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Abstract

Restaurant prices in the euro area saw an unprecedented increase after the introduction of the euro. We use an extension of commonly used models of sticky prices and argue that the increase in restaurant prices can be explained by menu costs. The extension we use involves the state-dependent decision of firms about when to adopt the euro. Two main mechanisms drive the result. First, our model concentrates otherwise staggered price increases around the introduction of the euro. Second, before the adoption of the euro, prices do not reflect marginal cost increases expected to occur after the changeover. This horizon effect disappears as soon as the new currency is adopted, contributing to a jump in prices at that time. For realistic parameter values, the model generates a blip in inflation of the same magnitude observed in the data.

Key words: monopolistic competition, sticky prices, inflation, euro

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1 Introduction

Before the introduction of the Euro coins and bills in January 2002, many feared that the changeover could give rise to excessive price increases. As it turns out, according to an investigation by the European Commission, the increase in the overall Harmonized Index of Consumer Prices attributable to the introduction of the Euro was only between 0.12% and 0.29%. Although the aggregate price index saw little or no increases however, prices in particular sectors, most notably restaurants and cafés, increased at a historically unprecedented rate in the three months after the Euro coins and bills were introduced.

In January 2002, the annualized monthly price increase in the Euro area restaurant sector was 15.63%. In the same month, several countries saw price increases in their restaurant sector that went way beyond this: Germany (28.80%), France (18.75%), Finland (26.11%), and the Netherlands (50.05%) are the most extreme cases. These increases stand in stark contrast to the moderate restaurant price increases observed in the EU countries that did not adopt the Euro, the U.K., Denmark, and Sweden.

What could explain such remarkable restaurant price increases in response to the introduction of the Euro? Did restaurant owners use the introduction of the Euro as an opportunity to collude and raise prices? This seems fairly unlikely. The restaurant sector in the Euro area is a sector largely populated by small family-owned businesses. Explicit collusion between the many restaurant owners across all the countries in the Euro area seems to be a far-fetched scenario. Of course, as suggested for example by Adriani et. al. (2003), collusion between restaurant owners in the Euro area might have been tacit. The introduction of the Euro might have led them to coordinate a switch from a low-price to a high-price equilibrium. Although not impossible, such a multiple equilibrium story can only anecdotally explain why it was the introduction of the Euro that caused this equilibrium switch. A third theory emphasizes the importance of pricing points in the switch to the Euro. However, if pricing points are important in the restaurant sector, then why didn't they lead to comparable price increases in sectors that sell units of smaller amounts, like supermarkets?

In this paper we claim that there is another explanation for the price increases in the Euro area restaurant sector. This explanation is the existence of menu costs. Where else would menu costs be more applicable than in the restaurant sector?! In fact, evidence in Bils and Klenow (2004) as well as van

Els et. al. (2002) suggests that restaurant prices are among the most sticky prices observed.

Our explanation relies neither on the assumption of multiple equilibria nor on that of pricing points. Instead, it is based on an extension of commonly used sticky price models to the adoption of the Euro. These sticky price models form the backbone of the modern dynamic version of the IS-LM model, also known as the New-Keynesian model. They are a crucial part of the microfoundations underlying the New-Keynesian Phillips Curve, as discussed, derived, and estimated in, among others, King (2000), Clarida, Galí and Gertler (2000), Sbordone (2002) and Woodford (2003).

The main assumption that we make in this paper is that the introduction of the Euro on January 2002 forced all restaurants to reevaluate their prices to adjust to the new denomination. Price adjustments that might have been further delayed, or anticipated to a few months prior to January 2002, all happened together in (or right after) January 2002. We include this assumption in four models with sticky prices that take into account the adoption of the Euro.

The first three models that we consider are: a version of Calvo (1983), a hybrid of Calvo (1983) and Taylor (1980), and the model by Dotsey, King, and Wolman (1999). In these three models we assume that all firms adopt the Euro in the month it is introduced. It turns out that this assumption implies a price increase in January 2002 that is much higher than observed in the data.

Our fourth model is an extension of Dotsey, King, and Wolman (1999) that incorporates an endogenous adoption decision of the new currency. In equilibrium, this implies a gradual adoption of the Euro over the course of the first half of 2002. For reasonable parameter values, this model generates a blip in restaurant price inflation of the same magnitude observed in the Euro area. Two main mechanisms generate this blip.

The first, which we call 'distributional churning', produces a concentration of otherwise staggered price changes at the time of the adoption of the Euro. The second mechanism, which we call the 'horizon effect', is determined by the fact that the prices set before the changeover do not include any of the increases in marginal costs anticipated to occur afterwards. The prices set at the time of the switch, however, do include these cost increases. This leads adopting firms to increase their prices at a much higher rate than their counterparts that do not.

These results have important policy implications. They show that the adoption of a new currency is not necessarily neutral in a monetary sense and that the degree of non-neutrality depends on the width of the time window within which firms are allowed to adopt.

The structure of the paper is as follows. In the next section we present the evidence on the anomalous price increases in the Euro area restaurant sector in, or around, January 2002. In section 3 we introduce our theoretical sticky price framework. We show how the anticipated introduction of the Euro can be included in a general model of sticky prices that nests the four models of sticky prices and menu costs mentioned above. The general model that we introduce is a partial equilibrium model for a small sector. The equilibrium in this sector is assumed not to affect the path of macroeconomic aggregates. We choose this setup because the introduction of the Euro seems to have had negligible effects on the aggregate price level but has had a big effect on the prices in the restaurant sector. We discuss the main mechanisms that determine the equilibrium path of prices and inflation in the small sector in Section 4. It is in this section that we introduce the concept of 'distributional churning' and the 'horizon effect', which are the two most important driving forces behind our results. In section 5 we show that, for realistically calibrated parameter values, the model with endogenous adoption of the Euro generates a blip in inflation that is remarkably similar in magnitude to that observed in the data. Section 6 concludes. Mathematical details are left for Appendix A.

2 European inflation and the introduction of the Euro

In the run up to the introduction of the Euro, the European Commission noted that the

> '...public is increasingly concerned that it will be subject to abuses during changeover and there have been complaints in several countries about abusive price rises both in the public and in the private sector'
> (Commission for the European Communities (2001), page 4)

Even though the Commission itself deemed the risk of price rises

'... broadly speaking, very slight or non-existent'
(Commission for the European Communities (2001), page 4),

several policy measures were put in place to prevent such price rises from happening. These measures included member states committing to converting public tariffs to the Euro in a non-inflationary way and the signing of an agreement by representatives of traders and consumers, guaranteeing overall price stability during the transition to the Euro.

In this section we present evidence on the extent to which the changeover to the Euro in January 2002 was accompanied by any discernible anomaly in the behavior of prices and inflation. We will do so in two steps.

First, we show that the general price level in the EU12 - the so-called Harmonized Index of Consumer Prices, or HICP[1] - did not experience any significant jump around the changeover. The same is true for the overall price levels in each of the 12 Countries that adopted the new currency.

Second, we show that this aggregate evidence hides anomalous behavior of prices in particular sectors of the economy. The sector with the most profound anomaly in inflation dynamics in January 2002 is the restaurant and café sector, which is the focus of this paper. We present evidence on how the behavior of inflation in the restaurant and café sector in the countries that converted to the Euro deviated from its historical behavior as well as from that in countries that did not adopt the Euro.

2.1 The general price level

Figure 1 shows the evolution of the EU12[2] HICP log-price level and monthly inflation rate from January 1995 to March 2004.

We report the non-seasonally adjusted series here for two main reasons. First and foremost, we are looking to uncover unusual jumps in inflation concentrated in the first few months of 2002, corresponding to the introduction of the Euro. If present, such jumps would most likely be smoothed out by seasonal adjustment methods. Secondly, the disaggregated series for the

[1] Diewert (2002) explains the conceptual framework underlying the HICP.

[2] The EU12 countries are Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain. Eurostat's harmonized CPI for the Euro-zone is compiled using country weights based on each country's share of private final domestic consumption expenditure in the Euro-zone total. The EU HICP series includes Greece only since 2001

restaurant sector that we will be looking at next are also only available in non-seasonally adjusted form.

As is evident from the figure, nothing remarkable happened in or around January 2002. The inflation rate in January was around 2% and inflation peaked in March 2002 at around 8%, but very similar peaks recurred in each March since 2001[3].

Of course, the aggregation of the underlying national inflation rates into the monetary union's aggregate might very well hide a significant degree of national heterogeneity in the effect of the changeover. This turns out not to be the case. In all countries in the EU12 price movements in or around January 2002 do not clearly stand out against the backdrop of the general volatility and pronounced seasonality of the series. Possible exceptions are Germany and Spain. In December 2001, the German monthly inflation rate hit 15% on an annualized basis. This is the highest level in the sample. In Spain, inflation climbed to 11% and 18% in March and April of 2002.

On balance, our reading of this evidence does not support the idea that the changeover to the Euro had an unusual impact on European consumer price inflation. Furthermore, the inflation experience in the 12 countries converting to the Euro in January 2002 was not very different from that in Denmark, Sweden, and Britain, which opted out of the Monetary Union.

Several studies, like Deutsche Bundesbank (2004), have come to the same conclusion. In fact, the European Commissions' official answer to the question 'Has the introduction of euro notes and coins caused prices to rise?' reads

> 'Analyses by Eurostat, the European Commissions statistical service, indicate that the Euro changeover led to some price increases in specific sectors, such as restaurants, cafes and hairdressers, but that the overall effect on prices in the Euro area was limited. For the all items Harmonized Index of Consumer Prices, the price increase most likely falls within the range 0.12 to 0.29%.'[4]

[3]What is noticeable is the increase in the volatility of inflation in the overall HICP for the Euro area starting in January 2001. This is accompanied by a more pronounced seasonal pattern, with peaks in the first and fourth quarter followed by troughs in the middle of the year. This increase in inflation volatility is apparently due to changes in the way sales are dealt with in the construction of the overall price index. See Lünneman and Mathä (2004).

[4]See http://europa.eu.int/comm/economy_finance/euro/faqs/faqs_16_en.htm

This answer suggests, however, that there are some sectors where the introduction of the Euro led to significant price increases. One of the sectors that is specifically mentioned is restaurants and cafés, to which we turn our attention next.

2.2 Restaurant and café prices

Price increases in January 2002 and, in some countries, the subsequent few months were exceptionally high in the restaurant and café sector all across the Euro area. These price increases did not go unnoticed. In fact, in some countries, questions were raised about the reason for these price increases. In the Netherlands, for example, this led to an official memo to parliament, see Centraal Plan Bureau (2002). So, what was so peculiar about restaurant and café prices in the EU12 in January 2002?

This question is most easily answered by Figure 2, which depicts the level and inflation rate of the HICP for restaurants and cafés in the EU12. The average annualized monthly inflation rate in the EU12 restaurant and café sector over the period January 1995 through March 2004 was 2.81%. In January 2002, the month in which the Euro was introduced, inflation was 15.63%. This shows up in the top panel of Figure 2 as a jump in the price level and as a blip in the inflation rate in the bottom panel. Even in the three months following January 2002, restaurant and café prices in the EU12 rose at an annualized rate that exceeds 5%. Just eyeballing Figure 2, it is clear that the January 2002 jump in restaurant and café prices in the Euro area was several orders of magnitude bigger than anything ever seen before.

The EU12 pattern of restaurant and café prices was not caused by the behavior of these prices in one country in the Union in particular. Instead, this blip in restaurant and café prices was observed all across the Euro area. In many countries the price increases were concentrated in January 2002. This was particularly the case for Finland, France, Germany and the Netherlands. These countries saw an annualized inflation rate for restaurants and cafés for January 2002 between 20% and 50%. In other countries, like Italy and Spain, the price increases were more moderate in January 2002 and seem to have persisted during the subsequent months.

To further corroborate the hypothesis that these price jumps were due to the changeover to the new currency, we compare the behavior of restaurant and café prices in the three biggest economies that switched to the Euro, i.e. Germany, France, and Italy, with that of the three EU countries that did not switch to the Euro. These countries are Britain, Denmark and Sweden. The fact that there is a set of countries that did not switch to the Euro allows us to think of this as a sort of "natural experiment" on the effect of a change in currency on inflation. Figure 3 compares the 'treatment' group that switched to the Euro and the 'control' countries that didn't. The restaurant inflation time series for the countries that adopted the Euro are in the panels on the left while the panels on the right depict the time series for non-adopting countries. To a more, i.e. Germany, or lesser, i.e. Italy, extent all the 'treatment' countries exhibit a blip in restaurant price inflation of the same form as the EU12 overall. The 'control' countries do not show such a blip at all.

Table 1 summarizes this striking anomaly for all countries. The table contains the annualized rate of restaurant price inflation in January 2002, denoted by $\pi_{Jan2002}$, the average inflation rate over the period 1995-2003, and its standard deviation over the same period. Comparing the January 2002 inflation rate with its historical average, we find that, except for Greece, the January 2002 inflation rate exceeds the historical average by 3% or more for all EU12 countries. In the three non-adopting countries, this difference is 0.08% or smaller.

The column of the table headed $\frac{\pi_{Jan2002}-\overline{\pi}}{s}$ scales the difference between the January 2002 inflation level and the historical average by the historical standard deviation. For all EU12 countries, except Greece, the January 2002 restaurant price inflation level is 1.74 or more standard deviations higher than its historical average.

We use non-seasonally adjusted data. Therefore, part of the deviation of the January 2002 number from the historical average might simply be due to restaurant inflation generally being higher in January than in other months. To control for this, we present the measure $\frac{\overline{\pi}_{Jan}-\overline{\pi}}{s}$ in the last column of Table 1. This reflects the deviation of the average level of inflation in the month of January from the historical average inflation rate, again in units of standard deviations. Even though average inflation in January comes from the right tail of the distribution in all Countries but Belgium, only in Spain its magnitude is more than two standard deviations. This confirms that the January 2002 observation is clearly anomalous, even once we take into consideration January's seasonal characteristics.

So, now that we have established that inflation in the EU12 restaurant sector behaved anomalously after the introduction of the Euro, we are left with the challenge to come up with a theory to explain this anomaly. It turns out that the introduction of the Euro generates a blip in inflation, as observed in the data, in commonly used models with sticky prices due to menu costs.

3 The introduction of the Euro in sticky price models

Our aim is to show that standard models of sticky prices actually predict a blip in inflation when there is an announced change in the denomination of the currency. Even though we consider a set of models that have been frequently analyzed in the literature, the application of these models here is not standard. For this reason, we use this section to explain the details of the thought experiment that is at the heart of the theoretical part of this paper. Subsequently, we show how this experiment translates in terms of the four price setting models that we consider. These models are: (*i*) a Calvo (1983)-type model, (*ii*) a hybrid of the Calvo (1983) and the Taylor (1980) models, similar to the one implemented by Klenow and Kryvtsov (2003), and (*iii*) a version of the model by Dotsey, King and Wolman (1999), DKW in the following. Finally, (*iv*) we augment DKW to include an endogenous state-dependent decision to adopt the Euro. Throughout the rest of the paper, as well as in Appendix A, we will adhere as much as possible to the notational conventions in DKW.

3.1 Thought experiment

In our analysis, we focus on the following scenario. Suppose the economy is going along nicely on its steady state balanced growth path with a positive rate of inflation. Now, at time 0 the government announces that at time $T > 0$ the denomination of the currency will change. Among other things, this change requires firms to change their posted prices from the old currency to the new one.

In principle, one could analyze this scenario in a general equilibrium setup. Since our focus here is solely on the restaurant sector, we will assume that this sector is relatively small in the overall economy. For our theoretical application, this implies that we will assume that what happens in the sector that we model has no effect on the path of macroeconomic aggregates.

3.2 The model

This path of macroeconomic aggregates is defined as follows. Let aggregate output for the economy be denoted by Y_t, the aggregate price level by P_t, the nominal interest rate by r_t, and nominal wages by W_t. We assume that all along the endogenous equilibrium price path for the small sector that we consider, the aggregate economy moves exogenously along its steady state path. In particular,

$$Y_t = (1+g)^t y,\ P_t = (1+\pi)^t p,\ r_t = r > \pi + g + \pi g, \text{ and } W_t = [(1+g)(1+\pi)]^t w \quad (1)$$

where g denotes the constant growth rate of output along the balanced growth path, $\pi > 0$ is the steady state inflation rate, and r is the steady state nominal interest rate[5].

Within this economy, there is a relatively small sector, which we will denote by the index i. This sector is the theoretical equivalent of the restaurant and café sector in the data. The demand for the output of this sector is given by

$$Y_{it} = \left(\frac{P_{it}}{P_t}\right)^{-\eta} Y_t, \text{ where } \eta > 1 \quad (2)$$

The parameter η is the elasticity of substitution between the output of sector i and that of the other monopolistically competitive secors in the economy. P_{it} is an appropriately defined price index for sector i, which we will discuss in more detail below.

The sector is populated by a continuum of firms, indexed by $k \in [0,1]$, each of which supplies a slightly differentiated good. Each of the firms in the sector faces an individual demand function of the form

$$Y_{ikt} = \left(\frac{P_{ikt}}{P_{it}}\right)^{-\varepsilon} Y_{it} = \left(\frac{P_{ikt}}{P_{it}}\right)^{-\varepsilon} \left(\frac{P_{it}}{P_t}\right)^{-\eta} Y_t, \text{ where } \varepsilon > 1 \quad (3)$$

The CES preferences that underlie these demand functions pin down the appropriate price index as

$$P_{it} = \left[\int_0^1 \left(\frac{1}{P_{ikt}}\right)^{\varepsilon-1} dk\right]^{\frac{1}{1-\varepsilon}} \quad (4)$$

[5] The assumed lower bound on the nominal interest rate is to ensure that the objective function for a representative household with CRRA preferences along the economy's balanced growth path is bounded.

This price index will be essential in our subsequent analysis. This is because it is exactly a blip in the growth rate of P_{it} around period T that we would like to explain.

We will consider four different sticky price models and study how they perform in explaining the observed blip in restaurant and café price inflation in the Euro area in (and around) January 2002. To deal with each of these four models in a coherent manner, we introduce a general framework that nests all four of them.

What makes prices sticky in the four models we consider is that firms in sector i face a (stochastic) fixed cost of adjusting their prices. The magnitude of this cost is drawn independently for each firm in each period. We denote its value in terms of units of labor by ξ_{kt}, where k indexes the firm and t time. Such a fixed cost is generally referred to as a 'menu cost'. There are many different factors that are claimed to make up menu costs. However, for the restaurant sector it seems appropriate to take the term 'menu costs' literally, to mean the costs associated with printing new menus whenever prices need to be changed.

All firms in sector i use a constant returns to scale technology to produce their output and face the same nominal marginal, and thus average, cost of production[6]. We denote their nominal marginal cost by Ψ_t. We assume that its path is determined by markets for factor inputs of which the factor demands of sector i make up a negligible fraction. That is, we assume that Ψ_t is on a balanced growth path, just like the rest of the aggregate economy. In particular, we specify

$$\Psi_t = (1+\pi)^t \psi \tag{5}$$

Given this path of marginal costs, the flow profits of firm k in sector i at time t, that charges a price P_{ikt} in terms of the domestic currency, equal

$$(P_{ikt} - \Psi_t)\, Y_{ikt} - W_t f_t^D \tag{6}$$

Here f_t^D denotes the flow cost of charging prices in the domestic currency at time t. The idea is that, after the introduction period T, there might be a revenue loss whenever the firm still charges its prices in terms of the

[6]Golosov and Lucas (2003) drop the assumption of identical marginal costs. Our main results are robust to this change in assumption, as long as the unanticipated variations in marginal costs (across firms and, most importantly, across time) are relatively small compared to the menu costs in our model.

domestic currency when the Euro has been officially adopted. The parameter f_t^D reflects this loss of revenue in terms of units of labor.

Similarly, the flow profits of a firm that charges P_{ikt} in terms of Euros at time t are given by

$$(P_{ikt} - \Psi_t)\, Y_{ikt} - W_t f_t^E \tag{7}$$

Here f_t^E reflects the loss in revenue due to charging in Euros at time t, denoted in units of the labor input. As before, this cost captures the revenue loss incurred by firms charging in Euros before time T.

Let $V_{0,t}^D$ denote the value of a firm, gross of the adjustment cost, if it adjusts its price at time t and decides to denominate its new price in the 'old' domestic currency. Similarly, let $V_{0,t}^E$ be the value of a firm that adjusts its price at time t and decides to charge its new price in Euros. Let $V_{j,t}^D$ be the value at time t of a firm that set its domestic currency denominated price j periods ago and let $V_{j,t}^E$ be the value of a firm that set its Euro denominated price j periods ago. Let $\Pi_{j,t}^D$ denote the flow profits earned at time t by a firm that adjusted its domestic currency denominated price j periods ago. $\Pi_{j,t}^E$ is similarly defined for firms with a Euro-denominated price.

The value function of a firm adjusting its price at time t in terms of the original currency can be written as follows

$$V_{0,t}^D = \max_{P_{D,t}^*} \left\{ \Pi_{0,t}^D + \frac{1}{1+r} E_t \max \left\{ V_{0,t+1}^D - W_{t+1}\xi_{t+1}, V_{0,t+1}^E - W_{t+1}\xi_{t+1} - W_{t+1}c, V_{1,t+1}^D \right\} \right\} \tag{8}$$

That is, a firm that adjusts its price at time t and sets this adjusted price in terms of the domestic currency will choose its new price level, $P_{D,t}^*$, to maximize the sum of its current flow profits and the expected discounted continuation value.

This continuation value is the expected maximum net value of three options faced by the firm in the next period. The first option is to adjust its price in the next period and pay the menu cost ξ. The second is to adjust its price as well as change to the Euro in the next period and pay both the menu cost ξ as well as the Euro adjustment cost c. The third option is to continue during the next period at the price already set.

Both the menu cost, ξ, and the Euro adoption cost, c, are expressed in units of labor. Our specification of the adjustment costs implies that when a firm decides to adopt the Euro it has to pay both the Euro adoption cost, c, as well as the menu cost, ξ. The decision to adopt the Euro clearly requires to print new menus, generating the usual cost ξ. Moreover, the extra complication of switching to a new currency is likely to make this process more burdensome than usual. This extra burden on price setters is captured by the one time cost c.

In this setting, the only source of heterogeneity across firms is the realized level of the adjustment cost they face, $\xi_{k,t}$. This is what determines whether firms adjust their prices ex-post . However, since the adjustment costs are independent over time and across firms, the firm-specific realization $\xi_{k,t}$ does not affect the firm's value ex-ante. This implies that all firms that change their price and continue to denominate it in the domestic currency will change it to the same level, $P^*_{D,t}$. For this reason, we have dropped the firm index k in the equation above.

A firm that changes its Euro denominated price at time t has the value

$$V^E_{0,t} = \max_{P^*_{E,t}} \left\{ \Pi^E_{0,t} + \frac{1}{1+r} E_t \max \left\{ V^E_{0,t+1} - W_{t+1}\xi_{t+1}, V^E_{1,t+1} \right\} \right\} \tag{9}$$

It again chooses its new price, in this case $P^*_{E,t}$, to maximize the sum of its flow profits plus the discounted value of its expected continuation options.

Since we assume that the switch to the Euro is irreversible, this firm faces one less option in the next period than the firm that is still charging its prices in the domestic currency. Its continuation value is the expected maximum of the net value of only two options. The first is to change the price in period $t+1$, incurring the menu cost ξ. The second is to stay put and continue at the set price.

Finally, a firm that does not adjust its price and still charges in terms of its domestic currency has value

$$V^D_{j,t} = \Pi^D_{j,t} + \frac{1}{1+r} E_t \max \left\{ V^D_{0,t+1} - W_{t+1}\xi_{t+1}, V^E_{0,t+1} - W_{t+1}\xi_{t+1} - W_{t+1}c, V^D_{j+1,t+1} \right\} \tag{10}$$

Similarly, a firm that set its price in Euros j periods ago has value at time t equal to

$$V^E_{j,t} = \Pi^E_{j,t} + \frac{1}{1+r} E_t \max \left\{ V^E_{0,t+1} - W_{t+1}\xi_{t+1}, V^E_{j+1,t+1} \right\} \tag{11}$$

Again, because of the irreversibility of the switch to the Euro, the option of charging in the old domestic currency does not appear in the continuation value.

The adjustment cost ξ is drawn independently over time and across firms from a distribution with cdf $G(\xi)$. We will consider two parametrizations of this distribution. The first generates the price setting model introduced by Calvo (1983) as well as the hybrid of Calvo (1983) and Taylor (1980) studied by Klenow and Kryvtsov (2003)

$$G_{1,t}(\xi) = \begin{cases} 0 & \text{for} \quad \xi < 0 \\ \alpha & \text{for} \quad 0 \leq \xi < \overline{\xi}_t \\ 1 & \text{for} \quad \overline{\xi}_t \leq \xi \end{cases} \tag{12}$$

If $\overline{\xi}_t \to \infty$, firms only adjust their prices when they face no adjustment cost. This happens with probability α, irrespective of what price they are currently charging. Because the probability of adjusting is independent of the price currently charged, this is known as a time-dependent price adjustment rule. If $\overline{\xi}_t < \infty$, firms adjust their price when they face no adjustment cost or whenever the benefit of adjusting their price outweighs the adjustment cost $\overline{\xi}_t$. This depends on the price that the firm is currently charging, and on other macroeconomic conditions. Because of this dependence, this is known as a state-dependent price adjustment rule.

The second distribution that we consider is the one proposed by DKW. It is given by

$$G_{2,t}\left(\xi; \overline{\xi}_t, \gamma_1, \gamma_2, \gamma_3, \gamma_4\right) = \begin{cases} 0 & \text{for} \quad \xi < 0 \\ \gamma_{1t} + \gamma_{2t}\tan\left(\gamma_{3t}\xi + \gamma_{4t}\right) & \text{for} \quad 0 \leq \xi < \overline{\xi}_t \\ 1 & \text{for} \quad \overline{\xi}_t \leq \widetilde{\xi} \end{cases} \tag{13}$$

However, for reasons explained in Appendix A, we reparametrize $G_{2,t}$ in terms of $\overline{\xi}_t$, $\overline{\phi}$, and $\underline{\phi}$ as

$$\begin{aligned} \gamma_{1t} &= -\gamma_{2t}\tan\left(\left(\underline{\phi} - 0.5\right)\pi\right) & (14) \\ \gamma_{2t} &= 1/\left[\tan\left(\left(\overline{\phi} - 0.5\right)\pi\right) + \tan\left(\left(\underline{\phi} - 0.5\right)\pi\right)\right] & (15) \\ \gamma_{3t} &= \left(\overline{\phi} - \underline{\phi}\right)\pi/\overline{\xi}_t & (16) \\ \gamma_{4t} &= \left(\underline{\phi} - 0.5\right)\pi & (17) \end{aligned}$$

where $0 < \overline{\phi} < \underline{\phi} < 1$. Appendix A also shows how $G_{1,t}(.)$ can be interpreted as a limiting case of $G_{2,t}(.)$[7].

[7] Klenow and Kryvtsov (2003) show that, in the neighborhood of the steady state, the

In summary, the dimensions along which our four models differ are (i) the distribution of menu costs, including its evolution over time, and (ii) the existence of adjustment costs due to changing the denomination of prices, c, and of fixed costs due to charging prices in a particular denomination, f_t^D and f_t^E. Table 2 lists the assumptions that underlie the four models.

The first three models are sticky price models that have previously been considered in the literature. The first has a menu cost distribution that generates a price setting schedule as in Calvo (1983). In the second model the menu costs generate a hybrid Calvo-Taylor price setting schedule[8]. The third model is based on the menu cost distribution used by DKW. These three models share the assumption that the adoption of the Euro is triggered by an anticipated change in the menu cost distribution at time T. In particular, we assume that the firms do not face any menu costs at time T. This can be interpreted as the firms incurring an unavoidable fixed cost for changing to the Euro, which for once also allows them to change their prices for free. In these three models we essentially exogenously impose that all firms adjust to the Euro at time T.[9]

The fourth model is different from the first three in the sense that it endogenizes the timing of the adjustment to the Euro. In this model, the menu cost distribution is constant over time and it is the structure of the fixed costs, f_t^D and f_t^E, associated with charging prices in different denominations and of the adjustment cost, c, that determine whether firms switch to the Euro and when.

DKW model with a calibration of $G_{2,t}(.)$ close to the limiting case behaves essentially like the Calvo (1983) model. This calibration results from the observation that, in the U.S., the frequency of price adjustment for particular goods is almost constant over time and across firms and does not seem to depend on the level of inflation firms face.

[8]We define the Calvo-Taylor hybrid model in terms of a state-dependent, rather than a time-dependent, price setting rule. Klenow and Kryvtsov (2003) show that this distinction does not matter much around the steady state. As we show later, this distinction does matter in our off steady state analysis.

[9]We chose to make all firms adopt the Euro at time T by assuming that $\overline{\xi}_T = 0$. This assumption, as well as the results that follow, is equivalent to assuming that $f_t^D = \infty$ for $t \geq T$ and $f^E = \infty$ for $t < T$.

4 Equilibrium inflation dynamics

So, what happens to the path of inflation in the restaurant sector in response to the announcement of the introduction of the Euro? In this section we explain the three basic mechanisms that determine the transitional equilibrium path of inflation, which we refer to as (*i*) distributional churning, (*ii*) the horizon effect, and (*iii*) strategic complementarity. Here, we limit ourselves to the intuitive illustration of these concepts and of the way in which they influence the evolution of prices in equilibrium. Most of the analytical details are left for Appendix A.

The equilibrium dynamics for sector i after the announcement of the introduction of the Euro are determined by three important factors: (*i*) how many firms in each period update their prices, (*ii*) what fraction of firms chooses to change denomination, and (*iii*) at what rate these firms raise their prices.

The path of prices in sector i reflects the evolution of two classes of equilibrium objects. First, we have the optimal prices set by reoptimizing firms. We already showed that there are only two of these prices, $P^*_{D,t}$ and $P^*_{E,t}$ respectively. They are the same for all firms that update their price at time t and choose the same denomination, either D, for the domestic currency, or E, for the Euro. The second equilibrium variable is the distribution of firms over the relevant state space. At each point in time, the two factors that distinguish firms and are relevant for their price setting behavior are (*i*) how long ago they changed their price, indexed by j, and (*ii*) in what denomination they are charging their price, denoted by $S \in \{D, E\}$. As in DKW, we denote the fraction of firms in period t that changed their price j periods ago and that charge their price in denomination S as $\omega^S_{j,t}$.

How many firms in each period update their price and change denomination determines the behavior of this distribution over time. In order to capture its dynamics, we consider the joint price adjustment and denomination choice probabilities. They are given by $\alpha^{S'}_{j,t}$ for $S' \in \{C, D, E\}$, where C stands for change. Here, $\alpha^{S'}_{j,t}$ for $S' \in \{D, E\}$ denotes the fraction of firms charging a price set j periods ago in denomination S', which change their price at time t but still charge in the same denomination. Then $\alpha^C_{j,t}$ denotes the fraction of firms charging a price set j periods ago in the domestic currency, which change their price at time t *and* switch to the Euro.

Given these definitions, we can write the dynamics of $\omega^S_{j,t}$ in terms of the following identities

$$\begin{aligned}
\omega_{0,t}^{E} &= \sum_{j=1}^{\infty}\left(\alpha_{j,t}^{E}\omega_{j-1,t-1}^{E}+\alpha_{j,t}^{C}\omega_{j-1,t-1}^{D}\right) && (18)\\
\omega_{0,t}^{D} &= \sum_{j=1}^{\infty}\alpha_{j,t}^{D}\omega_{j-1,t-1}^{D} && (19)\\
\omega_{j,t}^{E} &= \left(1-\alpha_{j,t}^{E}\right)\omega_{j-1,t-1}^{E} && (20)\\
\omega_{j,t}^{D} &= \left(1-\alpha_{j,t}^{D}-\alpha_{j,t}^{C}\right)\omega_{j-1,t-1}^{D} && (21)
\end{aligned}$$

In equilibrium, the set of different prices charged is countable. This implies that the integral in equation (4), which determines the price level, P_{it}, simplifies to a summation. Hence, the equilibrium price level is determined by

$$P_{it}=\left[\sum_{S\in\{D,E\}}\sum_{j=0}^{\infty}\omega_{j,t}^{S}\left(\frac{1}{P_{S,t-j}^{*}}\right)^{\varepsilon-1}\right]^{\frac{1}{1-\varepsilon}} \tag{22}$$

which shows how the overall price level depends on the distribution of prices charged across firms.

This equation highlights the two basic factors that determine the path of P_{it}, (i) the distribution of firms over price vintages, $\left\{\omega_{j,t}^{S}\right\}_{j}$ and (ii) the prices charged by each vintage $\left\{P_{S,t-j}^{*}\right\}_{j}$.

In Appendix A, we solve for the prices that the firms choose when they adjust them. Just like in Calvo (1983) and DKW (1999), the optimal price setting policy for firms in this economy is to set their prices equal to a markup times a weighted average of current and future levels of their marginal costs. Mathematically, this implies that firms choose

$$P_{S,t}^{*}=\frac{\varepsilon}{\varepsilon-1}\sum_{j=0}^{\infty}\Omega_{j,t}^{S}\Psi_{t+j}=\frac{\varepsilon}{\varepsilon-1}\Psi_{t}\sum_{j=0}^{\infty}\Omega_{j,t}^{S}\left(1+\pi\right)^{j}\text{ for }S\in\{D,E\} \tag{23}$$

where $\varepsilon/\left(\varepsilon-1\right)>1$ is the markup term and the weights $\Omega_{j,t}^{S}$ sum to one across j's. As shown in the appendix, the weights $\Omega_{j,t}^{S}$ depend on three things.

The first is the discount factor $\lambda=\left(1+g\right)\left(1+\pi\right)/\left(1+r\right)<1$. The lower the discount factor, the less the firm cares about future profits relative to current profits. This reduces the degree to which the firm takes into account future marginal costs in setting the current price. That is, $\Omega_{j,t}^{S}$ is increasing in λ.

Second, $\Omega_{j,t}^{S}$ depends on the probability of not having adjusted the price j periods after time t. The intuition is fairly straightforward. Under flexible prices, the firm always chooses its price to equal the markup times the current level of marginal cost. However, when it is not sure when it will adjust its prices again, the firm not only takes into account current marginal costs, but also the marginal cost levels that it is likely to face before adjusting its price again. The more likely it is to face a particular marginal cost level, the more weight this gets in the price setting policy. When a firm adjusts its price at time t, the likelihood of facing a marginal cost level of Ψ_{t+j} before adjusting its price again is determined by the probability of not having adjusted the price j periods after time t.

The final factor affecting the weights $\Omega_{j,t}^{S}$ is the effect of the sector's price level on the demand for a firm's good. As long as a firm does not adjust its price, its price will drop relative to the sector's price level P_{it}. The effect of the level of P_{it} on the demand for firm k is given by the demand function

$$Y_{ikt} = P_{ikt}^{-\varepsilon} P_{it}^{\varepsilon-\eta} P_t^{\eta} Y_t \tag{24}$$

Hence, whenever the within sector price elasticity of demand, ε, is bigger than the price elasticity of demand for the sector as a whole, η, an increase in the sectorial price level P_{it} will increase the marginal revenue of firm k. In that case, if all other firms charge a higher price, contributing to an increase in P_{it}, firm k will want to charge a higher price as well. Because an individual firm's best price setting response is increasing in the prices set by the other firms, this is a strategic complementarity in the sense of Cooper and John (1988).

Three basic mechanisms affect the path of P_{it} in sector i after the announcement of the introduction of the Euro. They are (i) distributional churning, (ii) the horizon effect, and (iii) strategic complementarity. In our version of the model, the first two account for the bulk of the quantitative effect of the Euro on inflation in the restaurant sector. In the rest of this section we discuss each of these effects in turn and how they relate to the equilibrium variables described above.

Distributional churning On the balanced growth path that the sector is on before the announcement of the introduction of the Euro, a constant fraction of firms update their price in each period. Klenow and Kryvtsov (2003) find that this is approximately the case for most sectors in the U.S..

The Euro, however, causes an anticipated deviation from this pattern. It induces all the firms to change their prices within a short time period around the time the Euro is introduced. Hence, when the Euro is introduced, the distribution of prices, ω_{jt}, shifts towards prices that have been set relatively recently. That is, most of the mass of this distribution will be at $j = 0$. In fact, in models (i) through (iii), in which we assume that all firms update their price at time T, all the mass will be at $j = 0$ at time T by assumption. This churning of the distribution of prices charged has two effects on the level of inflation. First of all, it leads to higher inflation at, or around, time T. This is because in that period a disproportionate number of firms are raising their prices. The second effect is that, after the adoption of the Euro, the distribution of prices has a relatively small variance, so that firms adjusting their price in the subsequent periods will not raise it as much as they did in the steady state. This leads to a reduction in inflation after time T. This is illustrated in the bottom panel of Figure 5, which depicts the price adjustments in the steady state relative to those s^* periods after T. At time $T + s^*$, the distribution of firms over how long ago they last adjusted prices is truncated at s^*, resulting in smaller average price increases for firms that change their prices.

Horizon effect As we noted above, the weights with which future increases in marginal costs are reflected in prices set in period t, $\Omega^S_{j,t}$, are decreasing in the probability of the firm adjusting its price before $t + j$. The introduction of the Euro implies that firms charging their price in the domestic currency will certainly change their price on, or around, time T.

Consequently, prices set before firms adjust to the Euro do not take into account increases in the marginal costs after the adoption of the new currency. Once a firm adopts the Euro, its price adjustment horizon expands and its new price reflects the increases in marginal costs over a much longer horizon than before. This effect is illustrated in the top panel of Figure 5. The thick line in the top half of the figure reflects the path of future increases in marginal costs. The bottom of the figure contains two weighting schemes. The first reflects the steady state weights of future marginal cost increases that firms apply when the economy is on its balanced growth path. The second is the truncated sequence of weights that firms use when they set their prices s^* periods before the introduction of the Euro in models (i) through (iii). In model (iv) these weights are not necessarily truncated but will decline rapidly around s^*, depending on the speed of adoption of the Euro.

The result of this horizon effect is that the prices set by Euro adopters reflect future marginal cost increases that were not incorporated in the prices they previously charged in the domestic currency. This implies that these firms will increase their prices at a much higher rate than their counterparts that stick to charging their prices in the old currency. Note that this effect only occurs whenever marginal costs are expected to increase in the future. That is, the assumption that steady state inflation is positive, i.e. $\pi > 0$, is crucial for our argument.

Strategic complementarity When $\varepsilon > \eta$, strategic complementarity magnifies the two effects described above. The fact that other firms increase their prices when the Euro is introduced increases each individual firm's incentive to raise its price even more. Our numerical results, presented in the next section, suggest however that this mechanism is quantitatively not very important.

Hence, the two most important mechanisms governing the equilibrium behavior of prices in sector i are the distributional churning and the horizon effect. The former increases the fraction of firms that adjust their prices at time T. The latter increases the level of the prices set at the time of adoption. As shown in the next section, both are important contributors to the blip in inflation.

5 How does the model compare to the data?

In this section, we compare the implications of the introduction of the Euro in our four models for equilibrium inflation in sector i with the facts observed for restaurant price inflation in the Euro area. This is done by choosing values for the model's parameters based on historical and cross-sectional evidence. Given these parameter values, we then consider whether our models imply a path of inflation in a four year window around time T that is similar to that observed in the data around January 2002.

This section has four parts. In the first, we describe the choice of the parameters common to the four models. In the second part, we present the inflation path implied by the Calvo model, i.e. model (i). We use this model to illustrate the working of the 'horizon effect' and of the 'distributional churning'. We also show that commonly assumed degrees of price stickiness generate an inflation blip in this model that by far exceeds the one observed in the data. In the third part, we show how the changes in the menu cost distribution that produce the Calvo-Taylor hybrid and DKW models are associated with a reduction in the size of the inflation flare. This reduction however is still short of what is needed to match our empirical observation. Finally, in the fourth part, we show how dropping the assumption that all firms adopt the Euro exactly at time T, and allowing them instead to choose when to adopt, reduces the size of the blip to a level very close to that observed in the Euro area. That is, the state-dependent choice of both the price setting as well as the Euro adoption decisions are crucial to fitting the observed facts.

5.1 Choice of model parameters

The parameters common to all four models are those related to (i) the long-run balanced growth path and to (ii) the shape of the demand curves.

We set the parameters related to the long-run balanced growth path of the economy based on evidence for the Euro area for the period 1995-2003, obtained from Eurostat. We choose $r = 5.9\%$ (annual rate), which equals the average long term interest rate paid in the secondary market for government bonds with an average yield of 12 months. For inflation, we use $\pi = 2.8\%$ (annual rate), which is the average Euro area HICP restaurant and café price inflation over the sample period. Finally, for the growth rate of the economy, we take $g = 2.0\%$. This corresponds to the average growth rate of real GDP for the Euro area over the 1995-2003 period.

We normalize the parameters $y = w = \psi = 1$. They do not matter for the equilibrium price path in our model. This normalization does, however, affect our interpretation of c, f_t^D, f_t^E, and $\overline{\xi}$. For this reason, we present our results in the rest of the paper in terms of the menu costs and adjustment costs to the Euro as a percentage of total revenue under flexible prices.

Calibration of the demand parameters ε and η is a bit less straightforward. Fortunately, our results are not very sensitive to changes in their magnitudes. We choose $\varepsilon = 11$ as a benchmark for the within sector price elasticity, which corresponds to a 10% net markup in the flexible price equilibrium. This is a common choice in the empirical literature on the New-Keynesian Phillips

Curve (see for example Galí, Gertler, and López-Salido, 2001). Calibration of the elasticity of the relative demand for goods of different sector, η, is rather hard. However, it is reasonable to assume that goods within each category are closer substitutes than between categories. This would imply $\varepsilon \geq \eta$. Quite arbitrarily, we will focus here on the corner case $\eta = \varepsilon$. This is also the case in which there is no strategic complementarity. Our results however are relatively insensitive to a choice of $\varepsilon > \eta$. In other words, strategic complementarities are quantitatively unimportant for our application.

5.2 The Calvo-model benchmark

Both as a benchmark as well as a tool to illustrate the basic mechanisms driving equilibrium inflation in this model, it is worthwhile to start by considering the equilibrium path of inflation in the Calvo model. To do so, we need to choose a value of the price adjustment probability, i.e. α.

Our benchmark case is the one in which 75% of the restaurants adjust their price at least once a year. This calibration implies that, in each quarter, approximately 70% of the restaurants do not change their price, which is in line with the aggregate Phillips Curve estimates for the Euro area presented in Gali, Gertler, and López-Salido (2001). It also implies that in each month $\alpha = 11\%$ of the restaurants adjust their prices. This closely matches the observation by Bils and Klenow (2002) that, in an average month in the U.S., 9% of the prices of dinners and lunches consumed away from home change. This matched fact is included as fact 1 in Table 3, which contains all the facts that we use to calibrate our "stickyness" parameters.

Figure 6 depicts the actual annualized Euro area restaurant price inflation as well as the path implied by the Calvo model for the four years from January 2000 through December 2003. The equilibrium path of inflation in the Calvo model shows a slight decline before January 2002. This is the result of the horizon effect. That is, firms that change their price shortly before the introduction of the Euro only incorporate the increases in marginal cost into their price that occur before the Euro is introduced. This shortens the horizon of marginal cost increases included in the prices and consequently reduces the price increases and the inflation rate. After January 2002, the model predicts an even bigger decline which is completely due to distributional churning. In fact, the predicted annualized restaurant price inflation rate in February 2002 is below 0.5%, while the actual rate was 5.2%.

The predicted reduction in inflation after January 2002 is not the biggest shortcoming of the Calvo model, however. The calibrated degree of price rigidity generates a blip in inflation in January 2002 much higher than observed in the data. The model produces a rate of inflation in January 2002 of 61.3%, as compared with the 15.6% observed in the data. The degree of price rigidity in the model that would result in an inflation blip of 15.6% is one in which 98.5% of the restaurants adjust their prices at least once in a year. This is equivalent to a quarter of the restaurants changing their prices each month, which would imply that prices are much less sticky than suggested by the available evidence.

Why does the Calvo model generate an inflation blip much higher than the one observed in the data? The main reason is the assumption that a positive fraction of firms have not adjusted their prices for an arbitrarily long period. That is, $\omega_{j,t} > 0$ for all t and $j > 0$ and thus also for j arbitrarily large. In terms of restaurants, this implies that when the Euro is introduced in January 2002, there are pizzas still being sold at prices set in 1902! Those pizzerias that have not been able to set their price for a century end up changing their prices at time T, along with everybody else, and increase them by a very high percentage. The smaller α, the higher the fraction of this type of restaurants and the higher the inflation spike.

In traditional analysis of the Calvo model, and of most sticky price models, this assumption is not very important. This is because they are based on a log-linear approximation around a non inflationary steady state, in which the distribution of firms over price vintages never changes. In this experiment, on the contrary, the introduction of the Euro is modeled as an exogenous variation in the timing of price setting, which results in a reshuffling of the distribution of firms. In normal circumstances (i.e. in the ergodic state), only a fraction α of the pizzerias with 1902 prices would reset their price every period. Moreover, with zero average inflation, their very old price would be still fairly close to their current desired price. In our world instead, all the pizzerias, including those with very old prices, are given the chance to reset them at time T. This, together with the fact that a positive average inflation makes their 1902 price a very small fraction of their current desired price, is behind the blip in inflation produced by the model. The peculiarity of our experiment, which involves a "big" deviation from steady state, and non trivial transitional dynamics in the distribution of firms, also explains why we could not rely on the usual log-linearization approach, and opted instead to solve for the exact dynamics of inflation.

5.3 Calvo-Taylor hybrid and DKW model

The Calvo-Taylor hybrid model, our model (*ii*), assumes that, in any period, the maximum amount of time a firm has had its prices fixed is finite. That is, at any point in time the distribution $\omega_{j,t}$ is truncated in the sense that there exists a J_t such that $\omega_{j,t} = 0$ for all $j > J_t$. Such a truncation implies that in this model there will not be any pizzerias finally resetting their prices after a century. Because of this, the Calvo-Taylor hybrid model will tend to generate a smaller blip in inflation than the Calvo model.

Implementing the hybrid model requires the choice of two parameters. The first is the probability of facing no menu costs, α, and the second is the size of the maximum menu cost, denoted by$\overline{\xi}$.

For the maximum menu cost level, $\overline{\xi}$, we follow DKW. They choose $\overline{\xi}$ to equal 3.75% of the flexible price steady state labor supply. At their calibrated labor share of 2/3, this implies that the maximum menu cost incurred is 2.5% of flexible price steady state revenue. We replicate this calibration in our model.[10]. This is listed as matched fact 2 in Table 3. Given $\overline{\xi}$, the adjustment probability α is again chosen to match the first fact of the table, that. in steady state 11% of restaurants change their prices each month.

Figure 7 depicts the equilibrium path of inflation in the Calvo-Taylor hybrid model. As can be seen from the figure, the truncation of the distribution of the firms across the state space, the time since the last price adjustment, does reduce the implied inflation blip on January 2002 by about half. Inflation drops from 61.3% for the Calvo model to 32.6% for the Calvo-Taylor hybrid. However, this 32.6% is still two times as high as the inflation number actually observed.

Furthermore, the Calvo-Taylor hybrid model implies some counterfactual inflation echoes in response to the introduction of the Euro. For this particular calibration, these echoes occur once every 18 months. They are evident in Figure 7 in terms of the 13.4% annualized price increase in July 2003. That is, the inflation echo implied by the model is almost as big as the actual blip in inflation observed on January 2002, but no other spikes of comparable magnitude are apparent in the data.

The problem with the hybrid model is that to reduce the echoes one has

[10] Our model is calibrated at a monthly frequency, rather than at the quarterly frequency used by DKW. Hence, even though we use a similar calibration strategy, the maximum menu costs as a percentage of quarterly revenue in our calibration are only 1/3 of those in DKW.

to choose a large $\overline{\xi}$. In the limit, when $\overline{\xi} \to \infty$, the Calvo-Taylor hybrid model is equivalent to the Calvo model, which does not have any echoes. However, such a reduction in echoes due to an increase in $\overline{\xi}$ would increase the implied inflation blip in January 2002. On the other hand, to match that inflation observation, one has to reduce $\overline{\xi}$, which in turn increases the echoes. Either way, the model has clearly counterfactual implications.

There are, in principle, many ways to get rid of the implied echoes in sticky price models due to menu costs. One approach is to add more noise by adding a dimension to the state space. This is the approach taken by Golosov and Lucas (2003), who add to their model heterogenous levels of marginal costs across firms. Here, we will keep the state space the same and instead spread the probability mass of the menu cost distribution over the interval $\left(0, \overline{\xi}\right)$ by using a menu cost distribution of the form $G_{2,t}$, as in DKW. Relative to the first two models, this distribution requires the calibration of an additional parameter, i.e. both $0 < \underline{\phi} < \overline{\phi} < 1$ rather than only α.

Unfortunately, calibrating these parameters based on empirical facts is fairly challenging. For this reason we experimented with several values of $\underline{\phi}$, choosing $\overline{\phi}$ and $\overline{\xi}$ to match facts 1 and 2 of Table 3, the same we had matched with the hybrid model. Since we did not pin down $\underline{\phi}$ using any outside facts, we list it as a free parameter in the sixth row of Table 3. In practice, however, the results for $\underline{\phi} = 0.25$, 0.5, and 0.75 are virtually indistinguishable. For this reason, we will focus on $\underline{\phi} = 0.5$.

This result is depicted as 'DKW' in Figure 7. As can be seen from the figure, adding probability mass to $\left(0, \overline{\xi}\right)$ does smooth out the echo effects. It does not, however, resolve the issue that models (*i*), (*ii*), and (*iii*) all imply much too high a blip in inflation in January 2002.

5.4 Endogenous adoption of the Euro

In all three model simulations above, we assumed that 100% of the firms adopt the Euro in January 2002. Survey evidence, in Gallup Europe (2002), however, suggests that this was not the case in practice. When asked, in February 2002,

> 'At what time did or will your company pass on totally to the euro when it comes to ... its prices?'

49.2% of the firms surveyed answered 'in the course of January 2002', another 29.2% claimed they would adjust in that February, while the other 21.6% of the firms said it would be March 2002 or later.

This suggests that more than half of the firms delayed their switch to the Euro to beyond January 2002. Thus, the assumption of all firms switching in that January, on which the previous simulation results are based, grossly overstates the fraction of firms adjusting their prices in the month the Euro was introduced. This overstatement implies an overestimation of the blip in the models presented so far.

Hence, to compare the implications of the sticky price model with the data it is crucial to incorporate a state-dependent decision on the adoption of the Euro as well. This is the extension included in the augmented version of DKW, model (*iv*).

Implementation of this model requires calibrating the three parameters related to the adoption costs of the Euro. The first is the per period operating cost of adopting the Euro before January 2002, i.e. f^E. We choose f^E to be so large that none of the firms will adopt the Euro before January 2002, fact 5 in Table 3. This is consistent with the simple observation that Euro coins and bills were simply not available before that January. The second fact, listed as fact 4 in the same table, is taken from Centraal Plan Bureau (2002). It reports that Euro adoption costs were about 7.5% of average monthly revenue for the Dutch restaurant and café sector[11]. We therefore calibrate c so that in our model Euro adoption costs are 7.5% of steady state flexible price monthly revenue. Finally, we calibrate f^D, the monthly operating cost for charging in the domestic currency after the Euro has been introduced, to match a 50% January 2002 adoption rate. This is in line with the 49.2% found in the survey by Gallup Europe (2002).

For the calibration of the menu cost distribution parameters, we take the same approach here as we did for the original DKW model. We choose them to match fact 1 from Table 3 and consider the sensitivity of our results for the choice of the free parameter $\underline{\phi}$. Just like in the original DKW model, the results are very similar for $\underline{\phi} = 0.25$, 0.5, and 0.75. Again, we will only present the ones for $\underline{\phi} = 0.5$.

The resulting equilibrium path of restaurant price inflation is plotted in Figure 8. At 13.0%, the simulated inflation blip is remarkably close to the 15.6% observed in the data. Besides doing a fairly good job at generating a reasonable inflation blip, the delayed adoption in the model also implies that there is above average inflation in the months following the introduction of

[11]The Dutch term for this sector is actually HoReCa: Hotels, Restaurants, and Cafés.

the Euro. The model generates annualized restaurant price inflation levels of 7.4% and 4.1% in February and March of 2002, while the observed levels were 5.2% and 6.2% respectively. Hence, besides generating a blip of a size comparable to that in the data, the model also matches the persistently high restaurant price inflation during the first quarter of 2002. The persistence seems to be a bit higher in the data than generated by the model, however.

Besides the path of inflation, the equilibrium of the augmented DKW model also determines the path of the fraction of firms that have adopted the Euro as well as the fraction of restaurants that adjust their price in each month.

Figure 9 depicts the implied path of the share of firms that have adopted the Euro in the months following January 2002. It also contains the two observations on this path that are reported by Gallup Europe (2002), namely those for January and February. We matched the January observation to calibrate our parameters. Beyond this matched observation, the model implies an adoption path close to the one in the data for the month of February. The observed adoption share in February 2002 is 78.4. The model predicts this to be 75.7%. The model also implies that it will take until June 2002 for 99% of the firms to adopt the Euro and only in December 2002 will full adoption be accomplished. Although we know of no formal evidence, this is probably a slightly slower adoption than what actually occurred.

Finally, Figure 10 shows the fraction of firms that change their prices in each month. Bear in mind that, in the absence of the introduction of the Euro, this fraction would be constant at 11%. Three phases in the evolution of this fraction are evident from the figure. The first is the decline in the fraction of firms that adjust their prices before January 2002. This decline is caused by the horizon effect. That is, the anticipated price change occurring at the time of the switch makes price changes right before less valuable, inducing firms to forego them more often than in steady state. The second phase occurs in January 2002 and the months right after, when the adoption of the Euro causes 99% of the firms to adjust their prices at least once in a span of 6 months. In steady state this would only be 50%. The final phase is the drop in price adjustments induced by the distributional churning. In Figure 10, this drop lasts from April through September 2002.

In conclusion, for reasonable parameter values, the augmented DKW model closely replicates the response of Euro area restaurant price inflation to the introduction of the Euro in January 2002. The state-dependent choices of both the timing of price changes as well as the adoption of the

Euro are an integral part of the model's ability to replicate the facts. This is because the blip in inflation is due to changes in the timing of price adjustments relative to steady state. Such changes cannot be captured by models with time dependent pricing rules. Hence, contrary to Klenow and Kryvtsov (2003), who find that, around the steady state, state dependence versus time dependence does not matter quantitatively, we obtain that for understanding the influence of price stickiness on inflation when the currency is changed this distinction is essential.

Our sticky price model seems to fit the behavior of Euro area restaurant price inflation very well. This begs the question of why other sectors of the Euro area economy did not observe a price increase similar to that of restaurants and cafés. This is probably in large part due to the fact that prices in other sectors tend to be more flexible than those in restaurants and cafés. Evidence in Bils and Klenow (2002) and van Els et. al. (2002) suggests that restaurant prices are among the most sticky prices on both sides of the Atlantic.

6 Conclusion

The increase in restaurant prices in the Euro area right after the introduction of the Euro in January 2002 was unprecedented according to any recent historical standard. Countries like the Netherlands, Germany, and Finland, all registered annualized monthly price increases in their restaurant sectors in January 2002 higher than 20%.

In this paper we showed that, even though these price increases were unprecedented, they should not have been unexpected. We introduced a model with sticky prices and an endogenous decision to adopt the Euro and showed how, for realistic parameter values, it generates such a blip in inflation when the denomination of prices is changed. Because our model relies on the concept of menu costs, it seems especially applicable to restaurants and cafés.

Two main effects are responsible for the blip in inflation generated by the model.

The first, which we call 'distributional churning', makes all firms raise their prices in, or around, the period in which the Euro is introduced. Hence, the introduction of the Euro leads to a disproportionate number of firms raising their prices and thus to higher inflation.

Secondly, these firms also raise their prices at a higher rate than in the absence of the new currency. This result, which we call the 'horizon effect', is due to the optimal price setting policy implied by the sticky price model we consider. Since firms know that they will have the opportunity to adjust their prices when they switch to the Euro, the prices that they set before that time do not reflect the increases in marginal costs expected to occur after the adoption date. As soon as they adopt however, their new price will reflect these future cost increases. This change in the horizon of future marginal cost increases incorporated in the prices before and after the Euro implies that the adopters raise their prices at a higher rate than those which continue to charge prices in the old domestic currency.

Because our explanation is based on commonly used stick price models, we do not have to rely on more unconventional assumptions of collusion, multiple equilibria, or pricing points. Instead, our explanation is simply based on intertemporal optimization, where prices at different points in time reflect different weighted averages of future increases in marginal costs.

The results in this paper have important policy implications. They show that the adoption of a new currency is not necessarily neutral in a monetary sense. In fact, in economies with relatively sticky prices and high inflation rates, a change in the denomination of the currency might actually have significant inflationary effects. Such effects can be alleviated, however, by allowing for a broader window within which firms can adopt the new currency.

The model presented here is a partial equilibrium framework. Considering the effects on the overall economy would require adding the change in currency denomination to a general equilibrium model. We leave this task to future research.

References

[1] Adriani, Fabrizio, Giancarlo Marini, and Pasquale Scaramozzino (2003), "The Inflationary Consequences of a Currency Changeover: Evidence from the Michelin Red Guide", *CEIS Tor Vergata - Research Paper Series*, 9.

[2] Mark Bils, and Peter J. Klenow (2004), "Some Evidence on the Importance of Sticky Prices", *Journal of Political Economy*, forthcoming October 2004.

[3] Calvo, Guillermo A. (1983), "Staggered Prices in a Utility-Maximizing Framework", *Journal of Monetary Economics*, 12, 383-398.

[4] Centraal Plan Bureau, "Prijsstijgingen in de Horeca", *CPB notitie*, Centraal Plan Bureau, 10 September 2002.

[5] Clarida, Richard, Jordi Gali, and Mark Gertler (2000), "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory", *Quarterly Journal of Economics*,115, 147-180.

[6] Cooper, Russell, and Andrew John, (1988), "Coordinating Coordination Failures in Keynesian Models", *Quarterly Journal of Economics*, 103, 441-463.

[7] Diewert, W. Erwin, "Harmonized Indexes of Consumer Prices: Their Conceptual Foundations" (March 2002). *ECB Working Paper No. 130.*

[8] Els, P.J.A. van, C.K. Folkertsma, and A.C.J. Stokman (2001), "De Invloed van de Euroconversie op de Prijzen. Deel II: Een Empirische Verkenning voor Nederland", *Onderzoeksrapport WO&E nr 662/0117*, De Nederlandsche Bank N.V..

[9] Commission of the European Communities (2001), "Second Report on the Preparations for the Introduction of Euro Notes and Coins", *Commission Communication to the European Council, ECFIN/532/01-EN*, 10 October 2001.

[10] Deutsche Bundesbank (2004),"The Euro and Prices Two Years On", *Monthly Report,* Deutsche Bundesbank, January 2004.

[11] Dotsey, Michael, Robert G. King, and Alexander L. Wolman (1999), “State-Dependent Pricing and the General Equilibrium Dynamics of Money and Output”, *Quarterly Journal of Economics*, 114, 655-690.

[12] Gali, Jordi, Mark Gertler, and David López-Salido (2001), “European Inflation Dynamics”, *European Economic Review*, 45, 1237-1270.

[13] Gallup Europe (2002), “SMEs and the Euro”, *Flash EFS 122*.

[14] Golosov, Mikhail, and Robert E. Lucas, (2003), ”Menu Costs and Phillips Curves”, *NBER Working Paper No. 10187*.

[15] Greenwood, Jeremy, and Yorukoglu, Mehmet (1997), “1974.” *Carnegie-Rochester Conference Series on Public Policy,* 46, 49-95.

[16] King, Robert G. (2000), ”The New IS-LM Model: Language, Logic, and Limits”, *Federal Reserve Bank of Richmond Economic Quarterly*, 86, 45-103.

[17] Klenow, Peter J., and Oleksiy Kryvtsov (2003), “State Dependent or Time-Dependent Pricing: Does It Matter for Recent U.S. Inflation?”, working paper.

[18] Lünneman, Patrick, and Thomas Y. Mathä (2004), “How Persistent is Disaggregate Inflation? An Analysis Across EU15 Countries and HICP Sub-Indices”, *mimeo.*

[19] Sbordone, Argia (2002), “Prices and Unit Labor Costs: A New Test of Price Stickiness”, *Journal of Monetary Economics*, 49(2), 265-292.

[20] Taylor, John (1980), “Aggregate Dynamics and Staggered Contracts”, *Journal of Political Economy*, 88, 1-24.

[21] Micheal Woodford, “Interest and Prices: Foundations of a Theory of Monetary Policy”, *Princeton University Press*, 2003.

A Mathematical details

This appendix contains the mathematical details underlying the results in the main text. The results are explained in the order that they appear in the text.

Equation (13): DKW adjustment cost distribution

The intuition behind our parameterization, using $0 < \overline{\phi} < \underline{\phi} < 1$ and $\overline{\xi}$, of the DKW menu cost distribution function is most easily explained using figure 4. The distribution function that we consider is a transformation of the tangient function on $\left[\left(\underline{\phi} - 0.5\right)\pi, \left(\overline{\phi} - 0.5\right)\pi\right]$. This is the interval that is depicted in the figure by the arrow denoted by (i). The mapping of this interval on the support of the distribution function, i.e. $\left[0, \overline{\xi}_t\right]$,determines the value of the parameters γ_{3t} and γ_{4t}. Arrow (ii) depicts how γ_{1t} is determined. That is, γ_{1t} is such that the value of the distribution function at the minimum of its support equals zero. To assure that the menu cost assumes a value within its support with probability one, γ_{2t} is chosen such that arrow (iii) is of lenght one.

Note that $G_{1,t}(.)$ is a limiting case of $G_{2,t}(.)$ in the sense that $G_{2,t}(.) \to G_{1,t}(.)$ when $\underline{\phi} \to 0$ and $\overline{\phi}$ is chosen according to

$$\overline{\phi} = 0.5 + \frac{1}{\pi}\arctan\left(-\left(\frac{1-\alpha}{\alpha}\right)\tan\left(\left(\underline{\phi} - 0.5\right)\pi\right)\right) \tag{25}$$

Section 4: Equilibrium inflation dynamics

For the derivation of the equilibrium inflation dynamics and equilibrium price adjustment behavior it turns out to be convenient to write the problem in terms of variables that are constant along the balanced growth path. For this purpose, we define

$$\pi^S_{j,t} = \frac{\Pi^S_{j,t}}{\left[(1+\pi)(1+g)\right]^t},\ v^S_{j,t} = \frac{V^S_{j,t}}{\left[(1+\pi)(1+g)\right]^t}, \tag{26}$$

$$p^*_{S,t} = \frac{P^*_{S,t}}{(1+\pi)^t}, \text{ and } p_{i,t} = \frac{P_{i,t}}{(1+\pi)^t} \tag{27}$$

for $s \in \{D, E\}$ and $j = 0, \ldots, \infty$.

Given these definitions, we can write the detrended profits as

$$\pi^S_{j,t} = \left(\frac{p^*_{S,t-j}}{(1+\pi)^j} - \psi\right)\left(\frac{1}{(1+\pi)^j}\frac{p^*_{S,t-j}}{p_{it}}\right)^{-\varepsilon}\left(\frac{p_{it}}{p}\right)^{-\eta} y \tag{28}$$

where again $s \in \{D, E\}$ and $j = 0, \ldots, \infty$.

Furthermore, we can write the functional equations for the detrended value function as

$$v^D_{0,t} = \max_{p^*_{D,t}}\left\{\pi^D_{0,t} + \lambda E_t \max\left\{v^D_{0,t+1} - w\xi, v^E_{0,t+1} - w\xi - wc, v^D_{1,t+1}\right\}\right\} \tag{29}$$

$$v^E_{0,t} = \max_{p^*_{E,t}}\left\{\pi^E_{0,t} + \lambda E_t \max\left\{v^E_{0,t+1} - w\xi, v^E_{1,t+1}\right\}\right\} \tag{30}$$

$$v^D_{j,t} = \left\{\pi^D_{j,t} + \lambda E_t \max\left\{v^D_{0,t+1} - w\xi, v^E_{0,t+1} - w\xi - wc, v^D_{j+1,t+1}\right\}\right\} \tag{31}$$

$$v^E_{j,t} = \left\{\pi^E_{j,t} + \lambda E_t \max\left\{v^E_{0,t+1} - w\xi, v^E_{j+1,t+1}\right\}\right\} \tag{32}$$

where $\lambda = (1+g)(1+\pi)/(1+r)$.

Since these value functions are defined in terms of variables that are constant along the economy's balanced growth path, we will use this representation of the value functions to solve for the transitional path in the price level if sector i that results from the announcement of the conversion to the Euro.

In order to solve the equilibrium inflation dynamics in this model, we need to define the proper state space. The structure of the state space in this model is very similar to that in DKW. The main difference is that it is not only defined as the discrete distribution of firms over the length over which they have not adjusted their prices but also over the denomination in which they charge their prices.

Let $\theta_{j,t}^{S}$ for $S \in \{D, E\}$ denote the fraction of firms at the *start* of period t that changed their price j periods ago and that charge their price in denomination S. Furthermore, let $\alpha_{j,t}^{S'}$ for $S' \in \{D, E\}$ denote the fraction of firms that are charging a price that they set j periods ago in denomination S' that change their price at time t and that keep on charging their price in the same denomination. Let $\alpha_{j,t}^{C}$ denote the fraction of firms that are charging a price that they set j periods ago in their old domestic currency that change their price at time t as well as switch to the Euro. Finally, let $\omega_{j,t}^{S}$ for $S \in \{D, E\}$ denote the fraction of firms at the *end* of period t that changed their price j periods ago and that charge their price in denomination S. Here, the end of period refers to the part of the period after which firms have made their pricing decisions. This is the part of the period in which revenue is generated and prices are measured.

The dynamic transition equations for the state are given by the following identities

$$
\begin{aligned}
\omega_{0,t}^{E} &= \sum_{j=1}^{\infty} \left(\alpha_{j,t}^{E} \theta_{j,t}^{E} + \alpha_{j,t}^{C} \theta_{j,t}^{D} \right) && (33) \\
\omega_{0,t}^{D} &= \sum_{j=1}^{\infty} \alpha_{j,t}^{D} \theta_{j,t}^{D} && (34) \\
\omega_{j,t}^{E} &= \left(1 - \alpha_{j,t}^{E}\right) \theta_{j,t}^{E} && (35) \\
\omega_{j,t}^{D} &= \left(1 - \alpha_{j,t}^{D} - \alpha_{j,t}^{C}\right) \theta_{j,t}^{D} && (36) \\
\theta_{j+1,t+1}^{S} &= \omega_{j,t}^{S} \text{ for } S \in \{D, E\} && (37)
\end{aligned}
$$

where, since the state represents a distribution of firms, $\omega_{j,t}^{S} \geq 0$ and $\sum_{s=0}^{\infty} \omega_{j,t}^{S} = 1$. Furthermore, since they represent transition probabilities, $0 \leq \alpha_{j,t}^{S} \leq 1$ for $S \in \{C, D, E\}$.

This definition of the state allows us to define the price level at the end of the period as a function of the state and the prices set by the firms. That is, we can write the measured price level at each point in time as

$$
P_{it} = \left[\sum_{S \in \{D,E\}} \sum_{j=0}^{\infty} \omega_{j,t}^{S} \left(\frac{1}{P_{S,t-j}^{*}} \right)^{\varepsilon - 1} \right]^{\frac{1}{1-\varepsilon}} \tag{38}
$$

In terms of the detrended prices, this yields

$$p_{it} = \left[\sum_{S\in\{D,E\}} \sum_{j=0}^{\infty} \omega_{j,t}^{S} \left(\frac{(1+\pi)^{j}}{p_{S,t-j}^{*}} \right)^{\varepsilon-1} \right]^{\frac{1}{1-\varepsilon}} \tag{39}$$

which is constant on the balanced growth path.

Solving for the firms' optimal price setting decision involves solving for three decisions: (i) whether or not to adjust their price, (ii) whether or not to switch to the Euro (in case they are charging prices in the domestic currency), and (iii) what price to charge if the price is adjusted. We will tackle parts (i) and (ii) first and then solve (iii).

A firm that charges its price in Euros in period t and set that price j periods ago will adjust its price whenever the menu cost it draws is smaller than the gain in value that the firm obtains when it adjusts its price. Mathematically, this boils down to

$$\xi \leq \left(v_{0,t}^{E} - v_{j,t}^{E} \right) / \, w \tag{40}$$

The probability that this happens is depends on the distribution function of menu costs. In particular

$$\alpha_{j,t}^{E} = G\left(\left(v_{0,t}^{E} - v_{j,t}^{E} \right) / \, w \right) \tag{41}$$

We will denote the expected menu cost for such a firm, conditional on adjusting its price as

$$\Xi_{j,t}^{E} = \int_{0}^{\left(v_{0,t}^{E} - v_{j,t}^{E}\right)/w} \xi dG(\xi)$$

This price adjustment rule is essentially the same as that in DKW.

This is not the case for the a firm that charges its price in the domestic currency, though. Rather than deciding on whether or not to change its price, such a firm decides on whether to change its price and continue to charge it in the domestic currency, change its price and start charging it in Euros, or not change its price at all.

If the firm decides to change its price, it will start charging it in Euros whenever the value of charging it in Euros net of the Euro conversion adjustment cost is higher than the value of continuing to charge it in the domestic currency. That is, if the firm adjusts its price, it will convert to the Euro whenever

$$v_{0,t}^{E} - cw \geq v_{0,t}^{D} \tag{42}$$

This result implies that, if this inequality holds strictly one way or the other, either all firms that charge their prices in domestic currency and adjust their prices will change to Euros or they will all keep on charging their prices in the domestic currency. Hence, in that case $\alpha_{j,t}^{D}\alpha_{j,t}^{C} = 0$.

A firm that set its domestic currency denominated price j periods ago will adjust its price whenever the menu cost it draws satisfies

$$\xi \leq \max\left\{ v_{0,t}^{E} - cw - v_{j,t}^{D}, v_{0,t}^{D} - v_{j,t}^{D} \right\} / \, w \tag{43}$$

This allows us to solve for the adjustment probabilities

$$\alpha_{j,t}^{D} = \begin{cases} G\left(\left(v_{0,t}^{D} - v_{j,t}^{D} \right) / \, w \right) & \text{whenever} \quad v_{0,t}^{D} > v_{0,t}^{E} - cw \\ 0 & \text{otherwise} \end{cases} \tag{44}$$

and

$$\alpha_{j,t}^{C}=\begin{cases} G\left(\left(v_{0,t}^{E}-cw-v_{j,t}^{D}\right)/w\right) & \text{whenever} \quad v_{0,t}^{E}-cw>v_{0,t}^{D} \\ 0 & \text{otherwise}\end{cases} \tag{45}$$

Here, we assume that, in case of indifference, firms will switch to the Euro. Its expected menu cost, conditional on adjusting its price and still charging it in the domestic currency

$$\Xi_{j,t}^{D}=\begin{cases} \int_{0}^{\left(v_{0,t}^{D}-v_{j,t}^{D}\right)/w}\xi dG\left(\xi\right) & \text{whenever} \quad v_{0,t}^{D}>v_{0,t}^{E}-cw \\ 0 & \text{otherwise}\end{cases} \tag{46}$$

and its expected menu cost, conditional on adjusting its price and switching to the Euro equals

$$\Xi_{j,t}^{C}=\begin{cases} \int_{0}^{\left(v_{0,t}^{E}-cw-v_{j,t}^{D}\right)/w}\xi dG\left(\xi\right) & \text{whenever} \quad v_{0,t}^{E}-cw>v_{0,t}^{D} \\ 0 & \text{otherwise}\end{cases} \tag{47}$$

The solution of these adjustment probabilities and expected adjustment costs now allows us to solve for the optimal price $P_{S,t}^{*}$ for $S\in\{D,E\}$. However, we will solve for the optimal price detrended price, $p_{S,t}^{*}$, rather than for $P_{S,t}^{*}$. In order to do so, it is convenient to first rewrite the functional equations that define the value function by substituting in the optimal price adjustment decisions. This yields

$$\begin{aligned} v_{0,t}^{D} &= \max_{p_{D,t}^{*}}\left\{\pi_{0,t}^{D}+\lambda\alpha_{1,t+1}^{D}v_{0,t+1}^{D}+\lambda\alpha_{1,t+1}^{C}\left(v_{0,t+1}^{E}-wc\right)\right. && (48)\\ &\quad \left.+\lambda\left(1-\alpha_{1,t+1}^{D}-\alpha_{1,t+1}^{C}\right)v_{1,t+1}^{D}-\lambda w\Xi_{1,t+1}^{D}-\lambda w\Xi_{1,t+1}^{C}\right\} \\ v_{0,t}^{E} &= \max_{p_{E,t}^{*}}\left\{\pi_{0,t}^{E}+\lambda\alpha_{1,t+1}^{E}v_{0,t+1}^{E}+\lambda\left(1-\alpha_{1,t+1}^{E}\right)v_{1,t+1}^{E}-\lambda w\Xi_{1,t+1}^{E}\right\} && (49)\\ v_{j,t}^{D} &= \left\{\pi_{j,t}^{D}+\lambda\alpha_{j+1,t+1}^{D}v_{0,t+1}^{D}+\lambda\alpha_{j+1,t+1}^{C}\left(v_{0,t+1}^{E}-wc\right)\right. && (50)\\ &\quad \left.+\lambda\left(1-\alpha_{j+1,t+1}^{D}-\alpha_{j+1,t+1}^{C}\right)v_{j+1,t+1}^{D}-\lambda w\Xi_{j+1,t+1}^{D}-\lambda w\Xi_{j+1,t+1}^{C}\right\} \\ v_{j,t}^{E} &= \left\{\pi_{j,t}^{E}+\lambda\alpha_{j+1,t+1}^{E}v_{0,t+1}^{E}+\lambda\left(1-\alpha_{j+1,t+1}^{E}\right)v_{j+1,t+1}^{E}-\lambda w\Xi_{j+1,t+1}^{E}\right\} && (51)\end{aligned}$$

which allows us to derive the first order necessary conditions for the optimal prices $p_{D,t}^{*}$ and $p_{E,t}^{*}$.

The first order necessary condition for the choice of $p_{D,t}^{*}$ reads

$$\begin{aligned} 0 &= \frac{\partial}{\partial p_{D,t}^{*}}\left\{\pi_{0,t}^{D}+\lambda\alpha_{1,t+1}^{D}v_{0,t+1}^{D}+\lambda\alpha_{1,t+1}^{C}\left(v_{0,t+1}^{E}-wc\right)\right. && (52)\\ &\quad \left.+\lambda\left(1-\alpha_{1,t+1}^{D}-\alpha_{1,t+1}^{C}\right)v_{1,t+1}^{D}-\lambda w\Xi_{1,t+1}^{C}-\lambda w\Xi_{1,t+1}^{D}\right\} \\ &= \frac{\partial\pi_{0,t}^{D}}{\partial p_{D,t}^{*}}+\lambda\frac{\partial\alpha_{1,t+1}^{D}}{\partial p_{D,t}^{*}}\left(v_{0,t+1}^{D}-v_{1,t+1}^{D}\right)-\lambda w\frac{\partial\Xi_{1,t+1}^{D}}{\partial p_{D,t}^{*}} && (53)\\ &\quad \lambda\frac{\partial\alpha_{1,t+1}^{C}}{\partial p_{D,t}^{*}}\left(v_{0,t+1}^{E}-wc-v_{1,t+1}^{D}\right)-\lambda w\frac{\partial\Xi_{1,t+1}^{C}}{\partial p_{D,t}^{*}} \\ &\quad +\lambda\left(1-\alpha_{1,t+1}^{D}-\alpha_{1,t+1}^{C}\right)\frac{\partial v_{1,t+1}^{D}}{\partial p_{D,t}^{*}} && (54)\end{aligned}$$

However, the envelope theorem implies that

$$0 = \lambda \frac{\partial \alpha^D_{1,t+1}}{\partial p^*_{D,t}} \left(v^D_{0,t+1} - v^D_{1,t+1} \right) - \lambda w \frac{\partial \Xi^D_{1,t+1}}{\partial p^*_{D,t}} \quad (55)$$

$$= \lambda \frac{\partial \alpha^C_{1,t+1}}{\partial p^*_{D,t}} \left(v^E_{0,t+1} - wc - v^D_{1,t+1} \right) - \lambda w \frac{\partial \Xi^C_{1,t+1}}{\partial p^*_{D,t}} \quad (56)$$

Hence, the first order condition simplifies to

$$0 = \frac{\partial \pi^D_{0,t}}{\partial p^*_{D,t}} + \lambda \left(1 - \alpha^D_{1,t+1} - \alpha^C_{1,t+1} \right) \frac{\partial v^D_{1,t+1}}{\partial p^*_{D,t}} \quad (57)$$

The partial $\frac{\partial v^D_{j,t+1}}{\partial p^*_{D,t}}$ can be derived in a similar way as the above condition. It equals

$$\frac{\partial v^D_{j,t+1}}{\partial p^*_{D,t}} = \frac{\partial \pi^D_{j,t}}{\partial p^*_{D,t}} + \lambda \left(1 - \alpha^D_{j+1,t+1} - \alpha^C_{j+1,t+1} \right) \frac{\partial v^D_{j+1,t+1}}{\partial p^*_{D,t}} \quad (58)$$

Solving the optimality condition through forward recursion yields that $p^*_{D,t}$ is chosen such that

$$0 = \frac{\partial \pi^D_{0,t}}{\partial p^*_{D,t}} + \sum_{j=1}^{\infty} \lambda^j \prod_{s=1}^{j} \left(1 - \alpha^D_{j+s,t+s} - \alpha^C_{j+s,t+s} \right) \frac{\partial \pi^D_{j,t+j}}{\partial p^*_{D,t}} \quad (59)$$

Since

$$\frac{\partial \pi^D_{j,t+j}}{\partial p^*_{D,t}} = \left[\frac{1-\varepsilon}{(1+\pi)^j} + \varepsilon \frac{\psi}{p^*_{D,t}} \right] \left(\frac{1}{(1+\pi)^j} \frac{p^*_{D,t}}{p_{it+j}} \right)^{-\varepsilon} \left(\frac{p_{it+j}}{p} \right)^{-\eta} y \quad (60)$$

This first order condition implies that

$$p^*_{D,t} = \frac{\varepsilon}{\varepsilon - 1} \psi \frac{\sum_{j=0}^{\infty} \chi^D_{j,t} (1+\pi)^j}{\sum_{j=0}^{\infty} \chi^D_{j,t}} \quad (61)$$

where

$$\chi^D_{j,t} = \begin{cases} 1 & \text{for} \quad j = 0 \\ \lambda^j \prod_{s=1}^{j} \left(1 - \alpha^D_{s,t+s} - \alpha^C_{s,t+s} \right) (1+\pi)^{\varepsilon j} p^{\varepsilon - \eta}_{i,t+j} & \text{for} \quad j > 0 \end{cases} \quad (62)$$

Similarly, we can solve for the optimal price charged in Euros as being

$$p^*_{E,t} = \frac{\varepsilon}{\varepsilon - 1} \psi \frac{\sum_{j=0}^{\infty} \chi^E_{j,t} (1+\pi)^j}{\sum_{j=0}^{\infty} \chi^E_{j,t}} \quad (63)$$

where

$$\chi^D_{j,t} = \begin{cases} 1 & \text{for} \quad j = 0 \\ \lambda^j \prod_{s=1}^{j} \left(1 - \alpha^E_{s,t+s} \right) (1+\pi)^{\varepsilon j} p^{\varepsilon - \eta}_{i,t+j} & \text{for} \quad j > 0 \end{cases} \quad (64)$$

In terms of the non-transformed prices, we thus obtain for $S \in \{D, E\}$ that

$$P^*_{S,t} = \frac{\varepsilon}{\varepsilon - 1} \sum_{j=0}^{\infty} \Omega^S_{j,t} \Psi_{t+j} \text{ where } \Omega^S_{j,t} = \frac{\chi^E_{j,t}}{\sum_{q=0}^{\infty} \chi^E_{q,t}} \quad (65)$$

which is the result used in the main text

Section 5: Numerical solution method

For the numerical solution of our model we use the 'extended path' method. This method has been applied in other studies of transitional dynamics, like Greenwood and Yorukoglu (1997). We will assume that our economy starts off in period 0 in the steady state in which everyone charges their prices in the domestic currency and charging prices in Euros is not an option. In period 0 the conversion to the Euro at time T is announced. We will solve for the transitional path of the economy under the assumption that at time $\overline{T} > T > 0$ the sector has converged to its new steady state. This new steady state is the one in which all firms charge their prices in Euros.

The numerical solution method basically works as follows

1. We start with a guess for the equilibrium price path $\{p_{i,t}\}_{t=0}^{\overline{T}}$.
2. We solve the optimal price setting response for the firms. This is done using the value function iterations, (48) through (51), the optimal price setting rules, (61) and (63), and the transition equations for the state space, (33) through (37) and (41), (44) and (45).
3. The new path of the prices and the state space is then used to solve the price level identity, (39) and obtain a new equilibrium price path $\left\{p'_{i,t}\right\}_{t=0}^{\overline{T}}$.
4. Steps 2 and 3 above are repeated until $\{p_{i,t}\}_{t=0}^{\overline{T}} \to \left\{p'_{i,t}\right\}_{t=0}^{\overline{T}}$.

Table 1: January 2002 restaurant inflation anomaly in the EU12

country	$\pi_{Jan2002}$	mean ($\overline{\pi}$)	std.dev.(s)	$\frac{\pi_{Jan2002}-\overline{\pi}}{s}$	$\frac{\overline{\pi}_{Jan}-\bar{\pi}}{s}$
Austria	6.72	2.10	2.31	2.00	0.82
Belgium	5.54	2.28	1.87	1.74	-0.15
Finland	26.11	2.05	4.03	5.98	1.05
France	18.75	2.24	2.00	8.28	1.46
Germany	28.80	1.52	2.96	9.22	0.79
Greece	3.53	9.33	29.85	-0.19	0.03
Ireland	15.08	4.94	5.05	2.01	0.49
Italy	9.82	3.21	1.99	3.32	0.38
Luxemburg	17.31	2.47	3.03	4.89	1.09
Netherlands	50.05	3.38	6.00	7.78	1.81
Portugal	18.67	4.02	4.97	2.95	1.03
Spain	14.84	3.94	2.86	3.82	2.41
EU12	15.63	2.81	1.85	6.91	1.66
Britain	1.01	3.25	1.73	-1.29	-0.54
Denmark	1.06	2.29	3.03	-0.41	0.33
Sweden	2.18	2.10	4.04	0.02	-0.22

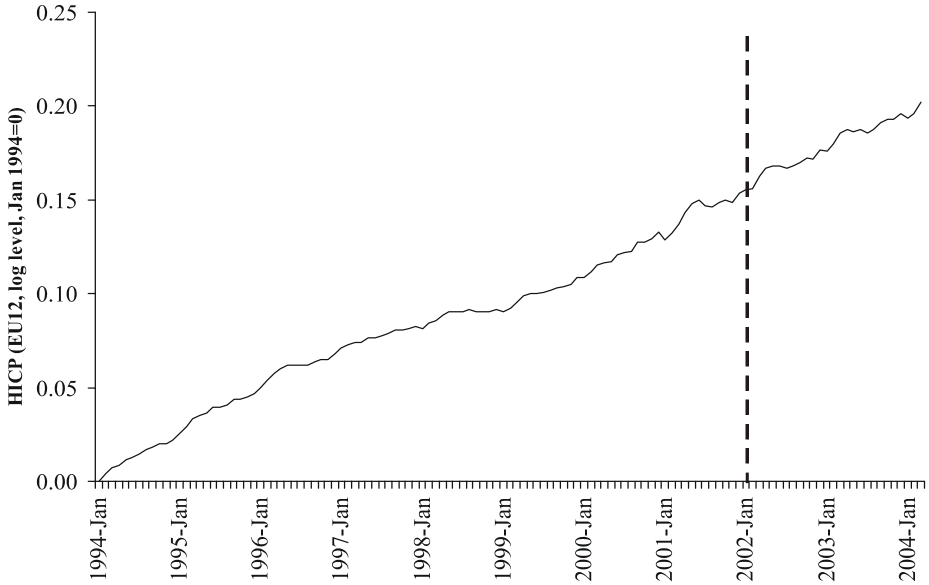
Table 2: Menu and fixed costs in the four models

parameter	period	Calvo *(i)*	Calvo-Taylor *(ii)*	DKW *(iii)*	Augmented DKW *(iv)*
distribution of ξ	all	G_{1t}	G_{1t}	G_{2t}	G_{2t}
$\overline{\xi}_t$	$t \neq T$	∞	> 0	> 0	> 0
	$t = T$	0	0	0	> 0
c	all	0	0	0	> 0
f_t^D	$t < T$	0	0	0	0
	$t \geq T$	0	0	0	$f^D > 0$
f_t^E	$t < T$	0	0	0	$f^E > 0$
	$t \geq T$	0	0	0	0

Table 3: Calibration of the menu and adjustment cost parameters

	matched fact	Calvo *(i)*	Calvo-Taylor *(ii)*	DKW *(iii)*	Augmented DKW *(iv)*
1.	11% of firms adjust their price each month	α	α	$\overline{\phi}$	$\overline{\phi}$
2.	maximum adjustment cost is 2.5% of revenue		$\overline{\xi}$	$\overline{\xi}$	$\overline{\xi}$
3.	50% of firms adopt the Euro in January 2002				f^D
4.	Euro adoption costs 7.5% of monthly revenue				c
5.	No firms adopt the Euro before January 2002				f^E
6.	Free parameter			$\underline{\phi}$	$\underline{\phi}$

Note: Matched facts consistent with: 1. Gali,Gertler, López-Salido (2001) and Bils and Klenow (2002), 2. Dotsey, King, and Wolman (1999), 3. Gallup Europe (2002), 4. Centraal Plan Bureau (2002), and 5. the fact that the Euro simply wasn't available before January 2002.



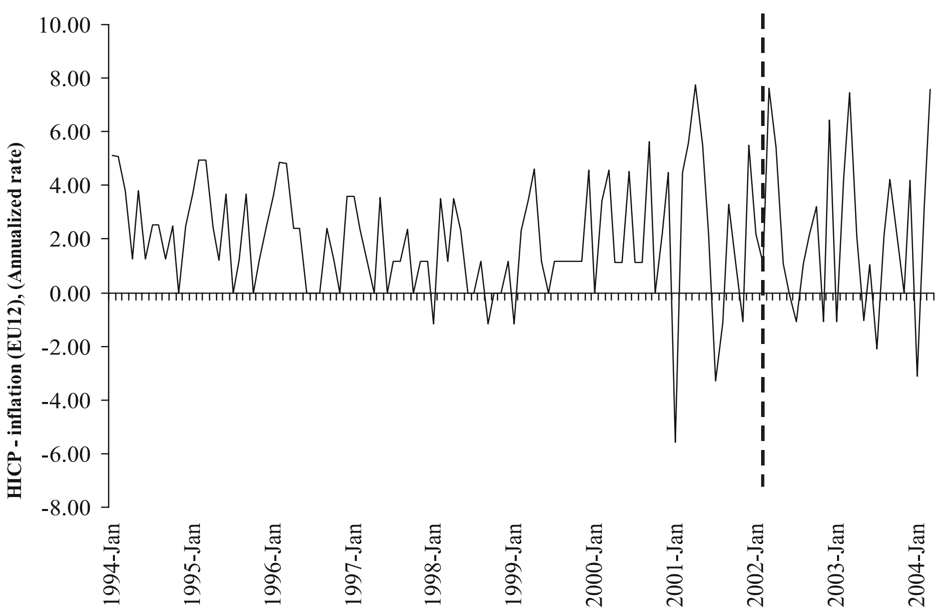


Figure 1: Harmonized Index of Consumer Prices for the EU12

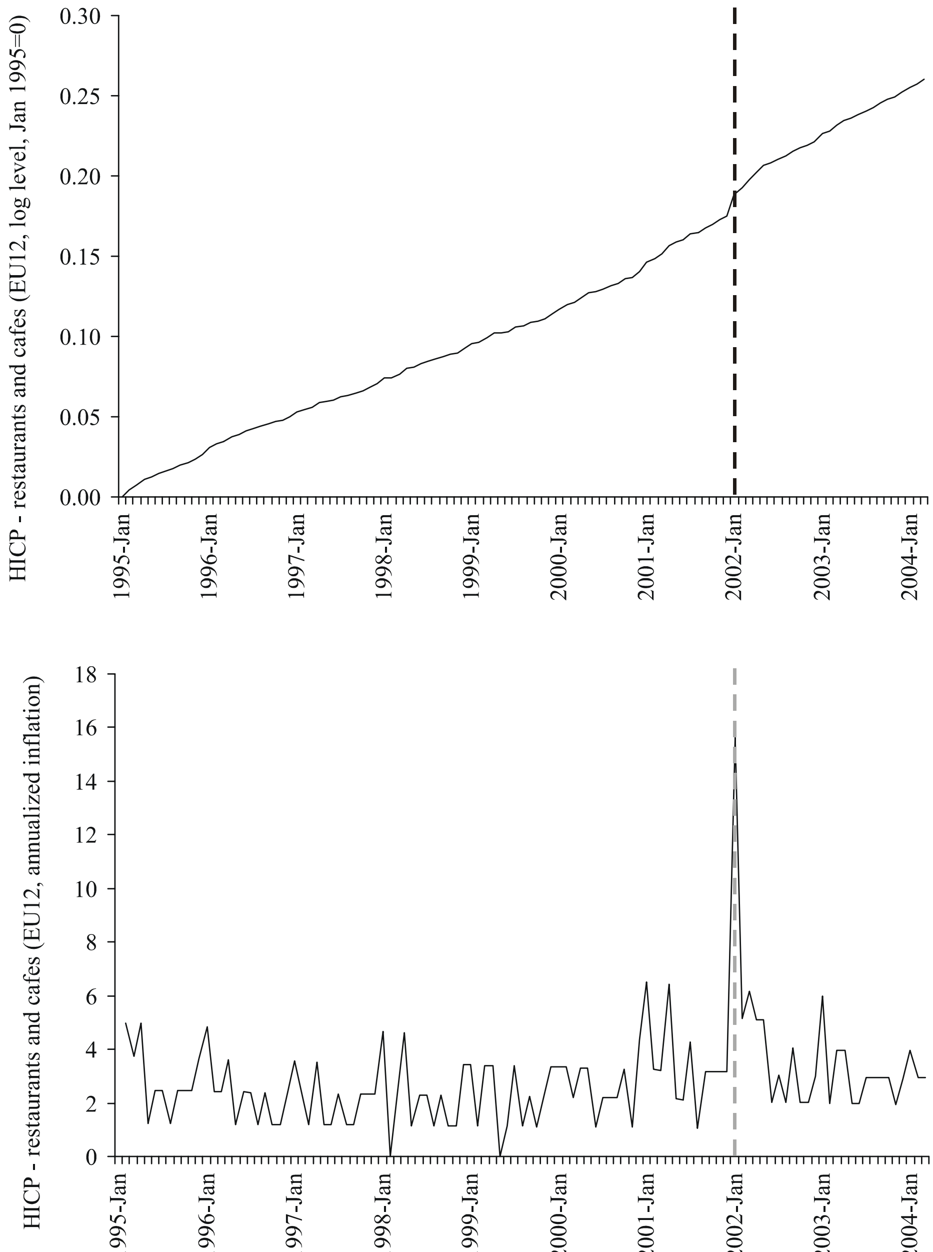


Figure 2: Restaurants and cafes component of HICP for EU12

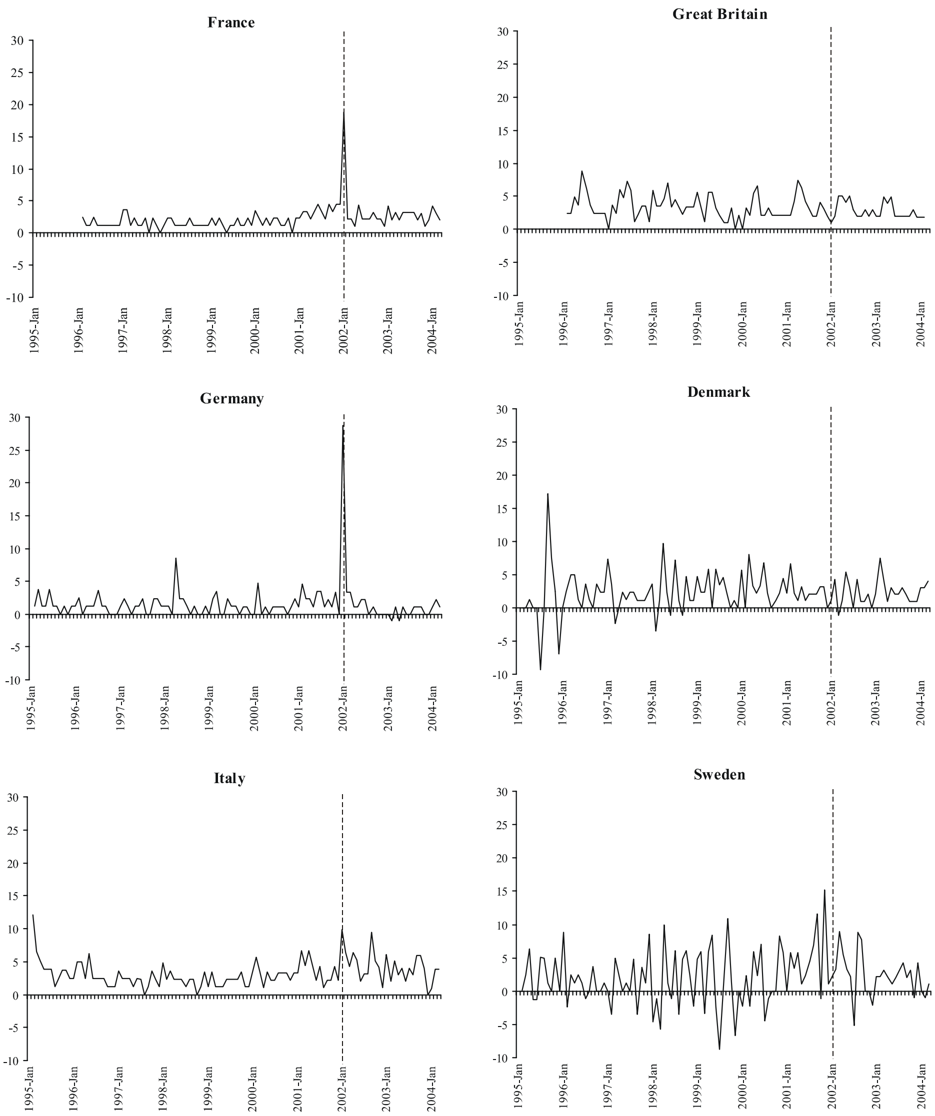


Figure 3: Annualized monthly restaurant price inflation in three 'treatment' and three 'control' countries

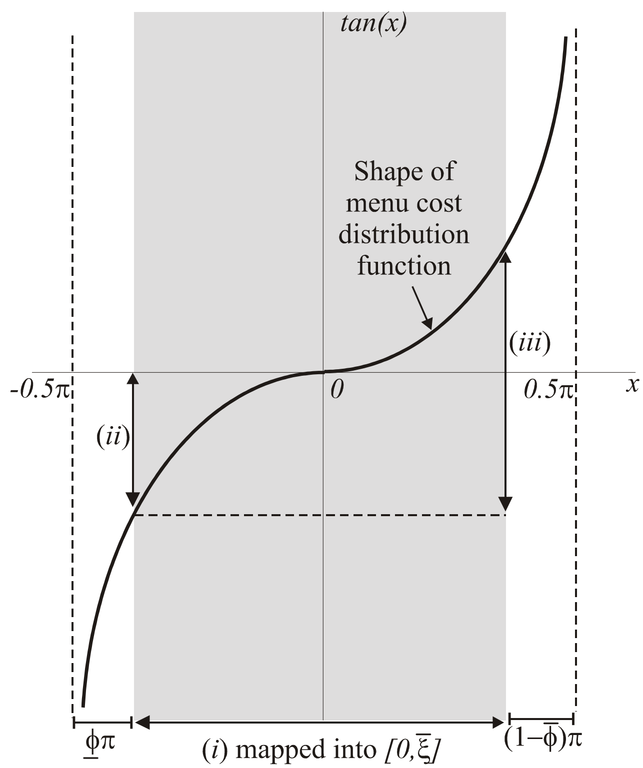


Figure 4: DKW menu cost distribution

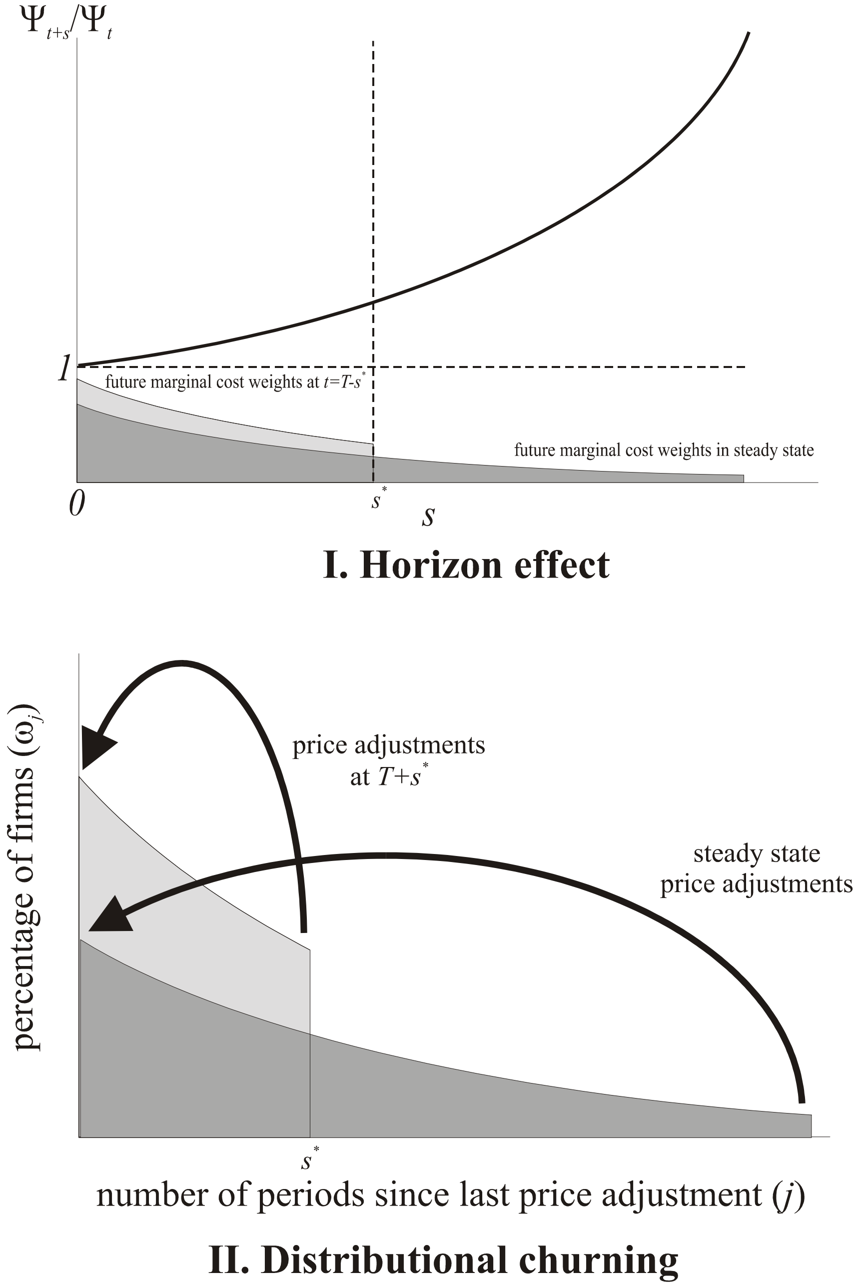


Figure 5: Two most important equilibrium dynamics mechanisms

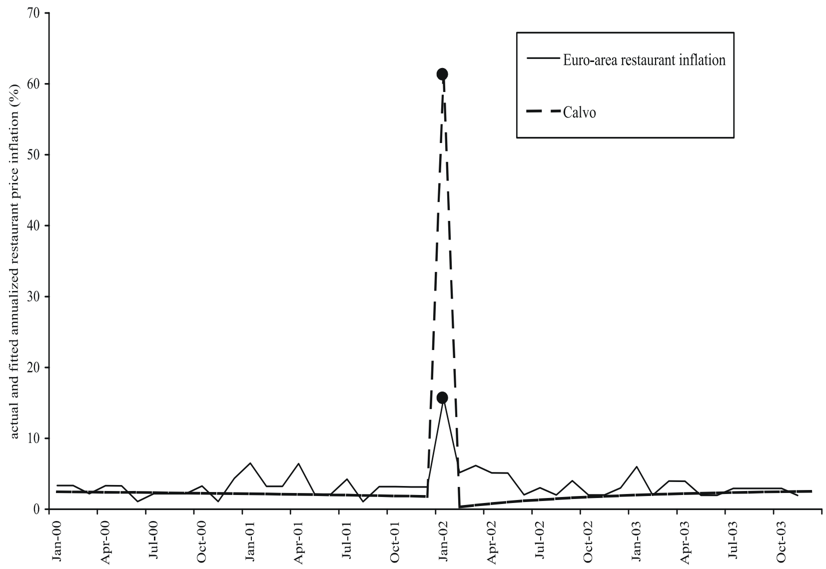


Figure 6: Calvo model

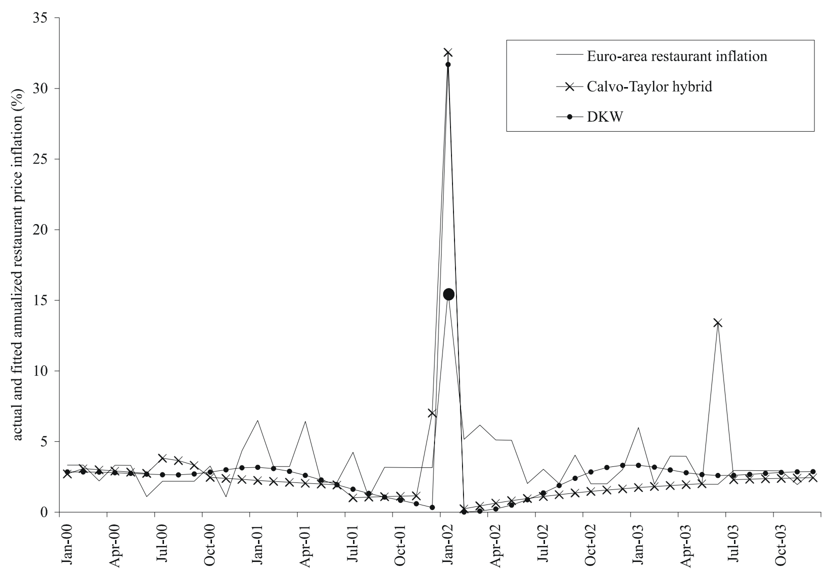


Figure 7: Calvo-Taylor hybrid and DKW

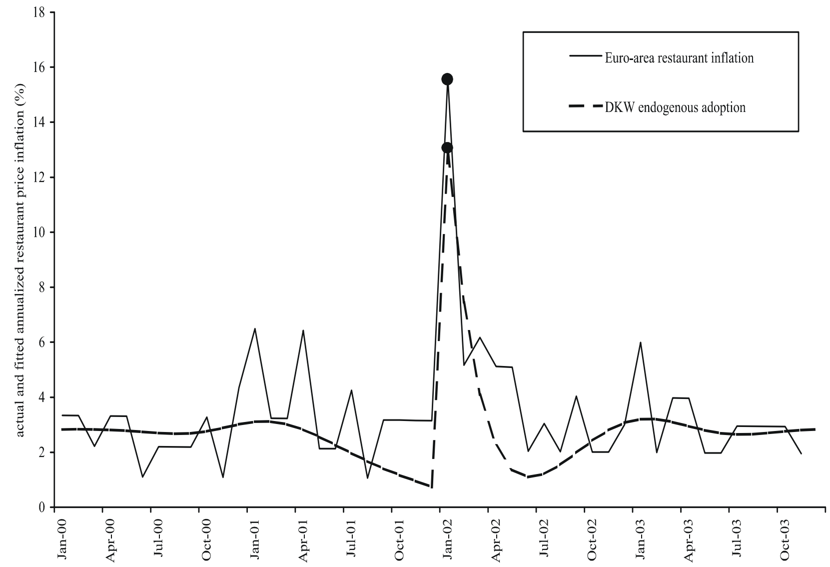


Figure 8: Augmented DKW, allowing for endogenous adoption of Euro

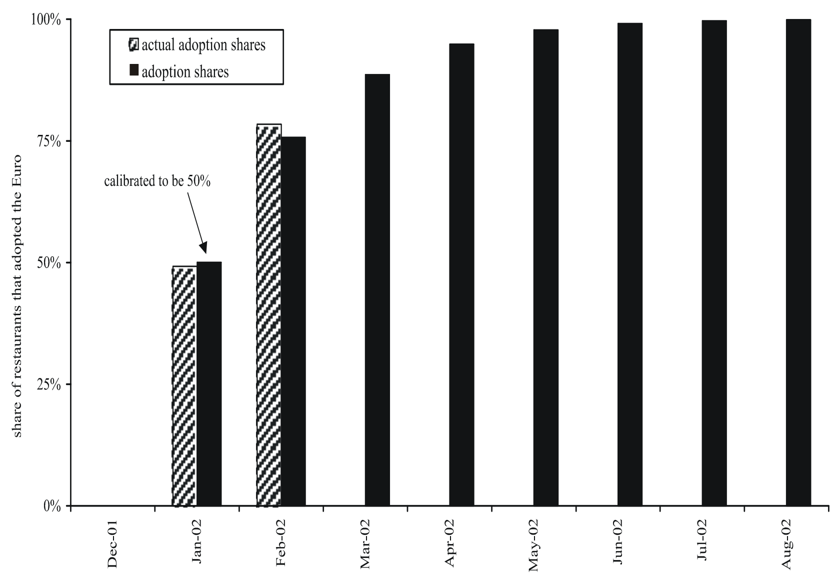


Figure 9: Implied adoption curve of the Euro

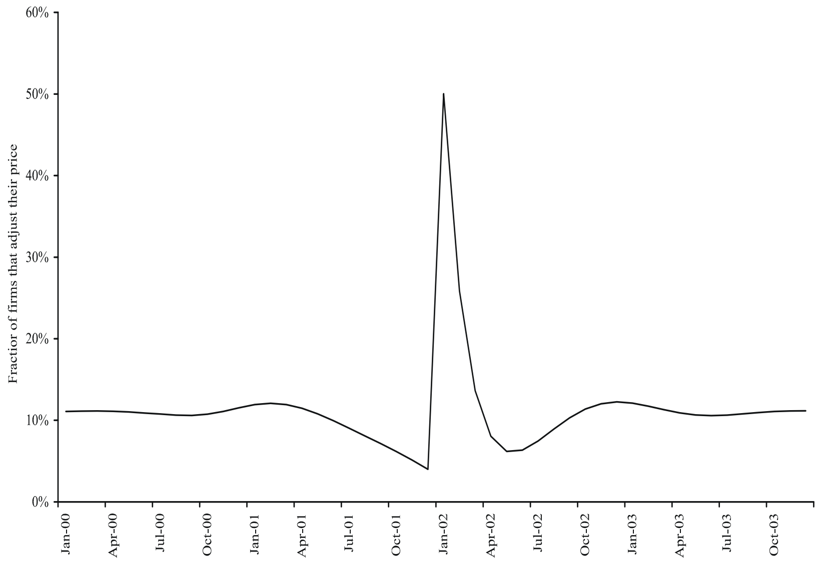


Figure 10: Implied path of fraction of firms adjusting their prices