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European inflation expectations dynamics

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Discussion Paper
Series 1: Economic Studies
No 37/2005

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ISBN 3–86558–093–9

Abstract:

This paper investigates the relevance of the sticky information model of Mankiw and Reis (2002) and Carroll (2003) for four major European economies (France, Germany, Italy and the United Kingdom). As opposed to the benchmark rational expectation models, households in the sticky information environment update their expectations sporadically rather than instantaneously owing to the costs of acquiring and processing information. We estimate two alternative parametrizations of the sticky information model which differ in the stationarity assumptions about the underlying series. Using survey data on households' and experts' inflation expectations, we find that the model adequately captures the dynamics of household inflation expectations. Both parametrizations imply comparable speeds of information updating for the European households as was previously found in the US, on average roughly once a year.

Keywords: Inflation, expectations, sticky information, inflation persistence

JEL-Classification: E 31

Non Technical Summary

The idea of sticky information has been proposed recently (see e.g. Mankiw and Reis (2002, 2003) and Carroll (2003)) to better understand real effects of nominal shocks. This line of argumentation states that agents update their information about future economic developments sporadically rather than instantaneously, due to the costs of acquiring and processing information. Furthermore, it is argued that models based on the assumption of sticky information may be useful to account e.g. for considerable inflation persistence and recessionary disinflations which have been frequently observed in the data.

This paper investigates the relevance of one model of sticky information ─ the "epidemiology of expectations" model of inflation dynamics introduced by Carroll (2003) ─ for four major European economies. The model also serves as an underpinning for other sticky information models, e.g. the sticky information Phillips-curve of Mankiw and Reis (2002). The basic intuition underlying the epidemiology model is as follows: Suppose a number of well-informed agents, experts or professional business cycle forecasters, collect the relevant information on future inflation in every period and make rational inflation forecasts. These forecasts are published in newspapers. Households, however, find it costly to read the newspapers all the time and to stay completely up-to-date. Under such circumstances only a fraction of households follows the latest inflation stories in the newspapers and update their expectations, while the remaining households stick to their forecasts from the previous period. In the aggregate, inflation expectations respond, thus, sluggishly to news about inflation. As a consequence, nominal shocks have real effects.

Using survey data on household and expert inflation expectations from Germany, France, Italy and the UK for the period from 1989 to 2003 we estimate and test the Carroll (2003) model of slow diffusion of information. Generally, we find that the model adequately captures the dynamics of household inflation expectations. We document that the qualitative and quantitative findings previously reported for the US generalize to major European countries. According to the econometric results, most European households adjust rather sluggishly to new information; they update their information on average once a year. Interestingly, it turns out that the households are forward-looking in the sense that they use information processed by experts rather than just rely on past information.

The findings appear to be robust to a number of parameterizations of the model we consider. In particular, unlike previous studies, we estimate the model for two alternative parameterisations. One parameterization assumes the underlying time series are stationary; the other parameterisation allows the time series to be integrated of order one, i.e. takes into account that macro-economic time series after an exogenous shock does not return to the pre-shock level. Both parameterisations imply comparable speeds of information updating for the European households as was previously found in the US, on average once a year. Our results indicate that the models of sticky information are promising candidates for a better understanding for European inflation expectation dynamics.

Nicht technische Zusammenfassung

Um reale Effekte nominaler Schocks besser verstehen zu können sind jüngst Modelle vorgeschlagen worden, die auf der Annahme verzögerter Informationsverarbeitung basieren (sog. „Sticky Information"-Ansätze, vgl. Mankiw and Reis (2002, 2003) und Carroll (2003)). In diesen Modellen passen Haushalte ihre Erwartungen über die zukünftige Inflation nur sporadisch und nicht kontinuierlich an, zum Beispiel, weil Kosten der Informationsbeschaffung und -verarbeitung existieren. Befürworter solcher Modelle argumentieren zudem, dass solche Ansätze in Übereinstimmung mit wichtigen makroökonomischen stilisierten Fakten stehen, wie etwa der hohen Persistenz der Inflationsrate und den in der Regel konjunkturdämpfenden Wirkungen von Disinflationen.

Das vorliegende Papier untersucht die Relevanz des von Carroll (2003) entwickelten „epidemiologischen" Modells, einer langsamen Diffusion von Informationen von professionellen Prognostikern zu privaten Haushalten. Dieses Modell wurde auch vorgeschlagen, um anderen Modellen, die auf dem „Sticky Information" Ansatz beruhen, etwa der „Sticky Information" Phillipskurve von Mankiw und Reis (2002), eine bessere theoretische Grundlange zu geben.

Der grundlegende Gedanke des Modells kann wie folgt erläutert werden. Angenommen, gut informierte Experten und professionelle Konjunkturbeobachter sammeln zu jedem Zeitpunkt relevante Informationen und erstellen daraus rationale Vorhersagen der zukünftigen Inflationsrate. Diese wird in Zeitungen veröffentlicht. Jedoch lesen nicht alle Haushalte zu jedem Zeitpunkt die Artikel über die Inflation, z.B. weil die Informationsbeschaffung Kosten verursacht. Unter diesen Umständen ist immer nur ein Teil der Haushalte über die aktuelle Inflationsentwicklung informiert und passt seine Erwartungen entsprechend an. Der andere Teil bleibt bei seinen Erwartungen aus der Vorperiode. Im Aggregate passen sich die Inflationserwartungen der Haushalte somit nur verzögert an und nominelle Schocks können reale Wirkungen entfalten.

Wir schätzen und testen das Modell von Caroll (2003) unter Verwendung von Befragungsdaten zu den Erwartungen professioneller Konjunkturprognostiker und Haushalten für den Zeitraum von 1989 bis 2003 für Deutschland, Frankreich, Italien und das Vereinigte Königreich. Unsere Ergebnisse zeigen, dass die Dynamik der Inflationserwartungen der Haushalte durch dieses Modell in den genannten Ländern alles in allem gut erfasst wird. Insbesondere entsprechen die Ergebnisse jenen, die von vorhergehenden Studien für die USA mit dem gleichen Ansatz ermittelt wurden. Danach passen sich die Haushalte recht langsam an das Vorliegen neuer Informationen an. Im Durchschnitt erfolgt eine Anpassung etwa einmal im Jahr, ein Wert, der auch für die USA ermittelt wurde. Die Haushalte verhalten sich insofern vorausschauend, als sie sich bei der Bildung ihrer Erwartungen stärker an den Vorhersagen der Experten orientieren als an den vergangenen Werten der Inflationsrate.

Die Ergebnisse erweisen sich als robust gegenüber einer Veränderung der Schätzmethoden. So wird das „Sticky Information“ Modell in zwei Varianten geschätzt. Zum einen wird angenommen, dass die Zeitreihen stationär sind. Zum anderen trägt das Papier auch der Möglichkeit Rechnung, dass die Zeitreihen sich nach einem exogenen Schock nicht zu ihrem ursprünglichen Niveau zurück entwickeln, also einem so genannten integrierten Prozess folgen. Die Schätzungen nach beiden Varianten führen zu recht ähnlichen Ergebnissen. Alles in allem schließen wir aus den empirischen Resultaten, dass die Modelle auf Basis des „Sticky Information“ Ansatzes einen Beitrag zum Verständnis der Dynamik der europäischen Inflationserwartungen leisten können.

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1. Introduction

In order to gain a better understanding of the real effects of nominal shocks, the idea of sticky information was proposed recently (see, for example, Mankiw and Reis (2002, 2003) and Carroll (2003)). Its advocates argue that the assumption that agents update their information sporadically rather than instantaneously resolves several puzzles in the output-inflation dynamics that many of its competitors still struggle with. For example, sticky information models are able to account for considerable inflation persistence and substantial sacrifice ratios (recessionary disinflations) typically observed in the data.

Microeconomic foundations for the sticky information paradigm were elaborated in Carroll's (2003) work on the "epidemiological model of expectations." The author argues that US survey data on inflation expectations are consistent with a model in which, for each period, only a fraction of households adopts inflation forecasts of rational experts. The remaining households find it costly to update their information and continue using their past expectations rather than forming fully rational predictions. In a related work Sims (2003, 2005), Branch (2004) and others provide alternative

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justifications for models in which agents do not instantaneously incorporate all available information as implied by most standard modern macro models.

While the sticky information approach seems to be useful for understanding the US data, corresponding evidence for European countries is still lacking.[1] This paper attempts to fill this gap by investigating inflation expectation data from four major EU economies (France, Germany, Italy and the UK). We believe it is particularly interesting to compare the results since the institutional settings in Europe and the US differ substantially in at least two ways. First, the monetary policy set-up and recent experience of inflation in various EMU countries, US and the UK are quite varied. For example, whereas Germany, under the Bundesbank regime, has always had moderate and stable inflation rates, Italy faced considerably higher inflation in the early 1990s and has witnessed pronounced declines in price level increases over the past decade in the run-up to and since the introduction of the euro. In addition, the fact that central banks have different communication strategies might affect how information spreads across households. Second, both the size and structure of the "forecasting industry" are dissimilar. (In the US it is dominated by private forecasters, while in Europe public forecasters play a more prominent role.) These factors may, in principle, affect how much the sticky information model is relevant for European countries as well as the implied speed of adjustment of households' expectations.

Interestingly, findings of our research in general confirm the usefulness of the sticky information model for the description of inflation dynamics in European countries. We find that households' inflation expectations adjust sluggishly to the more precise predictions of professional forecasters. The speed of this adjustment varies little across the four countries we investigate and is in line with that in the US: a typical household updates its inflation expectations roughly once a year. This estimate is remarkably robust across the estimation methods and various stochastic properties of the data. Finally, similarly to the US, European households are not backward-looking: they tend to update their expectation from experts' rational forecasts rather than actual past inflation rates.

[1] The only papers on testing the sticky information model on international data of which we are aware are Khan and Zhu (2002) and Handjiyska (2004).

The remainder of the paper is organized as follows. In Section 2 we describe the theoretical motivation for our empirical work. Section 3 describes the survey-based inflation expectation data used in the paper. Section 4 estimates two alternative parametrizations of the sticky information model. The final section concludes. Appendixes provide a detailed description of the data and report additional econometric results.

2 The epidemiology of household inflation expectations

Carroll (2003) proposed a micro-founded model of the transmission of inflation expectations between professional forecasters and households. He argues that the dynamics of aggregate household expectations is adequately captured by a model in which households choose to update their expectations sporadically rather than instantaneously. New information about inflation spreads slowly across households in the following "epidemiological" way. Suppose a number of informed agents, experts, collect relevant information on future inflation in every period and make rational inflation forecasts. These forecasts are published in newspapers. Households, on the other hand, find it costly to read the newspapers and to stay completely up-to-date (or make informed inflation forecasts). For that reason, in each period only a randomly chosen fraction λ of households follows the latest inflation stories in the newspapers and updates its inflation expectations. The remaining $1 - \lambda$ households stick to their forecasts from the previous period. The evolution of the (average) household (denoted HH) inflation (π) expectation (E) follows

$$\mathrm{E}_{t}^{HH}\pi_{t,t+1} = \lambda \mathrm{E}_{t}^{EX}\pi_{t,t+1} + (1-\lambda)\mathrm{E}_{t-1}^{HH}\pi_{t,t+1}, \tag{1}$$

where $E_t^{HH}\pi_{t,t+1}$ and $E_t^{EX}\pi_{t,t+1}$ denote one-period-ahead inflation expectations of households and experts, respectively.

Thus, news about inflation can be thought of as a disease that spreads slowly across the population, infecting λ households in each period. The calculation outlined in detail in Carroll (2003: 4) leads to the equation formulated for annual inflation rates, which are typically reported in surveys of inflation expectations. Carroll (2003: 7) derives:

$$E_t^{HH}\pi_{t,t+4} = \lambda E_t^{EX}\pi_{t,t+4} + (1-\lambda)E_{t-1}^{HH}\pi_{t-1,t+3} \quad (2)$$

Equation (2) holds if (i) inflation follows a random walk process or (ii) $E_{t-1}^{HH}\pi_{t-1,t+3} \approx E_{t-1}^{HH}\pi_{t,t+4}$. Both of these assumptions are likely to be satisfied in our dataset. As discussed below, the underlying CPI inflation process in the core European economies has, indeed, been very persistent recently, warranting the random walk approximation. Second, given the high persistence of the inflation process, there is not much difference between households expectations as at time t-1 of inflation rates at t+3 and t+4, which, in turn, implies that condition (ii) is also likely to be met.

3. Expectations data

To test the model of the information diffusion, two kinds of inflation expectation data are needed: inflation forecasts of households and professional forecasters. The forecasts of households were obtained from the European Commission's (EC) consumer survey and those of professional forecasters from Consensus Economics, a London-based macroeconomic survey firm.

Household expectations were constructed using the EC survey's question 6, which asks how, by comparison with the last 12 months, the respondents expect that consumer prices will develop in the next 12 months.[2] Unfortunately, the answers are qualitative rather than quantitative (unlike, for example, question 12 concerning expected inflation in the US Michigan Survey of Consumer Sentiment). This means that the respondents are asked about the direction of the expected movement of consumer prices (increase/fall), not about the exact quantitative value of this movement. Consequently,

[2] The exact wording of question 6 of the Consumer Survey of the Joint Harmonised EU Programme of Business and Consumer Surveys is "By comparison with the past 12 months, how do you expect that consumer prices will develop in the next 12 months?" For more information on the survey, see the Commission's webpage, http://europa.eu.int/comm/economy_finance/indicators/businessandconsumersurveys_en.htm.

care needs to be taken when transforming these data into quantitative measures of households expectations, required to test equation (2). We follow much of the existing literature (including Gerberding (2001), Mankiw et al (2003) and Nielsen (2003)) in adopting the Carlson and Parkin (1975) method, explained in detail in Appendix I.

Figure 1. compares experts' and households' inflation expectations with actual inflation rates. Apparently, both expert's and household's predictions are roughly in line with actual inflation. However, sometimes there are even rather persistent differences between expectations and actual inflation. More importantly, household's and expert's expectations differ considerably in certain time periods. Thus, a closer examination of the dynamic interaction of both variables is warranted.

4. Empirical results

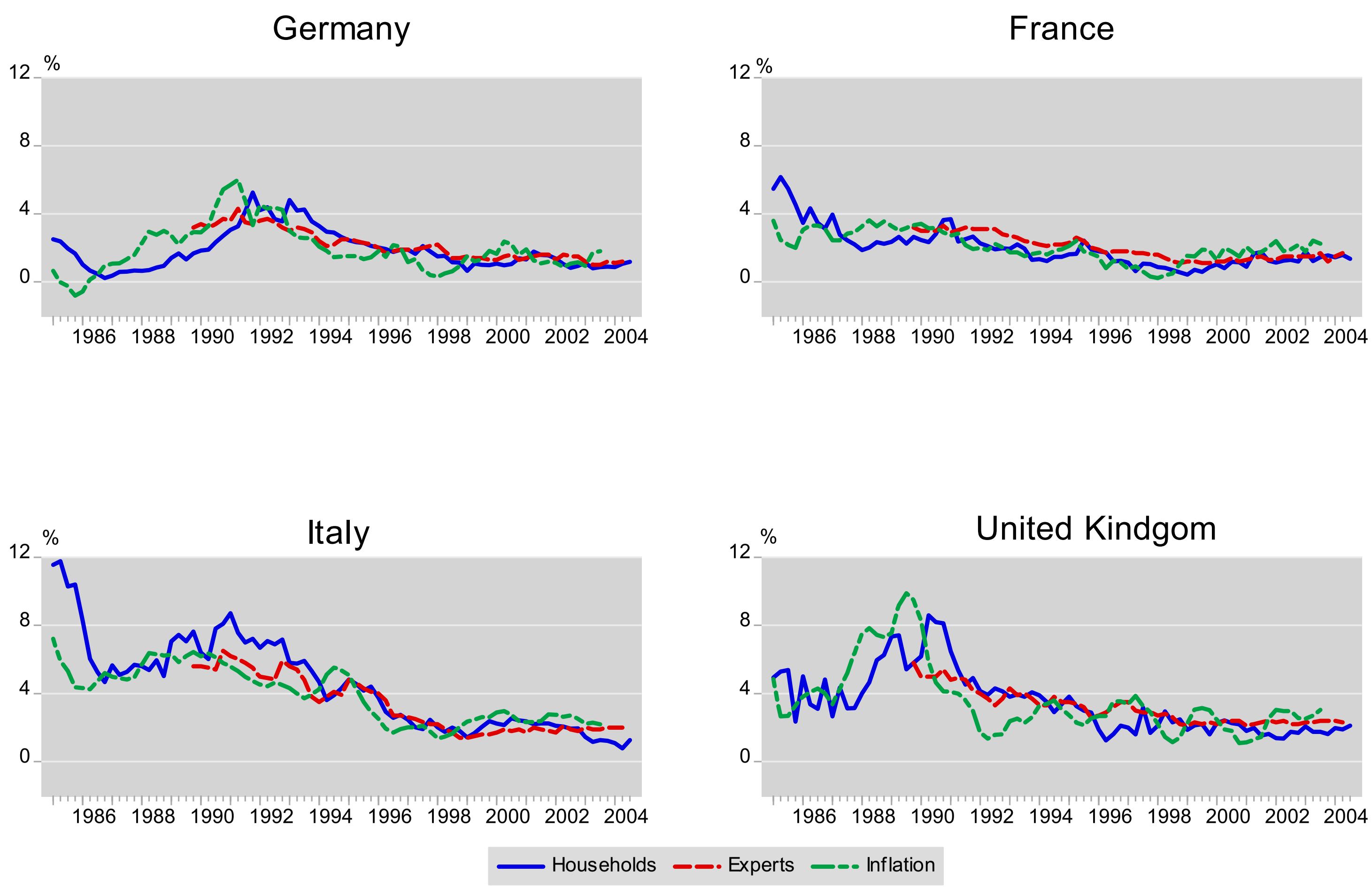
The choice of the appropriate empirical strategy to estimate equation (2) depends on the time series properties of the underlying expectations. If the series are stationary, model (2) can be estimated directly using OLS (as in Carroll (2003)). If they are non-stationary (I(1)) and cointegrated, the model should be transformed into vector error-correction (VEC) form. Below, we first discuss the degree of persistence in the inflation rates at hand. In a second step, we present estimates for both the stationary and the integrated case.

4.1 Persistence of inflation and inflation expectations

Before estimating equation (1) we test for stationarity of our inflation and inflation expectation series. Table 1 presents the results of augmented Dickey-Fuller tests together with estimates of the largest autoregressive roots, calculated following Stock (1991).[3]

[3] Qualitatively similar results hold for the Elliott, Rothenberg and Stock (1996), DF-GLS test.

Figure 1: Household and expert expectations and actual inflation.



The results imply that most series are highly persistent. The null hypothesis of unit roots cannot typically be rejected at conventional significance levels. The median unbiased estimates of the largest autoregressive root are often close to 1, sometimes even higher than 1; the 90% confidence interval includes 1 in almost all cases.

Table 1: Unit root tests, 1989 IV to 2004 II

	Inflation (year to year)	Inflation (quart. to quart.)	Households (past inflation scaled)	Households (HP inflation scaled)	Experts
			Germany		
Test specification	adf (4,8)	adf(4,8)	adf(3)	adf(5)	adf(3,7)
Test statistic	0.01	-2.39	-1.72	-1.68	-1.66
Stock	1.03	0.86	0.98	0.99	0.99
Med & 90% CI	(1.00;1.07)	(0.71;1.03)	(0.83;1.05)	(0.84; 1.05)	(0.81; 1.06)
			France		
Test specification	adf(3,4,8)	adf(1,2)	adf(3,6)	df	Df
Test statistic	-1.43	-2.35	-2.70*	-2.12	-1.71
Stock	1.01	0.87	0.81	0.91	0.98
Med & 90% CI	(0.88; 1.06)	(0.71; 1.03)	(0.64; 1.01)	(0.76; 1.03)	(0.83; 1.05)
			Italy		
Test specification	adf(1,4)	adf(3)	adf(1,2,6,7)	adf(5)	adf(5)
Test statistic	-0.88	-1.94	-1.09	-1.31	-2.06
Stock	1.02	0.94	1.02	1.01	0.91
Med & 90% CI	(0.94; 1.06)	(0.79; 1.04)	(0.92; 1.06)	(0.89; 1.06)	(0.74; 1.05)
			United Kingdom		
Test specification	adf(1,4,5)	adf(6)	adf(1,2,4,6)	adf(7)	adf(4,5,6)
Test statistic	-2.78*	-3.02**	-2.58	-2.02	-2.52
Stock	0.79	0.75	0.83	0.92	0.82
Med & 90% CI	(0.62; 1.01)	(0.57; 0.95)	(0.67; 1.02)	(0.78; 1.04)	(0.63; 1.03)

Notes: In the specifications of the ADF tests a constant and all significant lags up to lag 8 were kept. The number of lags in the ADF specification are indicated in the brackets, e.g. adf(4,8) implies that lags 4 and 8 were kept in the ADF tests. In those cases were all lags were restricted to zero, the ADF test reduces to the original Dickey-Fuller test (denoted as df). *(**, ***) denotes rejection of the null at 10%, 5% and 1% confidence level, respectively. The "Stock Med & 90% CI" reports the median unbiased estimates of the largest autoregressive root in a gives series and its 90% confidence interval, calculated following Stock (1991).

While there exists a relatively large literature on persistence properties of inflation in and outside the US (see, for example, Cogley and Sargent (2002), its discussion by Stock, and Piger and Levin (2003)), the empirical results on the persistence of inflation and its stability are often inconclusive. Although the above results indicate the possible existence of a unit root in most series considered, a potential criticism of the results shown in Table 1 is that our sample is too short to allow reliable inferences. The fact that we areunable to reject the null may well result from the notoriously low power of the unit root tests under such circumstances, rather than the existence of the unit root.

Since the main focus of this paper is not on providing a definitive answer on the order of integration of inflation (or inflation expectations), we now move on to estimating our theoretical model and investigate how sensitive its implications are in respect of whether we assume stationary or non-stationary environments. Because the tests do not clearly determine the stationarity properties in the relatively short sample we have, we will first estimate the Carroll model in the stationary environment. We will then consider how the results are affected if the nonstationary (VECM) set-up is adopted.

4.2 The stationary case: Carroll (2003) model

We will first estimate and test the epidemiological model under the assumption that the underlying expectations series are stationary (I(0)). Before estimating equation (2), we will examine some preliminary evidence on the relationship between expert and household expectations. Given the interest in the interaction between the expectations of both professional forecasters and households, a natural starting point is to ask, (i) which of the two groups forecasts, on average, better and (ii) what is the causality between the two expectations.

Relationship between Expert and Household Expectations

First, evidence reported in Appendix I (Table A.1) implies that the expert expectations are substantially more precise than the household expectations. The root mean squared errors of the expert forecasts are between 15% to 35% lower in Germany, Italy and the UK than for household expectations. The two expectations are comparably precise in France. This does not, of course, come as a surprise since the households may know the experts' forecasts when forming their own expectations. According to the epidemiology model, at least some of the households update their own expectations by following the experts.

Table 2: Test for Granger non-causality of expert's and household's expectations, 1989 IV to 2004 II

Country	Dep. Variable: Expectations of …	$\beta_j = 0, \forall j$ (p-value)	$\gamma_k = 0, \forall k$ (p-value)	$\Sigma\beta_j$	$\Sigma\gamma_k$	DW	$\overline{R}^2$
Germany	Experts	0.00	0.13	0.91	0.04	2.12	0.93
	Households	0.00	0.00	0.48	0.65	1.95	0.92
France	Experts	0.00	0.08	0.88	0.09	1.96	0.95
	Households	0.00	0.00	0.25	0.66	1.90	0.81
Italy	Experts	0.00	0.01	0.73	0.18	1.99	0.96
	Households	0.62	0.00	0.14	0.88	1.98	0.95
United Kingdom	Experts	0.00	0.15	0.78	0.09	1.93	0.92
	Households	0.01	0.00	0.57	0.62	1.74	0.88

Notes: Estimated equation: $E_t^i \pi_{t,t+4} = \beta_0 + \sum_{j=1}^{p} \beta_j E_{t-j}^{EX} \pi_{t-j,t+4-j} + \sum_{k=1}^{p} \gamma_k E_{t-k}^{HH} \pi_{t-k,t+4-k} + \varepsilon_{t+4}$

DW = Durbin-Watson test statistic. Household expectations scaled using the HP-filtered inflation. The tests were computed with p = 2 lags of independent variables.

Second, we can examine whether the expert forecasts Granger-cause the household forecast by testing for significance of the appropriate coefficients in the following equations.

$$E_t^i \pi_{t,t+4} = \beta_0 + \sum_{j=1}^{p} \beta_j E_{t-j}^{EX} \pi_{t-j,t+4-j} + \sum_{k=1}^{p} \gamma_k E_{t-k}^{HH} \pi_{t-k,t+4-k} + \varepsilon_{t+4}, \tag{4}$$

where the regressions are run with both expert and household expectations on the right-hand side, $i \in \{Ex, HH\}$. This is done in Table 2. Columns 3 and 4 indicate that lags of expert expectations are typically significant predictors of household expectations. Household expectations, on the other hand, tend not to Granger-cause the experts. Thus, in all countries, except for Italy we conclude that the direction of causality goes from experts toward households. This is also documented in columns 5 and 6, which display the sum of coefficients on past expectations. The sum of coefficients on expert expectations ($\sum \beta_j$) in household equations is bigger than the sum of household coefficients ($\sum \gamma_k$) in expert equations (in all countries except for Italy).

Equation-by-Equation Estimation

Having found supportive preliminary evidence for the epidemiological model of expectations formation, let us now turn to direct estimation of and inference about the speed of information updating, λ. Table 3 summarizes the estimation results of the following regressions

$$E_t^{HH} \pi_{t,t+4} = \lambda_0 + \lambda_1 E_t^{EX} \pi_{t,t+4} + \lambda_2 E_{t-1}^{HH} \pi_{t-1,t+3} + \varepsilon_{t+4} \quad (5)$$

in unrestricted and restricted forms.[4]

Rows 1 and 2 report coefficients and t statistics of $\lambda_0, \ldots, \lambda_2$ freely estimated in the unrestricted model (5). Three findings emerge: First, the constant λ_0 is insignificant for France and Italy, while significant for the UK and Germany. Second, the coefficient λ_1 that identifies the speed of updating of household expectations is highly significant for all countries. Third, λ_1 and λ_2 roughly add up to 1, as predicted by the Carroll model. Given that it makes little sense *a priori* to assume that regression (5) should be estimated with a constant, since that effectively implies that household expectations are

[4] Detailed results are shown in Appendix II, Tables A.2a-d.

systematically biased away from experts, together with mixed statistical evidence, we will now turn to estimating model (5) without a constant. This is done in rows "unrestricted 2". Interestingly, this does not much affect the previous conclusions. While the estimates of λ_1 fall somewhat, they remain significant for all countries (at least at 10% level).

Table 3: Baseline Regressions – epidemiology model, 1989 IV to 2004 II

Model	λ_0	λ_1	λ_2
		Germany	
Unrestricted 1	-0.18**	0.30***	0.77***
	(-2.19)	(4.58)	(16.99)
Unrestricted 2	--	0.22***	0.78***
		(5.69)	(23.42)
Restricted	--	0.22***	0.78***
		(3.55)	(12.48)
		France	
Unrestricted 1	-0.06	0.38***	0.55***
	(-0.41)	(4.42)	(6.84)
Unrestricted 2	--	0.35***	0.55***
		(5.03)	(6.60)
Restricted	--	0.21***	0.80***
		(2.63)	(10.18)
		Italy	
Unrestricted 1	-0.22	0.34**	0.74***
	(-1.37)	(2.21)	(7.43)
Unrestricted 2	--	0.23*	0.79***
		(1.84)	(8.39)
Restricted	--	0.18***	0.82***
		(2.74)	(12.85)
		United Kingdom	
Unrestricted 1	-0.61***	0.48***	0.69***
	(-2.61)	(3.91)	(9.29)
Unrestricted 2	--	0.20***	0.79***
		(2.88)	(9.28)
Restricted	--	0.21***	0.79***
		(2.78)	(10.25)

Notes: Equation-by-equation estimation: $E_t^{HH}\pi_{t,t+4} = \lambda_0 + \lambda_1 E_t^{EX}\pi_{t,t+4} + \lambda_2 E_{t-1}^{HH}\pi_{t-1,t+3} + \varepsilon_{t+4}$. Household expectations scaled using the HP-filtered inflation, Newey-West standard errors, 4 lags. "Unrestricted 1" refers to the unrestricted model with a constant, "Unrestricted 2" refers to the model without a constant ($\lambda_0 = 0$), "Restricted" refers to the model with the restrictions $\lambda_0 = 0, \lambda_1 + \lambda_2 = 1$). Models "Unrestricted 1," "Unrestricted 2" and "Restricted" are identical to the models M2, M1 and M3, respectively, described in detail in Appendix II. t statistics are given in the brackets.. *(**, ***) denotes rejection of the null at 10%, 5% and 1% confidence level, respectively.

In addition, as documented in Table A.2 in Appendix II (line M1) the adding up restriction $\lambda_1 + \lambda_2 = 1$ is easily met for three countries (except for France). It is then not surprising that imposing this restriction explicitly in the regressions, as is done in lines labelled “restricted”, results in little additional change in λ_1.

Interestingly, there is little heterogeneity in estimated λ_1 coefficients across countries with all estimates lying closely around 0.2. This is only slightly less than λ_1 = 0.27 estimated by Carroll (2003) and postulated by Mankiw and Reis (2002) for the US.[5] Our baseline estimates in Table 3 therefore imply that the *European households update inflation expectations from experts roughly once in 15 months*, only slightly less frequently than the US households, who do so on average once a year.

Detailed estimation results and specification checks are relegated to Appendix II. Tables A.2a-d show a number of additional interesting results. In particular, it may be asked whether the consumers really update inflation expectations from experts' forecasts or, rather, from past inflation. This can be investigated by adding past inflation among the regressors in equation (4) and testing for its significance (see equation (A.1) in Appendix II). It turns out that this term is not statistically significant in any model considered. This is again in line with Carroll's findings for the US: households are forward-looking rather than backward-looking (adaptive) in that they learn from rational experts rather than simply adopting actual past inflation rates.

Seemingly Unrelated Regression (SUR) Estimation

An obvious advantage of our set-up with four countries is that variants of the above equation (4) can be estimated as a system using seemingly unrelated regressions (SUR). This will improve the efficiency of the estimates if the equation-by-equation residuals are cross-correlated. Since this seems to be the case — the cross-correlation between residuals in our dataset is up to 0.3 — we now turn to estimate the parameters with SUR. In addition to obtaining potentially more efficient estimates, this also makes

[5] Carroll's (2003) sample, 1981:3-2002:1, is slightly different from ours. Re-estimating the model with the US data and our sample range gives λ = 0.22.

it possible to test cross-equation restrictions and answer questions such as "Does the speed of information updating vary across countries?"

The results of our SUR estimation are summarized in Table 4 (and detailed in Tables A.3a-d in Appendix II). The results are broadly similar to those obtained above for the equation-by-equation estimation.

Table 4: Baseline regressions – epidemiology model, SUR Estimation, 1989 IV to 2004 II

Model	λ_0	λ_1	λ_2
		Germany	
Unrestricted 1	-0.21*	0.29***	0.80***
	(-1.78)	(3.68)	(14.10)
Unrestricted 2	--	0.18***	0.82***
		(3.03)	(14.02)
Restricted	--	0.20***	0.80***
		(3.35)	(13.66)
		France	
Unrestricted 1	-0.04	0.33***	0.61***
	(-0.33)	(3.43)	(6.64)
Unrestricted 2	--	0.32***	0.60***
		(4.23)	(6.48)
Restricted	--	0.18***	0.82***
		(2.59)	(11.73)
		Italy	
Unrestricted 1	-0.18	0.25*	0.81***
	(-1.18)	(1.92)	(8.82)
Unrestricted 2	--	0.14	0.86***
		(1.35)	(9.87)
Restricted	--	0.11*	0.89***
		(1.83)	(14.63)
		United Kingdom	
Unrestricted 1	-0.67**	0.53***	0.66***
	(-2.20)	(3.34)	(7.44)
Unrestricted 2	--	0.23***	0.77***
		(2.71)	(10.02)
Restricted	--	0.23***	0.77***
		(3.05)	(10.26)

Notes: Seemingly unrelated regressions $E_t^{HH}\pi_{t,t+4} = \lambda_0 + \lambda_1 E_t^{EX}\pi_{t,t+4} + \lambda_2 E_{t-1}^{HH}\pi_{t-1,t+3} + \varepsilon_{t+4}$ Household expectations scaled using the HP-filtered inflation, Newey-West standard errors, 4 lags. "Unrestricted 1" refers to the unrestricted model with a constant, "Unrestricted 2" refers to the model without a constant ($\lambda_0 = 0$), "Restricted" refers to the model with the restrictions $\lambda_0 = 0,\ \lambda_1 + \lambda_2 = 1$). Models "Unrestricted 1," "Unrestricted 2" and "Restricted" are identical to the models M2, M1 and M3, respectively, described in detail in Appendix II. t statistics are given in the brackets. *(**, ***) denotes rejection of the null at 10%, 5% and 1% confidence level, respectively.

The three main findings remain to hold: (i) the constant λ_0 is typically insignificant (again, except for the UK), (ii) the speed of updating λ_1 is significant (for every country at least at 10% confidence level) and finally (iii), the adding-up restriction $\lambda_1 + \lambda_2 = 1$ holds (again expect for France).

Compared to the above results there is a bit more heterogeneity in the λ_1 coefficients across countries: they lie between 0.11 for Italy and 0.23 for the UK. These imply that Italian households update inflation expectations on average roughly once in two years (27 months), whereas the British ones do so about once a year (13 months). The results reported in Appendix II furthermore confirm the findings from the equation-by-equation set-up on the insensitivity of household expectations with respect to past inflation.

Table 5: Testing cross-equation restrictions

Model		$H_0 : \lambda_1^{Germany} = \lambda_1^{France} = \lambda_1^{Italy} = \lambda_1^{UK}$	$H_0 : \lambda_1^{Germany} = \lambda_1^{France} = \lambda_1^{Italy} = \lambda_1^{UK} = 0.25$
Unr. 1	test stat.	1.78	7.75
	p-value	0.619	0.101
Unr. 2	test stat.	2.81	3.32
	p-value	0.422	0.506
Restr.	test stat.	1.26	5.88
	p-value	0.499	0.419

Note: "Unr. 1" refers to the unrestricted model with a constant, "Unr. 2" refers to the model without a constant ($\lambda_0 = 0$), "Restr." refers to the model with the restrictions $\lambda_0 = 0, \lambda_1 + \lambda_2 = 1$). Models "Unr. 1," "Unr. 2" and "Restr." are identical to the models M2, M1 and M3, respectively, described in detail in Appendix II.

The cross-equation restrictions can easily be tested in the SUR set-up. Table 5 displays two examples. Column two tests the hypothesis that the speed of updating is the same for the four countries considered. Perhaps not surprisingly, the null cannot be rejected. Similarly, the hypothesis that the European households update information on inflation on average once a year, at the same frequency as in the US, seems to hold in our dataset.

Our findings confirm that the epidemiology model of information diffusion performs similarly well, quantitatively as well as quantitatively, for the core European countries as it does for the US. The expert inflation expectations are typically more precise than the household expectations. Econometric tests indicate that the Carroll model is adequate along several dimensions (for example, the speed of updating is positive and statistically significant, the summing-up restriction holds fairly well and household inflation expectations are not sensitive with respect to the past inflation). While several models imply that European households update a bit more slowly than US households, on average once in 15 months compared with once a year, these differences are not pronounced enough to be statistically significant. Finally, there is strong evidence that, as suggested by the epidemiology model, European households update information from the professional forecasters rather than the past inflation rate.[6]

4.3 The nonstationary case: Carroll (2003) model in vector error correction form

Having estimated the epidemiology model in a stationary framework, let us now examine how the implications change when we assume that the expectation series are I(1) instead. Suppose we collect the two series in vector $x_t = (E_{t-1}^{HH}\pi_{t-1,t+3}, E_t^{EX}\pi_{t,t+4})'$. If the two series are cointegrated with cointegrating vector $\alpha = (1 - \alpha_1)'$, the system has the following vector error correction (VEC) representation

$$\Delta x_t = \lambda\, \alpha' x_{t-1} + \beta(L)\Delta x_t + \varepsilon_t, \tag{6}$$

[6] Consideration might be given to the possibility that households update their expectations by referring directly to other publicly available information, such as foreign prices. However, in the epidemiology framework this information is already captured and processed by professional forecasters. Moreover, obtaining such information is presumably much more costly than simply referring to the published professional forecasts.

where $\lambda = (\lambda_{HH}, \lambda_{Ex})'$ denotes the vector of loading coefficient and $\beta(L)$ is a matrix lag polynomial. Similarly to the stationary model (2), λ determines the speed of adjustment to the (long-run) equilibrium. In particular, we are interested in λ_{HH}, which corresponds to the speed of adjustment observed for the households. Furthermore, note that the theoretical derivation of the "epidemiology model" predicts a cointegrating vector $\alpha = (1\ -1)'$. This is due to the fact that, in the long-run, households completely adapt to the professional forecasts.

Before estimating the VEC representation (6) and its 'α-restricted' counterpart some preliminary specification tests need to be done. First, we test whether there exists a valid cointegrating relationship between the expert and (lagged) household expectations. In addition, we check whether the theoretical restriction on α is supported by the data. Detailed results of the Johansen cointegration tests are reported in Table A.4 in Appendix II. They show that, for all four countries, the two series are cointegrated. Furthermore, the values for α_1 are close to –1 (a value predicted by the model) and range from –1.21 for the UK to –1.00 for Germany. In fact, we can formally conclude that α' is not significantly different from (1 –1) as implied by the model, which is justified by the likelihood ratio statistics presented in Table 6.

Table 6: Baseline regressions – epidemiology model, VECM Estimation, 1989 IV to 2004 II

Model		Germany	France	Italy	UK
Unrestricted	$\hat{\lambda}_{HH}$	0.25***	0.28***	0.10***	0.22***
	t stat	(3.24)	(2.68)	(3.91)	(3.95)
Restricted	$\hat{\lambda}_{HH}$	0.26***	0.17**	0.27***	0.30***
	t stat	(3.26)	(2.00)	(3.24)	(3.62)
Test for restriction (1 –1) on α	LR - stat.	0.04	2.38	2.71	3.37
	p-value	(0.84)	(0.12)	(0.10)	(0.07)

Notes: "Unrestricted" refers to the unrestricted VECM,. "Restricted" refers to the VECM estimation results under the restriction $\alpha = (1\ -1)'$. Italy: 1992 II-2002 IV.

The VEC estimations are summarized in Table 7 (and detailed results are presented in Appendix II, Table A.5). The estimated speed of adjustment of the households, λ_{HH}, is remarkably close tothat in the previous section obtained under the assumption of stationarity.[7] All estimates are significant and lie in the neighbourhood of 0.25 – with the exception of Italy for the unrestricted model (0.10) and France for the restricted VECM (0.17). Hence, we again find a huge degree of homogeneity among the four countries with French households updating their inflation expectations on average once every 18 months, British households updating their views on average once every ten months, and the frequencies of Italian and German households lying closely below the British one.

Another point which supports the results of the 'stationary case' is the way in which deviations from the long-term equilibrium are corrected. Owing to the fact that, except for France, the loading coefficients, λ_{Ex}, in the experts' expectation equations are not significantly different from zero, we can conclude that the entire correction process is made via the household expectations. This confirms the earlier finding that expert forecasts Granger-cause the households' expectations, whereas household forecasts do not tend to Granger-cause the forecasts of experts.

With these findings, we show that the epidemiology model of Carroll can be easily extended to the 'non-stationary world'. The derived VEC epidemiology model of information diffusion performs similarly well to the stationary model. This result is especially useful for the analysis of European countries since it is a well-known fact that their inflation rates are more persistent than the US inflation rate. Thus, even though it is difficult to draw clear conclusions about the stationarity properties of the series with the short sample size at hand,[8] our VEC representation might be preferable once more data are available.

[7] In a way, this is perhaps not so surprising given that if there is not much autocorrelation in Δx_t the VEC model (6) is a simple transformation of the restricted stationary model (5) (with $\lambda_0 = 0$ and $\lambda_1 + \lambda_2 = 1$).

[8] This indeterminacy is *ex-post* 'justified' by the similarities between the results from the Carroll model and the results of the VECMs.

5. Conclusions

Inflation expectations are crucial determinants of future inflation dynamics. The model estimated here attempts to analyze how these expectations are formed and how information is transmitted from professional forecasters to households. Our estimates of the speed of information updating have important implications for the persistence of inflation and inflation expectations. We document that the qualitative and quantitative findings previously reported for the US generalize to major European countries. Most European households adjust rather sluggishly to new information; they update their information on average once a year. Interestingly, it turns out that the households are forward-looking in the sense that they use information processed by experts rather than just past information. These findings are robust to a number of estimation methods (suited for data with various stochastic properties) we consider.

We think of this paper as the beginning of a larger research project that can continue through a number of avenues. The survey data could possibly be used to directly estimate the sticky-information Phillips curve in addition to its epidemiological micro-foundations. Alternatively, it would be possible, in the spirit of Mankiw et al (2003), to analyze the micro-data on inflation expectations rather than just their mean values. Finally, the epidemiology model could, in principle, be estimated for additional countries, using cross-sectional dependence among countries to alleviate problems related to short samples.

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Appendix I: Inflation Expectation Data

Expert forecasts

The data on professional forecasts were obtained from Consensus Economics, a private macroeconomic survey firm (http://www.consensuseconomics.com/). The survey of experts of private and public institutions in major industrial countries has been collected monthly since 1989. Once every quarter the questionnaire contains a question on forecasts over the next six quarters. The consensus forecast, used in the paper as a measure of expert expectations, is the mean of about 20 to 30 forecasts of local experts from major banks or research institutes in each country.

Household forecasts

Our measures of household inflation forecasts are based on disaggregated answers to question 6 from European Commission's Harmonised Business and Consumer Surveys. The sample size of the survey is about 2,000 households in Germany, Italy and the UK, and roughly 3,300 households in France. The data are available monthly since 1985 to the present.

Extracting household inflation expectations from the qualitative survey data

To obtain quantitative expectations data from the balance statistics, a rescaling of the data is warranted. The standard method, the "probability method," follows Carlson and Parkin (1975) and its extensions (see, for example, Gerberding (2001), Mankiw et al (2003) and Nielsen (2003)). The observed data are from the pentachotomous survey. Consequently, they classify the responses into five subgroups:

Consumer prices will

- Increase more rapidly
- Increase at the same rate
- Increase at a slower rate
- Stay about the same
- Fall.

Assuming the unobserved inflation expectations are normally distributed, the fractions of responses ${}_tA_{t+1},\ldots,{}_tE_{t+1}$ are observed. Refer to Figure A.1, taken from Nielsen (2003). Batchelor and Orr (1988) derive for pentachotomous surveys how these can be transformed into a measure of inflation expectations ${}_t\mu_{t+1} = \tilde{\mu}_t \times f({}_tA_{t+1},\ldots,{}_tE_{t+1})$ for a known function *f* (see Batchelor and Orr (1988), p. 322, formula (11)).

Figure A.1: Pentachotomous survey

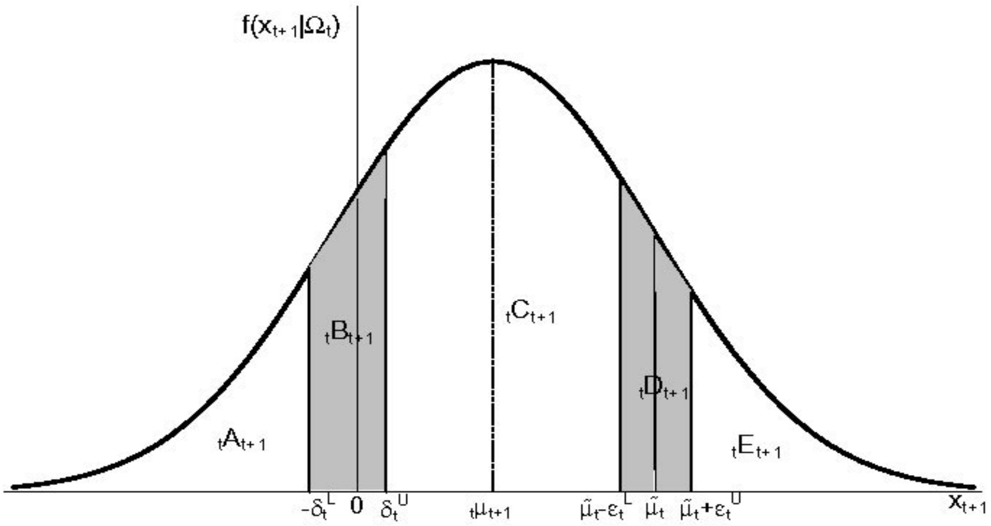


Table A.1: Comparison of RMSEs of alternative inflation expectations

	Germany	France	Italy	United Kingdom
Households				
Past Inflation	1.01	0.72	1.26	1.89
Recursive HP Filter	1.07	0.65	1.29	1.60
Recursive Mean	1.48	0.61	1.31	1.61
Indirect: Past Inflation	2.00	0.72	3.72	3.16
Indirect: Recursive Mean	1.43	0.54	3.67	2.07
Experts	0.85	0.70	0.88	1.17

Note: Time frame: 1989:Q4-2004:Q2, the same ranking holds for 1985:Q1-2004:Q2.

In general, the procedure requires that specification of a variable that captures the perceived current inflation rate, $\tilde{\mu}_t$ to scale the expectations. We investigate a number of alternatives that have been proposed in the literature in Table A.1 and Figure A.2.

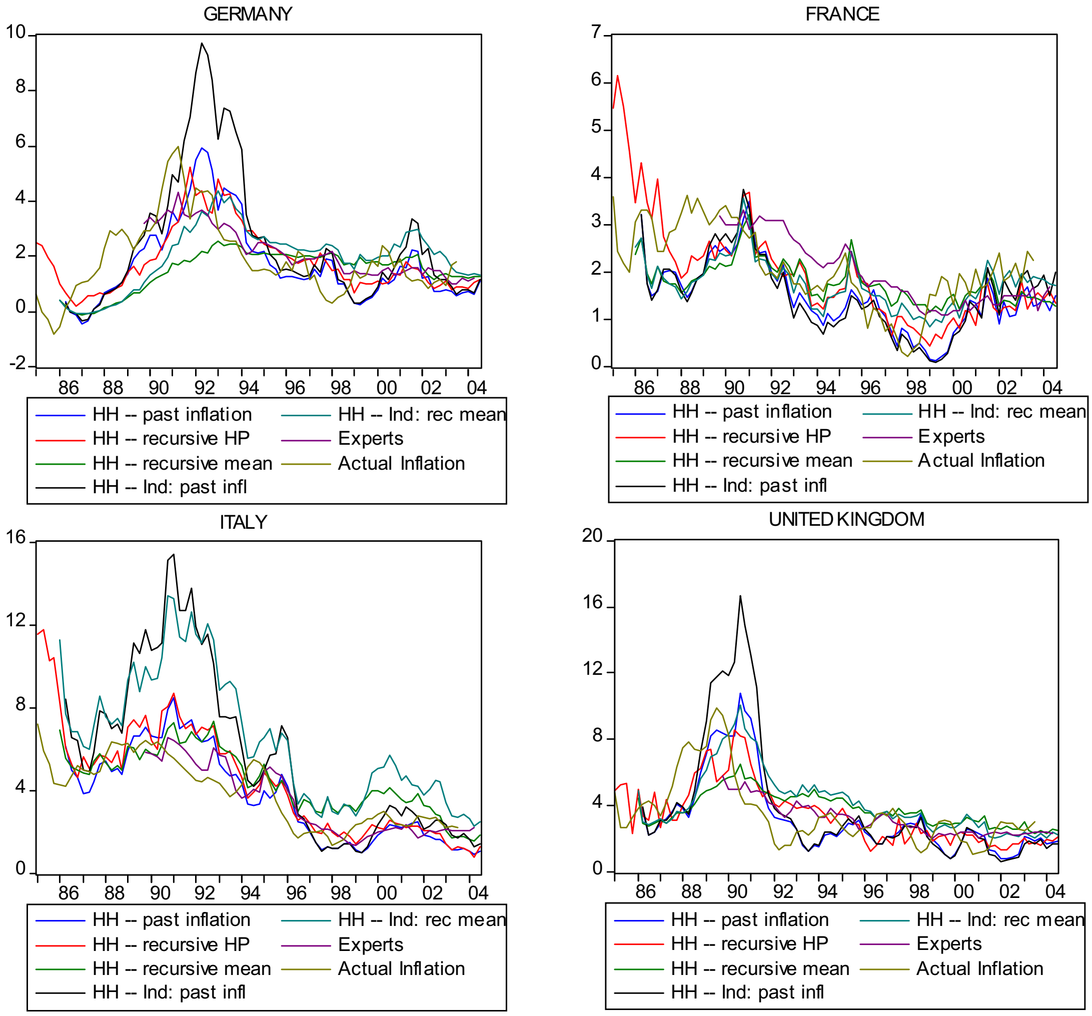
The Table (and Figure) compare(s) the household expectations constructed using the following five normalizations for $\tilde{\mu}_t$: (i) past inflation (over the last year, lagged by one quarter), (ii) inflation trend extracted using the recursive HP filter, (iii) recursive mean of past inflation calculated from the beginning of the sample till the current period, (iv) indirect method, normalized with past inflation and, finally, (v) indirect method, normalized with recursive mean.

The recursive HP filter was calculated using the following quasi-real-time procedure to minimize the well-known end-of-sample problems. For each period, t, we first forecast the underlying inflation process for the next 12 quarters with an ARMA model, selected with the Akaike criterion (maximum number of 4 lags on both AR and MA terms). We then apply the filter on this artificially extended series (with the HP filter with the usual penalty parameter $\lambda_{HP} = 1600$). Finally, we set $\tilde{\mu}_t$ equal to the value of the HP filtered inflation as of time *t*.

An alternative to the above method, proposed by Nielsen (2003), is to make use of the Survey's question 5 on the current perceived inflation ("How do you think that consumer prices have developed over the last 12 months?"). Unfortunately, this does not solve the problem, since the answers are again only qualitative. Consequently, this still requires specifying $\tilde{\mu}_t$, just at an earlier stage. This is investigated in rows four and five of Table A.1.

The Table documents a number of facts. First, the two normalizations of household inflation expectations that typically perform *best* in terms of minimizing the mean squared errors are (i) and (ii): *past inflation and recursive HP filter*. This holds for all countries, except for France, where all normalizations imply comparable RMSEs. Second, the indirect methods (iv) and (v) often imply inflation expectations very different from the actual inflation. This is particularly true in Italy, but also in Germany and the United Kingdom. Third, experts' expectations tend to be substantially more precise than household expectations (irrespective of the normalization). More precisely, the RMSEs of expert expectations are between 15% to 35% lower in Germany, Italy and the UK than for household expectations. The two expectations are comparably precise in France.

Figure A.2: Comparison of alternative inflation expectations



On the basis of these preliminary investigations, we decided to estimate the models with two alternative normalizations of household inflation expectations, using past inflation and recursive HP filter. The reason for this is that these tend to produce plausible-looking forecasts with low RMSEs across the four countries we consider. The results reported in the paper generally hold for alternative normalizations considered.

Appendix II: Detailed results of the epidemiology regressions

The stationary case

Tables A.2a-d and A.3a-d report detailed results alluded to in the main text for equation-by-equation and SUR estimation, respectively. The Tables summarize estimation results of variously restricted versions of the following equation

$$E_t^{HH}\pi_{t,t+4} = \lambda_0 + \lambda_1 E_t^{EX}\pi_{t,t+4} + \lambda_2 E_{t-1}^{HH}\pi_{t-1,t+3} + \lambda_3 \pi_{t-5,t-1} + \varepsilon_t \tag{A.1}$$

The format of the Tables follows that of Carroll (2003), Table III. The left-hand panels (the first four columns) display the point estimates of λs together with t statistics; the right-hand panels show some specification tests (adjusted R^2, the Durbin-Watson statistic and p values of various tests of coefficients). The alternative models are labelled M1-M6.

The first model, M1, estimates the following version of (A.1)

$$E_t^{HH}\pi_{t,t+4} = \lambda_1 E_t^{EX}\pi_{t,t+4} + \lambda_2 E_{t-1}^{HH}\pi_{t-1,t+3} + \varepsilon_t \tag{A.2}$$

in which coefficients λ_1 and λ_2 are estimated as unrestricted. The summing-up restriction implied by the Carroll model, $\lambda_1 + \lambda_2 = 1$ is clearly satisfied in all countries, except for France. However, even there the two coefficients add up to about 0.9, which is arguably very close to 1.

Model M2 is estimated for the restricted version with the summing-up restriction imposed. The point estimates of λ are pretty homogenous both across countries and the two estimation methods ranging from 0.18 to 0.23 and highly significant.[9] These estimates are close to the Carroll's baseline coefficient of 0.27 as well as the value Mankiw and Reis (2002) assume for their model. The alternative estimates of λ thus imply an average speed of updating ranging between 13 and 25 months. In addition, $\lambda = 0.2$ implies that roughly 40% of households use information which is outdated by more than one year and about 17% by more than two years.

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[9] The single exception is the SUR estimate for Italy of 0.11 with the t statistic of 1.83.

Table A.2a: Epidemiology regressions: Germany, stationary equation-by-equation estimation

Model	λ_0	λ_1	λ_2	λ_3	$\overline{R}^2$	DW	*p* val
M0	2.11***	-	-	-	0.00	0.11	$\lambda_0 = 0$
	(6.51)						0.000
M1	-	0.22***	0.78***	-	0.91	2.23	$\lambda_1 + \lambda_2 = 1$
		(5.69)	(23.42)				0.908
M2	-	0.22***	0.78***	-	0.91	2.23	$\lambda_1 = 0.25$
		(3.55)	(12.48)				0.648
M3	-0.18**	0.30***	0.77***	-	0.91	2.35	$\lambda_0 = 0$
	(-2.19)	(4.58)	(16.99)				0.033
M4	-	0.23***	0.81***	-0.04	.0.91	2.19	$\lambda_1 + \lambda_2 + \lambda_3 = 1$
		(5.62)	(10.69)	(-0.47)			0.841
M5	-0.21**	0.33***	0.84***	-0.08	0.91	2.38	$\lambda_3 = 0$
	(-2.23)	(4.82)	(10.23)	(-1.01)			0.318
M6	-	-	0.94***	0.05	0.91	2.16	$\lambda_2 + \lambda_3 = 1$
			(10.71)	(0.55)			0.516

Notes: Equation-by-equation estimation: $E_t^{HH}\pi_{t,t+4} = \lambda_0 + \lambda_1 E_t^{EX}\pi_{t,t+4} + \lambda_2 E_{t-1}^{HH}\pi_{t-1,t+3} + \lambda_3 \pi_{t-5,t-1} + \varepsilon_t$

Household expectations scaled using the HP-filtered inflation, Newey-West standard errors, 4 lags. t statistics are given in the brackets are. *(**, ***) denotes rejection of the null at 10, 5 and 1% confidence level, respectively.

Models M3-M6 investigate a number of alternative structures of household expectations. First, we add a constant to equation (A.2). This turns out to be significantly different from zero only for Germany and the UK. As advocated by Carroll (2003), it is, however, doubtful *a priori* that can be a reasonable structural specification of inflation expectations with a non-zero constant term, since this would imply predictions that are permanently biased away from the truth. Interestingly, all estimates of model M3, however, give us negative values for the constant term λ_0. One reason for that may be, as is apparent from Figure 1, that, over our estimation sample, actual inflation rates were actually falling. In such an environment, some households may have extrapolated this falling trend into the future, which is reflected in the negative values of the constant term.

Table A.2b: Epidemiology regressions: France, stationary equation-by-equation estimation

Model	λ_0	λ_1	λ_2	λ_3	$\overline{R}^2$	DW	*p* val
M0	1.58***	-	-	-	0.00	0.26	$\lambda_0 = 0$
	(8.45)						0.000
M1	-	0.35***	0.55***	-	0.80	1.83	$\lambda_1 + \lambda_2 = 1$
		(5.03)	(6.60)				0.004
M2	-	0.21***	0.80***	-	0.77	2.00	$\lambda_1 = 0.25$
		(2.63)	(10.18)				0.569
M3	-0.06	0.38***	0.55***	-	0.80	1.83	$\lambda_0 = 0$
	(-0.41)	(4.42)	(6.84)				0.683
M4	-	0.32***	0.46***	0.12	0.80	1.84	$\lambda_1 + \lambda_2 + \lambda_3 = 1$
		(4.73)	(3.76)	(1.37)			0.005
M5	-0.07	0.35***	0.45***	0.13	0.80	1.84	$\lambda_3 = 0$
	(-0.59)	(4.28)	(3.83)	(1.49)			0.142
M6	-	-	0.66***	0.27***	0.78	2.14	$\lambda_2 + \lambda_3 = 1$
			(5.31)	(2.69)			0.032

Notes: Equation-by-equation estimation: $E_t^{HH}\pi_{t,t+4} = \lambda_0 + \lambda_1 E_t^{EX}\pi_{t,t+4} + \lambda_2 E_{t-1}^{HH}\pi_{t-1,t+3} + \lambda_3\pi_{t-5,t-1} + \varepsilon_t$

Household expectations scaled using the HP-filtered inflation, Newey-West standard errors, 4 lags. t statistics are given in the brackets are. *(**, ***) denotes rejection of the null at 10, 5 and 1% confidence level, respectively.

Table A.2c: Epidemiology regressions: Italy, stationary equation-by-equation estimation

Model	λ_0	λ_1	λ_2	λ_3	$\overline{R}^2$	DW	*p* val
M0	3.74***	-	-	-	0.00	0.05	$\lambda_0 = 0$
	(5.98)						0.000
M1	-	0.23*	0.79***	-	0.95	1.79	$\lambda_1 + \lambda_2 = 1$
		(1.84)	(8.39)				0.679
M2	-	0.18***	0.82***	-	0.95	1.84	$\lambda_1 = 0.25$
		(2.74)	(12.85)				0.251
M3	-0.22	0.34**	0.74***	-	0.95	1.79	$\lambda_0 = 0$
	(-1.37)	(2.21)	(7.43)				0.176
M4	-	0.37***	0.80***	-0.14	0.95	1.87	$\lambda_1 + \lambda_2 + \lambda_3 = 1$
		(2.72)	(9.74)	(-1.44)			0.446
M5	-0.15	0.40***	0.76***	-0.10	0.95	1.84	$\lambda_3 = 0$
	(-0.72)	(2.67)	(6.82)	(-0.72)			0.477
M6	-	-	0.96***	0.02	0.92	1.96	$\lambda_2 + \lambda_3 = 1$
			(15.20)	(0.28)			0.190

Notes: Equation-by-equation estimation: $E_t^{HH}\pi_{t,t+4} = \lambda_0 + \lambda_1 E_t^{EX}\pi_{t,t+4} + \lambda_2 E_{t-1}^{HH}\pi_{t-1,t+3} + \lambda_3\pi_{t-5,t-1} + \varepsilon_t$

Household expectations scaled using the HP-filtered inflation, Newey-West standard errors, 4 lags. t statistics are given in the brackets are. *(**, ***) denotes rejection of the null at 10%, 5% and 1% confidence level, respectively.

Models M4-M6 investigate the possibility that consumers are, at least in part, backward-looking (adaptive) by adding past inflation on the right-hand side of (A.2). Similarly to the US, there is very little of the backward-looking element in household inflation expectations: the coefficient λ_3 is small both in terms of its size and its level of significance.

Table A.2d: Epidemiology regressions: United Kingdom, stationary equation-by-equation estimation

Model	λ_0	λ_1	λ_2	λ_3	$\overline{R}^2$	DW	*p* val
M0	3.10***	-	-	-	0.00	0.13	$\lambda_0 = 0$
	(6.60)						0.000
M1	-	0.20***	0.79***	-	0.88	1.99	$\lambda_1 + \lambda_2 = 1$
		(2.88)	(9.28)				0.788
M2	-	0.21***	0.79***	-	0.88	1.98	$\lambda_1 = 0.25$
		(2.78)	(10.24)				0.638
M3	-0.61**	0.48***	0.69***	-	0.89	1.99	$\lambda_0 = 0$
	(-2.16)	(3.91)	(9.29)				0.035
M4	-	0.20***	0.72***	0.07	0.88	1.94	$\lambda_1 + \lambda_2 + \lambda_3 = 1$
		(2.71)	(9.27)	(1.00)			0.628
M5	-0.61**	0.48***	0.62***	0.07	0.89	1.94	$\lambda_3 = 0$
	(-2.32)	(3.99)	(6.55)	(1.22)			0.229
M6	-	-	0.88***		0.08	0.81	2.08 $\lambda_2 + \lambda_3 = 1$
			(11.69)		(0.97)		0.225

Notes: Equation-by-equation estimation: $E_t^{HH}\pi_{t,t+4} = \lambda_0 + \lambda_1 E_t^{EX}\pi_{t,t+4} + \lambda_2 E_{t-1}^{HH}\pi_{t-1,t+3} + \lambda_3 \pi_{t-5,t-1} + \varepsilon_t$

Household expectations scaled using the HP-filtered inflation, Newey-West standard errors, 4 lags. t statistics are given in the brackets are. *(**, ***) denotes rejection of the null at 10%, 5% and 1% confidence level, respectively.

Table A.3a: Epidemiology regressions: Germany, stationary SUR estimation

Model	λ_0	λ_1	λ_2	λ_3	$\overline{R}^2$	*p* val
M0	2.11***	-	-	-	0.00	$\lambda_0 = 0$
	(13.95)					0.000
M1	-	0.18***	0.82***	-	0.98	$\lambda_1 + \lambda_2 = 1$
		(3.04)	(14.02)			0.764
M2	-	0.20***	0.80***	-	0.98	$\lambda_1 = 0.25$
		(3.35)	(13.67)			0.368
M3	-0.21*	0.29***	0.80***	-	0.91	$\lambda_0 = 0$
	(-1.78)	(3.68)	(14.11)			0.075
M4	-	0.19***	0.84***	-0.02	0.93	$\lambda_1 + \lambda_2 + \lambda_3 = 1$
		(3.06)	(8.79)	(-0.22)		0.745
M5	-0.23*	0.30***	0.85***	-0.05	0.91	$\lambda_3 = 0$
	(-1.80)	(3.58)	(8.96)	(-0.62)		0.538
M6	-	-	0.92***	0.06	0.93	$\lambda_2 + \lambda_3 = 1$
			(9.57)	(0.71)		0.299

Notes: SUR estimation: $E_t^{HH}\pi_{t,t+4} = \lambda_0 + \lambda_1 E_t^{EX}\pi_{t,t+4} + \lambda_2 E_{t-1}^{HH}\pi_{t-1,t+3} + \lambda_3\pi_{t-5,t-1} + \varepsilon_t$

Household expectations scaled using the HP-filtered inflation, Newey-West standard errors, 4 lags. t statistics are given in the brackets are. *(**, ***) denotes rejection of the null at 10%, 5% and 1% confidence level, respectively.

Table A.3b: Epidemiology regressions: France, stationary SUR estimation

Model	λ_0	λ_1	λ_2	λ_3	$\overline{R}^2$	*p* val
M0	1.58***	-	-	-	0.00	$\lambda_0 = 0$
	(17.22)					0.000
M1	-	0.32***	0.60***	-	0.97	$\lambda_1 + \lambda_2 = 1$
		(4.23)	(6.48)			0.002
M2	-	0.18***	0.82***	-	0.96	$\lambda_1 = 0.25$
		(2.59)	(11.73)			0.322
M3	-0.04	0.33***	0.61***	-	0.80	$\lambda_0 = 0$
	(-0.33)	(3.43)	(6.64)			0.741
M4	-	0.30***	0.48***	0.11	0.86	$\lambda_1 + \lambda_2 + \lambda_3 = 1$
		(3.69)	(3.94)	(1.08)		0.000
M5	-0.05	0.32***	0.52***	0.09	0.81	$\lambda_3 = 0$
	(-0.37)	(3.21)	(4.12)	(0.87)		0.386
M6	-	-	0.66***	0.26**	0.92	$\lambda_2 + \lambda_3 = 1$
			(5.53)	(2.54)		0.005

Notes: SUR estimation: $E_t^{HH}\pi_{t,t+4} = \lambda_0 + \lambda_1 E_t^{EX}\pi_{t,t+4} + \lambda_2 E_{t-1}^{HH}\pi_{t-1,t+3} + \lambda_3\pi_{t-5,t-1} + \varepsilon_t$

Household expectations scaled using the HP-filtered inflation, Newey-West standard errors, 4 lags. t statistics are given in the brackets are. *(**, ***) denotes rejection of the null at 10%, 5% and 1% confidence level, respectively.

Table A.3c: Epidemiology regressions: Italy, stationary SUR estimation

Model	λ_0	λ_1	λ_2	λ_3	$\overline{R}^2$	*p* val
M0	3.74***	-	-	-	0.00	$\lambda_0 = 0$
	(12.86)					0.000
M1	-	0.14	0.86***	-	0.99	$\lambda_1 + \lambda_2 = 1$
		(1.35)	(9.87)			0.991
M2	-	0.11*	0.89***	-	0.99	$\lambda_1 = 0.25$
		(1.83)	(14.63)			0.022
M3	-0.18	0.25*	0.81***	-	0.95	$\lambda_0 = 0$
	(-1.18)	(1.92)	(8.82)			0.239
M4	-	0.28**	0.87***	-0.14	0.95	$\lambda_1 + \lambda_2 + \lambda_3 = 1$
		(1.99)	(10.22)	(-1.49)		0.751
M5	-0.07	0.30**	0.85***	-0.12	0.95	$\lambda_3 = 0$
	(-0.41)	(2.11)	(8.92)	(-1.06)		0.287
M6	-	-	0.96***	0.01	0.93	$\lambda_2 + \lambda_3 = 1$
			(15.03)	(0.07)		0.064

Notes: SUR estimation: $E_t^{HH}\pi_{t,t+4} = \lambda_0 + \lambda_1 E_t^{EX}\pi_{t,t+4} + \lambda_2 E_{t-1}^{HH}\pi_{t-1,t+3} + \lambda_3\pi_{t-5,t-1} + \varepsilon_t$

Household expectations scaled using the HP-filtered inflation, Newey-West standard errors, 4 lags. t statistics are given in the brackets are. *(**, ***) denotes rejection of the null at 10%, 5% and 1% confidence level, respectively.

Table A.3d: Epidemiology regressions: United Kingdom, stationary SUR estimation

Model	λ_0	λ_1	λ_2	λ_3	$\overline{R}^2$	*p* val
M0	3.10***	-	-	-	0.00	$\lambda_0 = 0$
	(13.70)					0.000
M1	-	0.23***	0.77***	-	0.97	$\lambda_1 + \lambda_2 = 1$
		(2.71)	(10.02)			0.763
M2	-	0.23***	0.77***	-	0.97	$\lambda_1 = 0.25$
		(3.05)	(10.27)			0.781
M3	-0.67**	0.53***	0.66***	-	0.89	$\lambda_0 = 0$
	(-2.20)	(3.34)	(7.44)			0.028
M4	-	0.21*** (2.58)	0.71*** (6.66)	0.07 (0.95)	0.90	$\lambda_1 + \lambda_2 + \lambda_3 = 1$
						0.612
M5	-0.65** (-2.14)	0.51*** (3.23)	0.60*** (5.28)	0.07 (0.96)	0.89	$\lambda_3 = 0$
						0.336
M6	-	-	0.88*** (11.56)	0.08 (1.03)	0.84	$\lambda_2 + \lambda_3 = 1$
						0.083

Notes: SUR estimation: $E_t^{HH}\pi_{t,t+4} = \lambda_0 + \lambda_1 E_t^{EX}\pi_{t,t+4} + \lambda_2 E_{t-1}^{HH}\pi_{t-1,t+3} + \lambda_3 \pi_{t-5,t-1} + \varepsilon_t$

Household expectations scaled using the HP-filtered inflation, Newey-West standard errors, 4 lags. t statistics are given in the brackets are. *(**, ***) denotes rejection of the null at 10%, 5% and 1% confidence level, respectively.

The non-stationary case

Table A.4: Tests for cointegration between household and expert expectations

GERMANY				
Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5% Critical Value	Prob.*
None	0.20	16.31	12.32	0.01
At most 1	0.06	3.48	4.13	0.07
Normalized cointegrating coefficients (standard error in parentheses)				
Experts	Households			
1	-1.00			
	(0.064)			
FRANCE				
Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5% Critical Value	Prob.*
None	0.22	15.92	12.32	0.01
At most 1	0.03	1.96	4.13	0.19
Normalized cointegrating coefficients (standard error in parentheses)				
Experts	Households			
1	-1.16			
	(0.066)			
ITALY				
Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5% Critical Value	Prob.*
None	0.36	21.69	12.32	0.00
At most 1	0.09	3.65	4.13	0.07
Normalized cointegrating coefficients (standard error in parentheses)				
Experts	Households			
1	-1.16			
	(0.069)			
UNITED KINGDOM				
Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5% Critical Value	Prob.*
None	0.25	18.90	12.32	0.00
At most 1	0.05	2.60	4.13	0.13
Normalized cointegrating coefficients (standard error in parentheses)				
Experts	Households			
1	-1.21			
	(0.096)			

*MacKinnon-Haug-Michelis (1999) p-values

Table A.5: Epidemiology Regressions: VECM Estimation

Country		GERMANY				FRANCE		
Model	restr.		unrestr.		restr.		unrestr.	
Dep. Var.	ΔE^{HH}	ΔE^{EX}	ΔE^{HH}	ΔE^{EX}	ΔE^{HH}	ΔE^{EX}	ΔE^{HH}	ΔE^{EX}
α_0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
α_1	-1.00	-1.00	-1.02***	-1.02***	-1.00	-1.00	-1.14***	-1.14***
	-	-	(-12.21)	(-12.21)	-	-	(-17.01)	(-17.01)
λ_1/λ_2	0.26***	0.05	0.25***	0.05	0.17**	-0.12***	0.28***	-0.15**
	(3.26)	(1.22)	(3.24)	(1.39)	(2.00)	(-2.63)	(2.68)	(-2.55)
$\beta_{11}(1)/\beta_{12}(1)$	-0.01	0.09	-0.01	0.09	-0.09	-0.01	-0.01	-0.03
	(-0.03)	(1.38)	(-0.00)	(1.42)	(-0.71)	(-0.11)	(-0.07)	(-0.42)
$\beta_{11}(2)/\beta_{12}(2)$	0.16	0.03	0.16	0.03	-0.10	-0.09	-0.04	-0.11
	(1.23)	(0.39)	(1.27)	(0.43)	(-0.80)	(-1.35)	(-0.32)	(-1.53)
$\beta_{21}(1)/\beta_{22}(1)$	-0.33	0.15	-0.35	0.15	0.43*	-0.07	0.32	-0.02
	(-1.14)	(1.07)	(-1.19)	(1.01)	(1.70)	(-0.54)	(1.28)	(-0.14)
$\beta_{21}(2)/\beta_{22}(2)$	-0.09	-0.28**	-0.09	-0.29**	1.06***	-0.12	0.98***	-0.07
	(-0.30)	(-1.96)	(-0.32)	(-2.02)	(4.05)	(-0.88)	(3.85)	(-0.522)

Table A.5, cont.: Epidemiology Regressions: VECM Estimation

Country	ITALY				UNITED KINGDOM			
Model	restr.		unrestr.		restr.		unrestr.	
Dep. Var.	ΔE^{HH}	ΔE^{EX}	ΔE^{HH}	ΔE^{EX}	ΔE^{HH}	ΔE^{EX}	ΔE^{HH}	ΔE^{EX}
α_0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
α_1	-1.00	-1.00	-1.39***	-1.39	-1.00	-1.00	-1.19***	-1.19***
	-	-	(-10.33)	(-10.33)	-	-	(-12.99)	(-12.99)
λ_1/λ_2	0.27***	-0.03	0.10	0.03	0.30***	0.03	0.22***	0.05
	(3.24)	(-0.30)	(3.91)	(0.96)	(3.62)	(0.68)	(3.95)	(1.53)
$\beta_{11}(1)/\beta_{12}(1)$	0.12	0.58***	-0.07	0.57***	0.02	0.06	-0.02	0.07
	(0.84)	(3.82)	(-0.55)	(3.86)	(0.17)	(1.03)	(-0.22)	(1.16)
$\beta_{11}(2)/\beta_{12}(2)$	-0.43***	-0.20	-0.53***	-0.22	0.12	-0.04	0.09	-0.03
	(-3.45)	(-1.47)	(-4.47)	(-1.62)	(1.06)	(-0.65)	(0.83)	(-0.55)
$\beta_{11}(3)/\beta_{12}(3)$	-0.11	0.39***	-0.24*	0.36**	0.11	0.09	0.08	0.09
	(-0.86)	(2.67)	(-1.87)	(2.42)	(0.95)	(1.41)	(0.70)	(1.61)
$\beta_{11}(4)/\beta_{12}(4)$	0.04	-0.19	-0.03	-0.24*	-	-	-	-
	(0.40)	(-1.55)	(-0.29)	(-1.89)	-	-	-	-
$\beta_{21}(1)/\beta_{22}(1)$	0.52***	0.32**	0.59***	0.27*	-0.10	0.01	-0.16	-0.03
	(3.83)	(2.11)	(4.85)	(1.95)	(-0.36)	(0.09)	(-0.57)	(-0.19)
$\beta_{21}(2)/\beta_{22}(2)$	-0.24	-0.34*	-0.11	-0.35**	-0.07	-0.14	-0.10	-0.17
	(-1.48)	(-1.93)	(-0.73)	(-2.06)	(-0.25)	(-0.93)	(-0.39)	(-1.21)
$\beta_{21}(3)/\beta_{22}(3)$	0.33**	0.27	0.41***	0.27	0.27	-0.07	0.18	-0.12
	(2.17)	(1.63)	(2.90)	(1.62)	(1.07)	(-0.55)	(0.71)	(-0.91)
$\beta_{21}(4)/\beta_{22}(4)$	0.20	-0.60***	0.30**	-0.61***	-	-	-	-
	(1.34)	(-3.65)	(2.12)	(-3.80)	-	-	-	-

Notes: *, **, and *** indicate significance at the 10%, 5%, and 1% confidence level. The number of lags in *β(L)* was chosen, based on significance, equal to 2 for Germany and France, 4 for Italy and 3 for the UK.

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