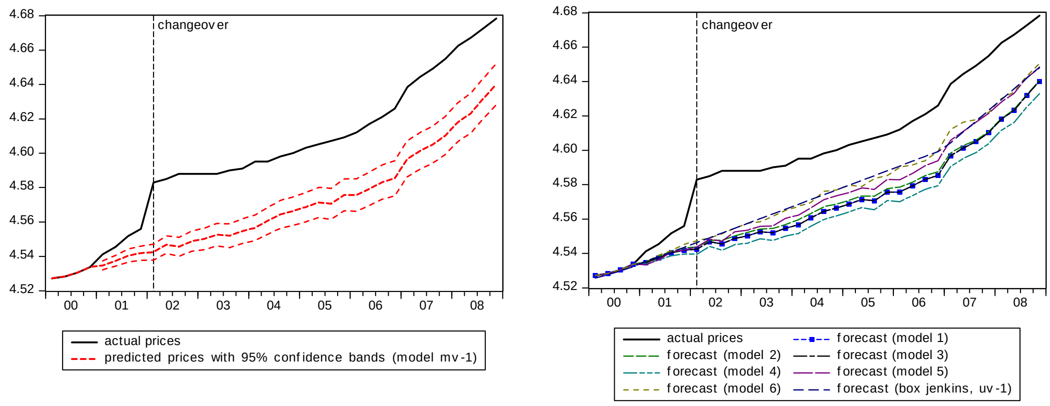


Figure 3: Left hand panel: forecast based on baseline model (mv-1) of multivariate forecasts with 95% confidence bands. Right hand panel: forecasts of all six models shown in table 2 together with forecast of model uv-1.

prices). Where the lagged dependent variable enters, previously forecasted values for the lagged dependent variable are used in forming forecasts of the current value.

2.3 Discussion

It seems safe to draw the following conclusions from the preceding analysis. First, restaurant prices increased significantly during the changeover and the increase appears unrelated to costs or business cycle movements. Second, even five years after the changeover, there is no obvious tendency of convergence. The gap between the actual and the predicted series appears rather stable. This result is robust to different methodologies and different specifications so that an extrapolation of five years seems permissible. I have plotted forecasts over longer horizons because they are interesting but they should be interpreted with care even if the confidence intervals are quite narrow.

Three more points are worth mentioning. First, from a theoretical point of view, input and output prices could be cointegrated. That is, the variables may follow a common trend in which case the methodology used above would not be efficient. There does, however, not appear to be a cointegrating relationship between input and output prices, which is probably due to the decline in rents. Intuitively, cointegration means that there is some kind of equilibrium relationship among the variables but that, at least in our sample, no such equilibrium exists. Second, the gap between actual and predicted prices appears to have closed somewhat during the event window. At the time of the changeover (January 2002), actual prices are roughly 3.5 percent higher than what is predicted by the models. Later, the gap stabilizes at around 3 percent. Third, the high inflation in the year before the changeover is striking. Already the first observation in the event window is outside the confidence bands of our forecasts. This is one of the reasons that make the menu-cost argument unlikely.

3 The Restaurant Pricing Game

In this section, I make the case for the multiple equilibria argument suggested by Adriani et al. (2009). There are a number of models that generate multiple equilibria and all are plausible in certain situations but one of the questions raised by figure 1 is, "Why restaurants?". I begin with a short description of the restaurant sector stressing the characteristics that I believe are important for an explanation. The goal of this description is primarily to argue that the assumptions made in the formal analysis below provide a reasonable description of the restaurant sector.

Years ago, when I entered university as a freshman, there was a kebab seller asking 4 Marks for a kebab. Though not the only food outlet, kebab was popular among students. Probably because of this popularity, another kebab seller opened shop a couple of months later, asking 3.50 Marks for a piece. The next day, the first had reduced its price to 3 prompting further reaction from the second. This went on for a few days until both charged 2.50 Marks. We students, happy about the forces of competition, were quite surprised to see both sellers asking 4 Marks at the beginning of the following week. We never found out whether the two sellers actually met or whether they were able to agree tacitly on the original price.

For this type of tacit (Bertrand) collusion to work, certain conditions are necessary as the incentives for sellers to deviate are strong. In the following lines, I argue that the restaurant market has a number of characteristics that facilitate collusion.

	mv-1	mv-2	mv-3	mv-4	mv-5	mv-6
constant	0.0004 (0.0003)	0.0008*** (0.0002)	0.0004 (0.0004)	0.000 (0.000)	0.0004 (0.0004)	0.0026 (0.0015)
$\Delta rp(-1)$			-0.0001 (0.0445)			
$\Delta rp(-2)$	0.1608*** (0.0359)		0.1608*** (0.0420)	0.2226*** (0.0502)	0.1318** (0.0529)	-0.3038 (0.2024)
$\Delta gdp(-1)$	0.0146 (0.0197)	0.0230 (0.0247)	0.0146 (0.0223)	0.0087 (0.0232)	0.0335 (0.0283)	0.0279 (0.0870)
$\Delta gdp(-2)$	0.1479*** (0.0230)	0.1222*** (0.0382)	0.1479*** (0.0229)	0.1707*** (0.0280)	0.1745*** (0.0237)	0.1473* (0.0553)
$\Delta pp(-1)$	0.0638*** (0.0179)	0.0458** (0.0211)	0.0638*** (0.0178)	0.0740*** (0.0137)	0.0483** (0.0179)	-0.0662 (0.0683)
$\Delta pp(-2)$	-0.0350^{**} (0.0146)	-0.0190 (0.0144)	-0.0350^{**} (0.0140)	-0.0338^{**} (0.0153)	-0.0603^{**} (0.0253)	0.0271 (0.0619)
$\Delta wage1(-1)$	0.0479*** (0.0171)	0.0455** (0.0178)	0.0479* (0.0237)	0.0501*** (0.0153)		
$\Delta wage1(-2)$	0.0151 (0.0167)	0.0517** (0.0221)	0.0152 (0.0160)	-0.0043 (0.0246)		
$\Delta wage1(-4)$	0.0444*** (0.0638)	0.0612*** (0.0096)	0.0444* (0.0102)	0.0464*** (0.0142)		
$\Delta wage2(-1)$					0.1014 (0.0800)	
$\Delta wage2(-2)$					-0.0733 (0.0564)	
$\Delta wage2(-4)$					0.0998** (0.0410)	
$\Delta wage3(-1)$						-0.0580 (0.1046)
$\Delta wage3(-2)$						0.0490 (0.0644)
$\Delta wage3(-4)$						0.0109 (0.0959)
$\Delta rents(-1)$				-0.0232^{*} (0.0128)		
$Q\,(4)$	1.788 [0.618]	1.510 [0.680]	1.786 [0.618]	1.949 [0.583]	3.105 [0.376]	3.088 [0.378]
$Q\,(8)$	2.608 [0.919]	3.310 [0.855]	2.607 [0.919]	3.020 [0.883]	4.370 [0.736]	9.965 [0.191]
$Q\,(12)$	4.339 [0.959]	5.649 [0.896]	4.338 [0.959]	5.132 [0.925]	5.453 [0.907]	21.110 [0.032]
$\bar{R}^2$	0.920	0.903	0.916	0.923	0.908	0.610
F-statistic	36.45***	32.5***	32.0***	33.8***	31.6***	3.03
S.E. of Reg.	0.0013	0.0014	0.0013	0.0012	0.0014	0.0016
n.obs.	35	35	35	35	35	14

Table 2: Multivariate models. Dependent variable: first difference of restaurant price (rp). Newey West standard errors in parenthesis (2 lags). *** indicates signifiance at one percent, ** at five, and * at ten percent. All models include tax dummies for 1993q1 and 1998q2 and an MA(1) term. Q(n) are the Ljung-Box Q-Statistics of the residual autocorrelations, p-values in brackets. Note the low F-statistic of model mv-6. Sample 1991:01 - 2000:04, quarterly data.

In general, restaurants are price (not quantity) setters and the decision by one restaurant (say, to enter the market or to raise prices) has a direct effect on the demand of its neighboring restaurants whose number is probably not very large.

Most restaurants enter a market for a longer period of time so that any interaction between them can be considered "repeated". The interaction is helped by two factors. First, regulations in many countries (including Germany) require restaurants to post prices well visible from outside the establishment. These requirements are intended to assist consumers but increase price transparency among competitors as well. Secret price cuts are difficult to imagine. Second, restaurant prices are rigid. On average, restaurants keep prices constant for between 12 and 24 months (Altissimo et al. 2006). Both the rigidity and the regulatory requirements make price setting in the restaurant sector highly transparent.

The nature of the product also helps collusion. Scherer (1980, p. 220) argues that profitable tacit collusion is most likely when orders are "small, frequent and regular". A description that nicely matches restaurants meals. In addition, substitutability is reasonably high. Naturally, a chef would never admit that he is producing a homogeneous product, but from the point of view of a customer, it is in most cases fairly easy to find substitutes.[3]

Summing up, the restaurant sector may be described as a market of (local) oligopolies in which firms compete in a repeated Bertrand manner. In addition, the market has a number of characteristics that are typically considered as facilitating collusion.

Collusion and the resulting multiplicity of equilibria is, however, not sufficient for an explanation as it begs the question why restaurants have not coordinated on the higher price before. The answer, I argue, is pricing points. Restaurants typically set prices at pricing points (also called attractive or threshold prices), such as 4.00 Euros for a kebab. The tendency to set prices at discrete intervals reduces the number of potential equilibrium prices and implies that at the firm

[3] Restaurant meals are a classic example of experience goods, that is, goods whose attributes can be determined only after purchase or during consumption (Nelson 1970). This characteristic is important for the study of the buyer-seller relationship but less important for the study of seller-seller relationship which is our concern here.

level, real prices will change during a changeover as some pricing points disappear and new ones come about.

Consider again the example of the two kebab sellers above. Converting this price at the official exchange rate of 1.95853 Marks per Euro yields a price of around 2.04 Euros. If the firm prefers round prices, it can either round up or down to the next attractive price. Rounding down to 2.00 implies a price reduction of more than 2 percent and rounding up to 2.10 implies a price increase of almost 3 percent. The important point here is that a price change from, say 2.04 to 2.00, is a change from a price that, due to the changeover, lost its equilibrium status to a price that only gained an equilibrium status with the changeover. In other words, a price of 2.00 Euros was not feasible before the changeover.

The formal analysis starts in the next section with the two polar cases of a monopoly and of a model of static Bertrand competition. Section 3.2 turns to a model of repeated Bertrand competition that I argue is a good description of the restaurant sector. There we will see that pricing points may both facilitate and hinder collusion and that in such an environment a changeover may lead to persistently higher prices.

3.1 Monopoly and static Bertrand competition

This section discusses the two polar cases of monopoly and (static) Bertrand competition. Note that the discussion about pricing points is analogous to the integer problem that arises when there is a smallest unit of account.

Let p be a firm's price and suppose that prices have to be named in some discrete multiple of Δ, the "unit of payment". If, for example, prices are multiples of 50 cents (such as 3.50 or 4.00) we have $\Delta = 50$. We can then express round prices in terms of Δ as

$$\Delta r \leq p \leq \Delta (r + 1)$$

for some $r \in \mathbb{N}$ with one inequality strict. It is sometimes convenient to use a more general notation for pricing points. Let the ceiling (floor) function denote a price that is rounded up (down). A rounded price is indicated by square brackets so that

$$[p] = \begin{cases} \lceil p \rceil = \Delta (r+1) & \text{if the firm rounds up} \\ \lfloor p \rfloor = \Delta r & \text{if the firm rounds down.} \end{cases}$$

The changeover alters the unit of payment. Instead of multiples of Δ, let the new unit be Γ, where Γ may be larger or smaller than Δ.[4] Prices are then given by

$$\Gamma s \leq p \leq \Gamma (s+1)$$

for some $s \in \mathbb{N}$, again, one inequality strict. Where necessary, subscripts indicate whether a price is denoted in the new or the old currency, such as

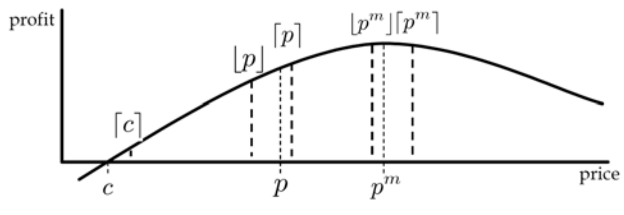
$$[p]_\Gamma \text{ or } [p]_\Delta .$$

I also assume that the unit of account is sufficiently small so that there are enough pricing points to assure that firms can always round up and down. This is to exclude cases where, say, a monopolist cannot round down because the lower price happens to be below marginal costs.

Consider first the case of a monopolist producing a single good whose constant average (and marginal) costs are equal to c. Let market demand be given by a strictly decreasing function $F(\cdot)$ and let p^m be the price that maximizes profits,

$$p^m = \arg\max_{p \geq 0} \pi(p),$$

where $\pi(p) = (p - c) F(p)$ are the firm's profits.



[4] The relationship between Δ and Γ is not necessarily given by the actual conversion rate as firms may decide to use different intervals (say, multiples of 10 instead of 50). Firms' choice is, however, restricted if the unit of payment reaches the unit of account (e.g., one cent). This is ruled out here.

The figure illustrates firm's rounding. The monopolist will round up when

$$\pi\left(\lfloor p^m \rfloor\right) < \pi\left(\lceil p^m \rceil\right) \tag{1}$$

and round down if the inequality sign is reversed. When the profit function (π) is symmetric around p^m, price decreases and price increases are equally likely.

A changeover leaves p^m unaffected so the decision to round up or down is as well given by equation (1) and, unless we assume that the profit function is skewed, price increases and price decrease are equally likely.

Now consider the Bertrand model of oligopolistic competition in which prices are the firms' strategic variables and where the individual firms $i \in \{1, 2, ..., n\}$ set their respective price p_i simultaneously. Suppose that the good produced by every firm is homogeneous and its aggregate market demand is given by a strictly decreasing function $F(\cdot)$. Assume that firms display an identical (linear) cost function with constant average (and marginal) cost being equal to c. In case of equal prices, a demand sharing rule is applied.[5]

Unlike in the case of a monopolist where imposing pricing points leads to both increases and decreases, firms competing in Bertrand manner will always round up when forced to set prices at pricing points and make equilibrium profits.

Proposition 1 *In the Bertrand model of price competition with pricing points, there is a unique Nash equilibrium in which all firms charge* $\lceil c \rceil > c$.

Proof. Note first that all firms get a strictly positive profit by using this strategy. No firm wants to raise its price. If one of them did so, its sales would be zero and it would make zero profit. No firm wants to lower its price because if one of them would lower its price to at least $\lfloor c \rfloor$, it would make non-positive profits since $\lfloor c \rfloor \leq c$. Therefore, given that the other firms charge $\lceil c \rceil$, charging $\lceil c \rceil$ is the unique best response. ■

A changeover leaves c unaffected. The decision to raise or lower prices depends

[5] We may allow firms to set different prices in equilibrium if consumers adjust prices by other factors such as quality. For example, if consumers care about the price-quality ratio, equilibrium requires that $P_i/Q_i = P_j/Q_j$ for two firms i and j.

on which pricing point is closer to c. That is, a firm would raise its price if

$$\lceil c \rceil_{\Gamma} > \lceil c \rceil_{\Delta}$$

and lower its price if the inequality sign is reversed.

3.2 Repeated Bertrand Competition

Consider now a situation in which firms compete for sales repeatedly, with competition in each period t described by the Bertrand model above. When setting prices, the firms know all the prices that have been chosen (by all firms) previously. There is a discount factor $\delta < 1$, and each firm i attempts to maximize the discounted value of profits $\sum_{t=1}^{\infty} \delta^{t-1} \pi_{it}$.

Consider the following Nash reversion strategy in which firm i's strategy specifies what price p_{it} it will charge in each period t as a function of the history of all past price choices by its rivals, $H_{t-1} = \{p_{1t}, ..., p_{nt}\}_{\tau=0}^{t-1}$. That is,

$$p_{it}(H_{t-1}) = \begin{cases} [p^m] & \text{if either } t = 1 \text{ or if all } n \text{ elements of } H_{t-1} \text{ equal } [p^m] \text{ or} \\ \lceil c \rceil & \text{otherwise.} \end{cases} \quad (2)$$

This strategy calls for the firm to initially play the monopoly price $[p^m]$ in period 1. Then, in each period $t > 1$, firm i plays $[p^m]$ if in every previous period all n firms have charged price $[p^m]$ and otherwise charges a price equal to the lowest feasible price $\lceil c \rceil$. In other words, firms cooperate until someone deviates and any deviation triggers a permanent retaliation. A firm that wants to deviate needs to lower prices by at least Δ. Let the rounded monopoly price be $[p^m] = \Delta r^m$, then the highest price a deviating firm can set equals $\lfloor [p^m] \rfloor = \Delta (r^m - 1)$. The following proposition states that if firms follow the strategy in (2), then all firms will end up charging the (rounded) monopoly price in every period.

Proposition 2 *The strategies described in (2) constitute a subgame perfect Nash equilibrium of the infinitely repeated game if*

$$\frac{1}{1-\delta}\frac{1}{n} > \frac{\pi(\lfloor [p^m] \rfloor)}{\pi([p^m]) - \pi(\lceil c \rceil)}. \quad (3)$$

Proof. A set of strategies is a subgame perfect Nash equilibrium of an infinite horizon game if and only if it specifies Nash equilibrium play in every subgame. Although each subgame of this repeated game has a distinct history of play leading to it, all of these subgames are identical to the game as a whole. Thus, to establish that the strategies in (2) constitute a subgame perfect Nash equilibrium, we need to show that after any previous history of play, the strategies specified for the remainder of the game constitute a Nash equilibrium of an infinitely repeated Bertrand game. In fact, we only need to be concerned with two types of previous histories: those in which there has been a previous deviation and those in which there has been no deviation.

First, consider a subgame after a deviation has occurred. Then we are in the case of proposition (1) where each firm makes positive profits of $\frac{1}{n}\pi\left(\lceil c\rceil\right)$ and setting $p = \lceil c\rceil$ is a Nash equilibrium. The discounted value of these profits equals

$$\frac{1}{1-\delta}\frac{1}{n}\pi\left(\lceil c\rceil\right).$$

Suppose now that up to period t, no deviation has occurred and that firm i contemplates deviating from price $[p^m]$ in period t. In order to maximize its payoffs, the firm will set the highest feasible price below the rounded monopoly, that is, $\lfloor [p^m] \rfloor$. In the periods after the firm deviates $(t+1, t+2, ...)$, the strategies call for firm i's rivals to charge a price $\lceil c\rceil$.

On the other hand, if the firm never deviates, it earns a discounted payoff of

$$\frac{1}{1-\delta}\frac{1}{n}\pi\left([p^m]\right).$$

Thus, a firm would not deviate as long

$$\frac{1}{1-\delta}\frac{1}{n}\pi\left(\lceil c\rceil\right) + \pi\left(\lfloor [p^m] \rfloor\right) < \frac{1}{1-\delta}\frac{1}{n}\pi\left([p^m]\right).$$

Rearranging yields the required result. ■

This result is a version of a well-known formalization of tacit collusion. The interesting facet of this formalization is that collusion is enforced through a purely noncooperative mechanism. To get some intuition for this result note first that the right hand side of equation (3) approaches 1 as $\Delta \to 0$. In this case, we are back in the familiar result without pricing points. Also note that the right hand side of equation (3) may be smaller or larger than one. That is, pricing points may both hinder and facilitate collusion. Pricing points hinder collusion in that the harshest punishment the strategy can call for still involves positive profits since $\lceil c \rceil > c$. But if on the other hand $\pi(\lceil c \rceil)$ is small, pricing points facilitate collusion because in order to deviate, a firm must lower prices by at least Δ.

A high discount factor (δ) and a small number of firms (n) facilitate collusion. The discount factor need not be interpreted literally. Suppose, for example, that in each period there is a probability η that the firms' interaction might end. In this case, the discount factor in equation (3) would be replaced by $\delta = \eta\delta'$, for some other discount factor $\delta' \in (0, 1)$. The higher the probability that the game continues, the more likely is collusion. This interpretation makes clear that the infinitely repeated game framework is relevant even when firms compete only for some finite amount of time. What is needed to fit the analysis into the framework above is a strictly positive probability of continuing the game. The discount factor may also be interpreted as a measure of the time it takes to detect a deviation. The longer it takes to detect a deviation, the lower δ.

The following corollary states the well-known result that in infinitely repeated games of this type, there is a profusion of possible equilibria.

Corollary 3 *In the infinitely repeated Bertrand game, with condition (3) satisfied, any price $p \in [\lceil c \rceil, [p^m]]$ can be supported as a subgame perfect Nash equilibrium using Nash reversion strategies.*

For the proof, simply replace $[p^m]$ by any $p \in [\lceil c \rceil, [p^m]]$ in the proof of proposition (1) above. This profusion of equilibria can be judged either positively or negatively. Positively, one may emphasize the fact that these results often allow game-theoretic models to recover the consistency with empirical observations that is lost when the situation is analyzed as a static game as in proposition (1). There, the only equilibrium was to set the lowest feasible price $\lceil c \rceil$ and competition between only two firms is enough to assure the perfect competitive outcome. On the negative side, however, it is often stressed that this very "success" sometimes does away with the usefulness of the approach. The models do not have much explanatory power if they are compatible with a whole range of different outcomes. In our case where prices are set at discrete pricing points, the profusion is lower than in the standard case but, of course, the range of possible equilibria is not necessarily smaller.

I finally turn to the changeover whose effect is summarized in the following corollary.

Corollary 4 *In the infinitely repeated Bertrand game with pricing points in which firms coordinated on some price* $p \in [\lceil c \rceil, \lfloor [p^m] \rfloor)$, *rounding up dominates rounding down.*

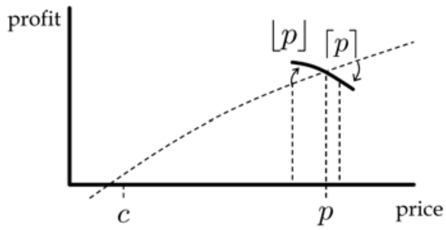
For the proof, note that the profit function is strictly increasing between $\lceil c \rceil$ and $\lfloor [p^m] \rfloor$, giving the result. If the firms already set the monopoly price, $[p^m]$, we are back in the monopoly case of section 3.1 and both rounding up and down may be optimal. The mechanism, thus, requires that there are firms that price below the monopoly price. Here it is important to remember that the changeover occurred in a period of positive inflation. The monopoly price is, therefore, not constant but varies over time so that the requirement that some firms are pricing below $[p^m]$ appears innocuous.

4 Discussion

This paper estimates the long-run effect of the 2002 currency changeover on German restaurant prices and shows (1) that restaurant prices increased significantly during the changeover and that the increase is unrelated to costs or business cycle movements. (2) Several years after the changeover, there is no obvious tendency of convergence. The gap between the actual and the predicted series is rather stable.

The explanation suggested has to elements, multiple equilibria and pricing points. I argued first that restaurants compete in a repeated Bertrand fashion and that the sector has several characteristics that facilitate collusion. Collusion allows firms to coordinate on a price above marginal costs. The second element, pricing points, explains why firms have not coordinated on the higher price before. Pricing points restrict the number of potential equilibria and a changeover disturbs the original set of equilibria and forces firms to raise or lower prices. In such an environment, rounding up is optimal as long firms price below the monopoly price.

Though I believe that the assumptions made above are reasonable and the explanation plausible, I want to make one qualification in this concluding discussion. From a theoretical point of view, it is as well conceivable that there are incentives *not* to round up. Berardi et al. (2011), for example, argue that consumers may be put off when a firm increase prices at the changeover and reduce demand. By lowering prices, on the other hand, a seller may be able to attract new customers. If this effect is strong enough, a firm may find it optimal to lower prices.



Graphically, this effect causes the profit function to pivot around the original price. For our case, this argument is interesting because - similar to the two polar cases of section 3.1 - consumers' behavior creates again a kind of "anchor" that is unaffected by the changeover and we may observe price reductions even if firms price below the monopoly price.

This paper focuses on the restaurant sector but many of characteristics of the restaurant sector that facilitate collusion are as well typical for other services such as dry cleaning or hair dressing and it is possible that we find a similar effect in these sectors as well. I leave this for future research.

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Appendix

Data Description All variables are in logs. Source: German statistical office, except commercial rents.

- rp : index of restaurant prices, monthly, 1991M1 - 2010M12.
- $rents$: commercial rents, annual data 1991 - 2010, source: BulwienGesa
- gdp : gross domestic product, quarterly, 1991q1 - 2010q4, seasonally adjusted.
  - national income, quarterly, 1991q1 - 2010q4, seasonally adjusted.
  - workers' compensation quarterly, 1991q1 - 2010q4, seasonally adjusted.
- PP : producer prices, monthly, 1991q1 - 2010q4, seasonally adjusted.
- $wage1$: wages paid in barber sector, quarterly, 1991q1 - 2008q4.
- $wage2$: wages paid in the food-processing sector, quarterly, 1991q1 - 2008q4.
- $wage3$: wages paid in restaurant sector, quarterly, 1996q1 - 2008q4.

Percentage of 2007 VAT Increase Passed on to Consumers The table shows the (scaled) point estimates of the eight dummies described in the text.

Quarter	Point Estimates	VAT passed on to buyers (accumulated)
2007q1	$8.31E-03$	27.8%
2007q2	$9.05E-03$	30.3%
2007q3	$9.72E-03$	32.6%
2007q4	$1.26E-02$	42.1%
2008q1	$1.66E-02$	55.7%
2008q2	$1.77E-02$	59.4%
2008q3	$2.30E-02$	77.6%
2008q4	$2.83E-02$	97.8%