Sticky prices in theory and practice

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Are prices sticky?

Aggregate price rigidity

Sticky prices is the distinguishing feature of Keynesian models. The new classical economists were discontent with the lack of micro foundations for the stickiness in prices. One would like to have the sticky prices explained as the result of firms' optimizing behavior. The New Keynesian models should be seen as an attempt to develop the models in this respect.

A number of studies have analyzed price rigidity in practice. This have been done with quite different methods, such as in structural models, time series models or by survey methods or interviews. In later years studies have been done as part of the Keynesian paradigm. That could be said about the studies done by (Assarsson, B. 1989), (Blinder, A. S. 1991, Blinder, A. S. and et al. 1998, Blinder, A. S. and N. G. Mankiw 1994), (Alvarez, L. J. 2006) and (Apel, M., R. Friberg and K. Hallsten 2005).

A simple way to uncover the rigidity in prices at the aggregate level was done by (Gordon, R. J. 1981) and goes as follows. Denote nominal GDP by $V \equiv P \cdot Y$ and $v \equiv p + q$ the corresponding log differences. Define q^* as the trend growth rate of output, $\hat{y} \equiv y - y^*$ as the relative change in the output gap and $\hat{v} \equiv v - q^*$ as a nominal shock. We then can specify the price equation

$$p = \alpha \hat{v} \tag{1}$$

and by definition it follows that

$$\hat{y} = (1-\alpha)\hat{v} \tag{2}$$

such that output gaps will depend on the degree of price flexibility α. The interpretation is then that the effects of a nominal shock is divided between a price response and an output gap, the division depending on the degree of price rigidity $1-\alpha$. This could be estimated econometrically in the equation

$$p_t = \overline{\alpha} + \sum_{i=0}^{n} \alpha_i \hat{v}_{t-i} + \varepsilon_t \tag{3}$$

and we can measure the degree of price flexibility with the value of $\sum \alpha_i$. In the long run equilibrium this value should be unity, such that the natural rate hypothesis holds and the growth rate of output equals the growth rate in trend or potential output. Gordon estimated such equations for the US during 1892-1979. Below I show results for a number of countries during the period 1970-1999. In the beginning of the 1990s several countries converted from a high to a low inflation regime and possibly also to inflation targeting. I show estimates of price rigidity for both periods. Table 1

Table 2. Summary statistics for inflation in various countries and time periods. Annual percentage change for the period 1965:1 – 1989:4.

Area	Common	Austria	Belgium	Canada	Denmark	Finland	France
Mean	0.078574	0.051078	0.052399	0.059630	0.070137	0.080045	0.075377
Max	0.286207	0.104985	0.133739	0.153355	0.119552	0.152457	0.148118
Min	-0.036530	0.012467	0.006849	0.010753	0.029112	0.013697	0.012852
Std dev	0.055723	0.022951	0.026211	0.033264	0.024243	0.030073	0.034344
Area	**Germany**	**Greece**	**Ireland**	**Italy**	**Japan**	**Netherl**	**Portugal**
Mean	0.040299	0.118674	0.094145	0.131464	0.052051	0.027359	0.126676
Max	0.087441	0.262978	0.225859	0.229658	0.220286	0.077939	0.276252
Min	0.004975	0.009211	0.015179	0.055804	-0.004507	-0.036530	-0.008658
Std dev	0.019479	0.073757	0.054779	0.055417	0.044171	0.025262	0.084564
Area	**Spain**	**Sweden**	**UK**	**USA**			
Mean	0.125843	0.073643	0.088737	0.049218			
Max	0.245387	0.148200	0.286207	0.109160			
Min	0.040686	0.023388	0.023346	0.009631			
Std dev	0.049797	0.030163	0.058947	0.025337			

Table 1. Summary statistics on inflation 1965 – 1989.

summarizes the inflation records for the period 1965-1989 as compared to the period 1990-1998 in Table 2 below. The rate of inflation is generally lower during the later period, reflecting the change of monetary policy regime between the two time periods.

Table 3. Summary statistics for inflation in various countries and time periods. Annual percentage change for the period 1990:1 – 1998:4

Area	Common	Austria	Belgium	Canada	Denmark	Finland	France
Mean	0.034140	0.025881	0.023176	0.014867	0.018740	0.022917	0.019002
Max	0.214530	0.046457	0.040363	0.037118	0.049630	0.078459	0.034949
Min	0.021989	0.006048	0.001831	0.007156	0.015166	0.005894	0.000964
Std dev	0.034292	0.011242	0.009981	0.011389	0.011343	0.017135	0.008018
Area	**Germany**	**Greece**	**Ireland**	**Italy**	**Japan**	**Netherl**	**Portugal**
Mean	0.028996	0.122971	0.019488	0.048764	0.006229	0.021226	0.070235
Max	0.095754	0.214530	0.049275	0.099086	0.030754	0.040179	0.132927
Min	0.005964	0.029318	-0.016732	0.016252	-0.021989	0.006667	0.019249
Std dev	0.021097	0.053740	0.016335	0.021936	0.013819	0.006851	0.037366
Area	**Spain**	**Sweden**	**UK**	**USA**			
Mean	0.045260	0.032518	0.036783	0.025318			
Max	0.073612	0.100141	0.086482	0.046545			
Min	0.002865	-0.002962	0.006107	0.008921			
Std dev	0.021208	0.029733	0.020834	0.010293			

Table 2. Summary statistics on inflation 1990 – 1998.

It is also notable that the standard deviation of inflation is lower in the later period for almost all countries, a phenomenon observed by several economists, e.g. see (Taylor, J. B. 1981). This has been used as an argument by both central banks and academic economists for a low inflation rate; a high variability distorts the information content of the price system and makes people mix up absolute and relative prices. High inflation might also increase the frequency of price changes as shown by e.g. (Sheshinsky, E. and Y. Weiss 1977).

Table 10. Estimates of α for selected countries and time periods.			
Country	α first five quarters	α second year	α after two years
Austria 1972:2 – 1999:1	0.626	0.365	0.991
Belgium 1963:2 – 1998:4	0.829	0.177	1.006
Canada 1963:2 – 1999:1	0.677	0.306	0.983
Denmark 1979:2 – 1999:1	0.687	0.229	0.916
Finland 1977:2 – 1998:4	0.555	0.293	0.848
France 1967:2 – 1999:1	0.728	0.241	0.969
Germany 1967:2 – 1999:1	0.499	0.310	0.809
Greece 1963:2 1998:4	1.000	0.033	1.033
Ireland 1963:2 – 1998:4	0.889	0.079	0.968
Italy 1972:2 – 1999:1	0.874	0.135	1.009
Japan 1967:2 – 1999:1	0.847	0.154	1.001
Netherlands 1979:2 – 1998:4	0.731	0.097	0.828
Portugal 1963:2 – 1999:1	0.847	0.116	0.963
Spain 1972:2 – 1999:1	0.911	0.131	1.042
Sweden 1963:2 – 1998:4	0.667	0.332	0.999
United Kingdom 1965:2 – 1999:1	0.993	-0.002	0.991
USA 1963:2 – 1999:1	0.491	0.444	0.935

Table 3. Estimates of price rigidity for selected countries and time periods.

Table 11. Estimates of α for selected countries before 1990.			
Country	α first five quarters	α second year	α after two years
Austria 1972:2 – 1989:4	0.612	0.340	0.952
Belgium 1963:2 – 1989:4	0.898	0.094	0.992
Canada 1963:2 – 1989:4	0.689	0.274	0.963
Denmark 1979:2 – 1989:4	0.535	0.116	0.651
Finland 1977:2 – 1989:4	0.616	0.410	1.026
France 1967:2 – 1989:4	0.724	0.191	0.915
Germany 1967:2 – 1989:4	0.504	0.307	0.811
Greece 1963:2 - 1989:4	1.026	0.000	1.026
Ireland 1963:2 – 1989:4	0.939	0.050	0.989
Italy 1972:2 – 1989:4	0.911	0.115	1.026
Japan 1967:2 – 1989:4	0.988	0.059	1.047
Netherlands 1979:2 – 1989:4	0.784	0.083	0.867
Portugal 1963:2 – 1999:1	0.873	0.085	0.958
Spain 1972:2 – 1989:4	0.952	0.156	1.108
Sweden 1963:2 – 1989:4	0.681	0.301	0.982
United Kingdom 1965:2 – 1989:4	1.013	-0.030	0.983
USA 1963:2 – 1989:4	0.443	0.428	0.871

Table 4. Estimates of price rigidity for periods before 1990.

Table 12. Estimates of α for selected countries after 1989.			
Country	α first five quarters	α second year	α after two years
Austria 1990:1 – 1999:1	0.703	0.422	1.125
Belgium 1990:1 – 1998:4	0.321	0.281	0.603
Canada 1990:1 – 1999:1	0.358	0.446	0.804
Denmark 1990:1 – 1999:1	0.665	0.323	0.989
Finland 1990:1 – 1998:4	0.266	0.283	0.549
France 1990:1 – 1999:1	0.293	0.384	0.677
Germany 1990:1 – 1999:1	0.486	0.294	0.780
Greece 1990:1 - 1998:4	0.624	0.540	1.164
Ireland 1990:1 – 1998:4	0.083	-0.513	-0.429
Italy 1990:1 – 1999:1	0.688	0.307	0.995
Japan 1990:1 – 1999:1	0.192	0.671	0.863
Netherlands 1990:1 – 1998:4	0.143	0.160	0.303
Portugal 1990:1 – 1999:1	0.668	0.239	0.907
Spain 1990:1 – 1999:1	0.888	0.187	1.075
Sweden 1990:1 – 1998:4	0.401	0.390	0.791
United Kingdom 1990:1 – 1999:1	0.458	0.744	1.202
USA 1990:1 – 1999:1	0.701	0.474	1.175

Table 5. Estimates of price rigidity for periods after 1990.

Tables 3-5 summarize the evidence from estimating equation (3). Table 3 shows the estimates for selected countries and time periods. The estimation results vary both across countries and time periods. The flexibility parameter for the first 5 quarters varies between 0.5 and 1 and for the second year (quarters 6-9) between 0 and 0.4. The price adjustment is approximately complete ($\alpha = 1$) after two years for almost all countries. Looking at the differences between the two periods with different monetary policy regimes it is apparent that prices are more flexible in the earlier than in the later period for most of the countries. Exceptions are Austria, Denmark, Greece and the US. Neither Denmark nor the US applied inflation targeting. For almost all the inflation targeting countries prices have become stickier during the low-inflation regime. Such behavior is consistent with a state dependent pricing model. Low inflation implies a low frequency of price changes since the difference

between the actual and the optimal price increase less over time. Therefore, the cost of keeping prices fixed is reduced and firms choose longer contracts (intervals with fixed prices). This has apparently been the case in the Swedish labor market.

Stickier prices also imply a larger impact from monetary policy on the real economy. A monetary shock will have a larger impact on the real economy; the distribution of relative prices and hence on the allocation of resources. Therefore, low inflation also implies a larger scope for monetary policy.

Asking about prices

A number of studies are based on interviews with firms. They report considerable stickiness in prices and a fairly low frequency of price changes, though this differs a lot between goods, firms, countries and time periods. Results are reported about

- ✓ frequency of price changes
- ✓ duration of price interval
- ✓ asymmetry of price change
- ✓ factors determining price
- ✓ price adjustment costs
- ✓ type of contract
- ✓ type of good, service

(Bils, M. and P. J. Klenow 2004) examined the frequency of price changes for 350 categories of goods and services covering about 70 percent of consumer spending for the period 1995-97. They found much more frequent price changes than in previous studies, with half of prices lasting less than 4.3 months. Even excluding temporary price cuts, they found that half of prices lasted 5.5 months or less. They also found that the frequency of price changes differed dramatically across goods. Their conclusion was the compared to the predictions of many sticky-price models, actual inflation rates are far more volatile and transient for sticky-price goods.

(Blinder, A. S. 1991) and (Blinder, A. S. and et al. 1998) report results from a survey study on pricing in the US.

(Apel, M., R. Friberg and K. Hallsten 2005) presents results from a survey study on price-setting behavior conducted on a large random sample of Swedish firms. The median firm adjusted the price once a year. State- and time-dependent price setting were about equally important. The four highest-ranked explanations for price rigidity in their study:

- ✓ implicit contracts
- ✓ sluggish costs
- ✓ explicit contracts
- ✓ the kinked demand curve

were similar to the top five places in two similar large-scale surveys carried out in the UK and the US by (Hall, S., M. Walsh and A. Yates 2000) and (Blinder, A. S. and et al. 1998), respectively. The results pointed to the importance of the long-term relations with customers for the rigidity of prices (the estimated share of sales that went to regular customers was more than 80%).

(Baharad, E. and B. Eden 2004) use a large unpublished data set with store prices on 381 products collected by the Israeli Bureau of Statistics during 1991-1992 in the CPI computing process. On average 24% of the stores changed their price within a month. Using the standard calculation this would imply that on average prices remain unchanged for 4.1 months. According to Baharad and Eden this may be biased and their best estimate suggests that prices remain unchanged on average for 7.9 months. They also find no evidence that price rigidity as measured by the frequency of nominal price changes is related to price dispersion, which is commonly assumed in standard versions of the staggered price setting model.

Based upon a large fraction of the price records used for computing the French CPI, (Baudry, L., H. Le Bihan, P. Sevestre and S. Tarrieu 2004) documented consumer price rigidity in France. The average estimated duration of prices in the sectors covered by the database (65% of CPI) was around 8 months. Heterogeneity across sectors both in the average duration of prices and in the pattern of price setting was found. There were no clear evidence of downward nominal rigidity, since price cuts were almost as frequent as price increases. They also found clear evidence of both time-dependent and state-dependent price setting behaviors by retailers, consistent with other studies.

(Alvarez, L. J. 2006) summarized the evidence on micro price-setting recently obtained for the EMU countries. They considered studies with micro data on consumer and producer prices, as well as survey information. The main findings were that

- ✓ in the euro area are sticky and stickier than in the US
- ✓ downward price rigidity is only slightly more marked than upward price rigidity
- ✓ heterogeneity and asymmetries are observed in price-setting
- ✓ the relevance of theories that explain price stickiness, such as implicit or explicit contracts, marginal costs, and coordination failure, is confirmed, whereas menu costs, pricing thresholds, and costly information explanations are judged much less relevant by firms

(Levy, D. 2006) summarizes fourteen empirical studies of price rigidity that are included in the special issue of *Managerial and Decision Economics* No. 6, 2007.

To summarize, there are evidence of sticky prices both on the micro and the macro level. This calls into question whether the sticky prices are harmful to the economy.

The consequences of sticky prices

In the basic new Keynesian macro model, as exposed for instance in (Gali, J. 2008) or (Woodford, M. 2003), sticky prices yields a inefficiency in the economy that the monetary authority may accommodate. In the (Calvo, G. A. 1983) model, so often used in the new models, this is clearly the case. Two questions arise in this context:

- ✓ Do sticky prices create large inefficiencies/cycles?
- ✓ Are sticky prices necessarily harmful?
- ✓ Do sticky prices at the micro level always imply sticky prices on the aggregate level?

The answers to these questions are: it can, no and no.

(Bils, M. and P. J. Klenow 2004) find that the frequency of price changes differs dramatically across goods but is moderate on average. Compared to the common predictions of sticky-price models, actual inflation rates are far more volatile and transient for sticky-price goods.

(Bils, M., P. J. Klenow and O. Kryvtsov 2003) show that in models with sticky prices monetary policy changes will affect relative prices and relative quantities in the short run because some prices are more flexible than others. In US micro data, the degree of price stickiness differs dramatically across consumption categories. Their study exploits that diversity to ask whether popular measures of monetary shocks (for example, innovations in the federal funds rate) have the predicted effects. The study finds that they do not. Short-run responses of relative prices have the wrong sign and monetary policy shocks seem to have persistent effects on both relative prices and relative quantities, rather than the transitory effects one would expect from differences in price flexibility across goods. The findings reject the joint hypothesis that the sticky-price models typically employed in policy analysis capture the US economy and that commonly used monetary policy shocks represent exogenous shifts.

As shown by (Klenow, P. J. and J. L. Willis 2007), in the US and Europe, prices change at least once a year. However, according to some studies nominal macro shocks seem to have real effects lasting well beyond a year (see (Mankiw, N. G. and R. Reis 2002)) that can reconcile micro flexibility with macro rigidity. Klenow and Willis simulated a sticky information model in which price setters update information on macro shocks less frequently than information on micro shocks. They examined price changes in the micro data underlying the US CPI and found that price changes reacted to old information, just as sticky information models predict.

(Wang, P.-f. and Y. Wen 2006) show that price rigidity is an important mechanism for propagating business cycles. They show that price rigidity can give rise to a strong propagation mechanism in standard models, provided that investment is also subject to a cash-in-advance constraint. Reasonable price stickiness can generate highly persistent, hump-shaped movements in output under either monetary or non-monetary shocks. Whether or not price rigidity is responsible for output persistence is an empirical question.

(Ball, L. and D. Romer 1991) link the "coordination failure" and "menu cost" approaches to the microeconomic foundations of Keynesian macroeconomics. If a firm's desired price is increasing in others' prices, then the gain from price adjustment after a nominal shock is greater if others adjust. This "strategic complementarity" leads to multiple equilibria in the degree of rigidity. Welfare may be much higher in the equilibria with less rigidity. Thus, nominal rigidity arises from a failure to coordinate price changes.

(Fishman, A. and A. Simhon 2005) develop a model in which even very small adjustment costs can lead to substantive price rigidity. They show that, facing a cost increasing shock, if firms expect competitors to keep prices unchanged, price rigidity may be a self-fulfilling prophesy.

(Levy, D. 2007) presents an introductory essay that briefly summarizes eight theoretical studies of price rigidity that are included in the special issue of *Managerial and Decision Economics* No. 6, 2007.

(Mankiw, N. G. 1985) shows that small menu costs may create large business cycles.

(Yun, T. 1996) investigated the ability of nominal price rigidity to explain the correlation between inflation with the cyclical component of output observed in the postwar US data. Yun constructed a dynamic general equilibrium model with monopolistic competition and nominal price rigidity in a standard real business cycle model and allowed for an endogenous money supply rule. He demonstrated that sticky price models can explain the observed associations between movements in inflation and output better than flexible price models can. The result did not depend on whether money supply was assumed to be endogenous or not.

There is also the question of how to translate sticky prices on the micro level to aggregate price rigidity, a problem discussed by several authors, for instance by (Caballero, R. J. and E. M. R. A. Engel 2007). In the (Calvo, G. A. 1983) model there is a one-to-one link between the micro and macro levels whereas in (Caplin, A. S. and D. F. Spulber 1987) there is no connection whatsoever. Caballero and Engel show that when price stickiness is measured in terms of the impulse response function, this result is not a consequence of aggregation, as is often assumed, but is due instead to the absence of price stickiness at the microeconomic level. They also show that the "selection effect", see (Golosov, M. and R. E. Lucas, Jr. 2007), according to which firms that reset their prices are those that benefit the most, is neither necessary nor sufficient to account for the higher aggregate flexibility of Ss-type models compared to Calvo models. Instead, the key concept is the contribution of the *extensive margin* of adjustment to the aggregate price response, defined as the additional price increase that results from the rise in the fraction of firms resetting their price upwards and the fall in the fraction of firms resetting their price downwards, as the response to a monetary shock. This is in contrast with the *intensive margin*, which shows the additional price increase (or reduced price decrease) of those firms that were going to adjust anyway. The aggregate price level is more flexible than suggested by the microeconomic frequency of adjustment if and only if the extensive margin is positive. The (Calvo, G. A. 1983) model only considers the intensive margin, while in Ss-type models both margins are strictly positive.

Inflation and relative prices

There is a positive relationship between inflation and the dispersion of relative prices according to a number of empirical studies. This could be due to confusion of absolute/relative price changes as suggested by (Lucas, R. E., Jr. 1973) in the case there is a positive relationship between unexpected inflation and some measure of variability. There could also be a positive relationship between expected inflation and the variability of relative price changes, as suggested by (Sheshinsky, E. and Y. Weiss 1977) in the presence of price adjustment costs and estimated by (Assarsson, B. 1986).

There is also a positive relationship between the skewness of relative price changes and inflation that can be derived from the simultaneous occurence of menu costs and skewed supply shocks. Few large shocks (triggering price increases) are matched by many small negative shocks (which keep prices unchanged) and thus temporarily increases inflation.

Pricing in macroeconomic models

It seems to be established as a fact that prices are sticky, though the extent of the stickiness varies and the consequences of it may be discussed. If firms are not price takers prices are usually set as a markup on marginal cost by non-competitive firms. This in itself does not imply price rigidity, for which some additional conditions are needed. The most common approaches for modeling the (nominal) rigidities are

- ✓ exogenous reason, such as in (Calvo, G. A. 1983)
- ✓ price adjustment costs, see for instance
- ✓ Ss model

A major criticism of standard specifications of price adjustment in models for monetary policy analysis is that they violate the natural rate hypothesis by allowing output to differ from potential in steady state. (Andres, J., J. D. Lopez-Salido and E. Nelson 2005) estimated a dynamic optimizing business cycle model whose price-setting behavior satisfied the natural rate hypothesis. They used the price-adjustment specifications considered in the sticky-information specification of (Mankiw, N. G. and R. Reis 2002) and the indexed contracts specification of Christiano et al. (Nominal rigidities and the dynamic effects of a shock to monetary policy. Journal of Political Economy 113, 1-45). Their results showed that empirical estimates of the real side of the economy were similar whichever price adjustment specification was chosen. Even though the different model specifications delivered similar estimates of the US output gap series, the empirical behavior of the gap series differed substantially from standard gap estimates.

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