Can we explain inflation persistence in a way that is consistent with the micro-evidence on nominal rigidity?

Huw David Dixon and Engin Kara.

November 23, 2009

1 Introduction

- In this paper we explore how far existing theories of wage and price setting are consistent with two empirical features:

  – first the *macroeconomic* persistence we observe in inflation,

  – second the *microeconomic* data on nominal rigidity prices.

- There has been a considerable focus on the macroeconomic aspects of modelling inflation persistence (Coenen et al 2007, CEE 2005, Mankiw and Reis 2002, Smets and Wouters 2003....)

- More recently there is now a considerable amount of microdata available on the behaviour of prices in the Eurozone and the U.S., which allows us to evaluate existing theories of pricing.

- US: Bils and Klenow 2004, Klenow and Krystov 2008, Nakamura and Steinsson 2008.
- Eurozone: ECB IPN network France - Baudry et al 2007, LeBihan and Silvestre 2008.....

- Are the current theories that explain inflation persistence consistent with the microdata and can we use the microdata to develop a model that can explain inflation persistence?

1.1 Theories of Pricing.

- Four broadcatogories of price setting models into four categories:

1. The wage-price is set in *nominal* terms for a fixed and known period (e.g. Taylor)

2. The wage-price is set in *nominal* terms for a random duration (Calvo)

3. There is a fixed or uncertain contract length, and the firm/union sets the wage-price for each period at the beginning of the contract (e.g. Fischer 1977, Mankiw and Reis 2002).

4. The initial wage-price is set, but throughout the contract length the nominal wage-price is updated according to recent inflation (Indexation): (e.g. Woodford (2003, p. 213-218), CEE 2005, Smets and Wouters 2003).

- Simple Story: the simple Taylor and Calvo models were not able to explain inflation persistence 1 and 2. New Theories were developed (3 and 4) to "explain" the persistence of inflation in the data.

1.2 Inflation Persistence.

- Debates over how persistent inflation is, the role of policy etc (Minford).

- Some economists believe that there is empirically a high degree of inflation persistence.

- Sum of AR coefficients on inflation are high (US 0.9 - Clarke 2005, Euro-zone 0.7 Batini 2002).

- Even if you allow for structural breaks and regime shifts, the coefficients are well away from zero.

- Vars: the timing and shape:

Feature 1 The biggest effect is not on impact (*hump shape*)

Feature 2: The biggest effect is (a) after 4Q, (b) after 8Q, or (c) after 12Q (*timing of hump*)

Feature 3: After 20 Q, the effect on inflation is (a) 1%, or (b) 5% of the maximum.(*persistence*).

Friedman: monetary policy has "long and variable lags"; the impact on inflation could peak as long as eight quarters or even more

- Timing of hump: BoE 8Q, ECB 6Q, Nelson 12Q, Smets and Wouters 4Q.
- CEE

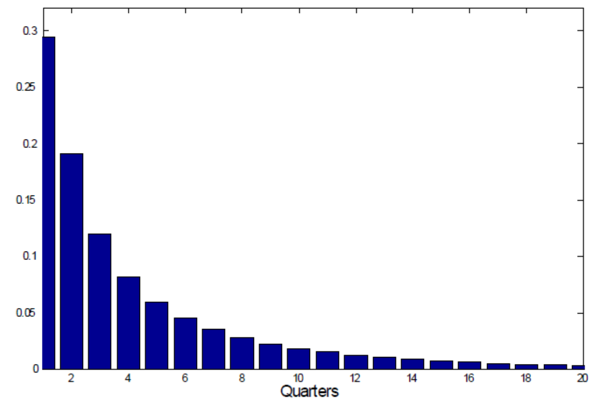
1.3 Micro-Data on prices.

- Now Many studies across a range of countries and time.

- Bils and Klenow (2004): give proportion of firms resetting prices per month over various CPI classes.

- We make the asssumption that there is a Calvo process going on within each CPI class, so that the proportion of firms resetting price is the Calvo reset probability.

- Transform the Calvo distribution of durations into the cross-section distribution across firms (Dixon 2006), Dixon and Kara (2006). This yields what we call the $B - K$ distribution of durations across firms:



- The mean contract length is 4.4 quarters (different from B-K).

- Skewness: high share of short-term durations, the share of 1 and 2 quarters is about 50%, but also a tail of very long durations. The European data is similar in broad outline.

PMD1: Nominal prices and wages remain unchanged for about 4Q on average.

PMD2: There is a highly skewed distribution of durations, with a high proportion of flexible prices but a tail of long durations.

2 The Model.

- Generalised Taylor Economy GTE. We allow for diferent contract lengths in different sectors. We allow for different types of contract (Fischer, indexed etc.). Do this in an encompassing generic log-linearized DSGE style model.

2.1 The Structure of Contracts.

- N sectors*, $i = 1...N$, with sector shares α_i $\sum_{i=1}^{N} \alpha_i = 1$.

- Contracts in sector i last for i periods. (Sector defined in terms of duration).

- There is a unit interval of firms $f \in [0, 1]$ and a matched unit interval of firm-specific household-unions (one per firm).

- The sector share α_i is the measure of firms in sector i (Cross-section of Panel).

*N can be infinite.

- Within each sector i there are i equally sized cohorts of unions and firms: each period one cohort comes to the end of its contract and starts a new one.

- A standard Taylor model is represented by an economy in which one sector (usually $i = 2$ or 4) has a share of unity, the rest zero.

- In the GTE, in each sector i there is a Taylor contract; in the GFE, a Fischer-style contract.

- Calvo wage setters do not know how long the contract will last: each period a fraction ω of firms/households chosen randomly start a new contract. However, the Calvo process can be described in deterministic terms at the *aggregate* level because the firm-level randomness washes out.

- As shown in Dixon and Kara JMCB 2006, $\alpha_i = \omega^2 i(1-\omega)^{i-1} : i = 1...\infty$.

- The Calvo model with indexation has the same structure of contract lengths, but there is indexation throughout the contract life in response to past inflation.

- The Mankiw-Reis sticky-information (SI) model is a special case of the GFE with the Calvo distribution of contract lengths.

2.2 The Macroeconomy.

- Output in sector i: log-linearization of a CES production function relating intermediate outputs to aggregate output):

$$y_{it} = \theta(p_t - p_{it}) + y_t \tag{1}$$

- Sectoral wages and prices: In log deviation form, sectoral price levels are given by the average wage set in the sector, and the wage is averaged over the i cohorts in sector i:

$$p_{it} = w_{it} = \frac{1}{i} \sum_{j=1}^{i} w_{ijt} \tag{2}$$

The log-linearized aggregate price index in the economy is the average of all sectoral prices:

$$p_t = \sum_{i=1}^{N} \alpha_i p_{it}$$

The inflation rate is given by $\pi_t = p_t - p_{t-1}$.

We close the model with the demand side, which is given by a simple quantity theory relation:

$$y_t = m_t - p_t$$

The money supply follows the following process,

$$m_t = m_{t-1} + \ln(\mu_t), \quad \ln(\mu_t) = v \ln\left(\mu_{t-1}\right) + \xi_t \tag{3}$$

where $0 < v < 1$ and ξ_t is a white noise process with zero mean and a finite variance.

2.3 Wage-Setting Rules.

- optimal flex wage in each sector is given by

$$w_t^* = p_t + \gamma y_t \tag{4}$$

with the coefficient on output γ being:

$$\gamma = \frac{\eta_{LL} + \eta_{cc}}{1 + \theta \eta_{LL}} \tag{5}$$

Where $\eta_{cc} = \frac{-U_{cc}C}{U_c}$ is the parameter governing risk aversion, $\eta_{LL} = \frac{-V_{LL}H}{V_L}$ is the inverse of the labor elasticity, θ is the sectoral elasticity'

- We can represent the alternative wage-setting behaviour in terms of a two general equations: one for the reset wage in sector i (x_{it}), one for the average wage in sector i (w_{it}).

$$x_{it} = \sum_{j=1}^{i} \lambda_{ij} E_t w^*_{t+j-1} - a \sum_{j=1}^{i} \sum_{k=j}^{i} \lambda_{ij+k} \pi_{t+j-1} \tag{6}$$

$$w_{it} = \sum_{j=1}^{i} \lambda_{ij} \left(x_{it-j-1} + a \sum_{k=0}^{j-2} \pi_{t+k-1} \right) \tag{7}$$

where $\lambda_{ij} = \frac{1}{i}$ and $0 < a \leq 1$ measures the degree of indexation to the past inflation rate.

- Calvo economy. To obtain the simple Calvo economy from (6), all reset wages at time t are the same ($x_{it} = x_t$), the summation is made with $i = \infty$ and $\lambda_{ij} = \omega(1-\omega)^{j-1} : j = 1...\infty$. and there is no indexation

$a = 0$. Assuming $0 < a \leq 1$ extends these model to the case in which the wages are indexed to past inflation.

- GFE, the trajectory of wages is set at the outset of the contract. Suppose an $i-$ period contract starts at time t; then the sequence of wages chosen from t to $t+i-1$ is $\left\{E_t w^*_{t+s}\right\}_{s=0}^{s=i-1}$. Hence, the average wage in sector i at time t is

$$w_{it} = \sum_{j=1}^{i} \lambda_{ij} E_{t-j+1} w^*_t \tag{8}$$

In the GFE, since cohorts are of equal size within sector i, $\lambda_{ij} = \frac{1}{i}$. The Mankiw-Reis sticky-information (SI) model has $\lambda_{ij} = \omega (1-\omega)^{j-1}$: $j = 1..\infty$.

2.4 The Choice of Parameters.

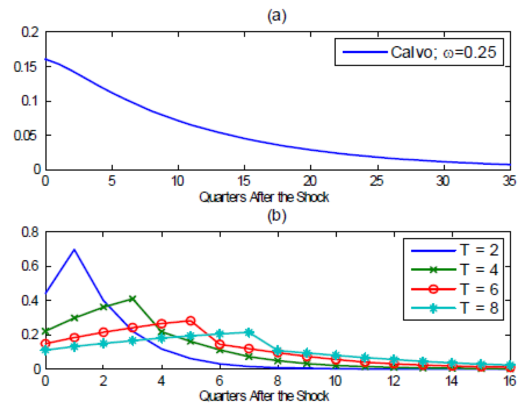
- Our reference set for γ is thus $\{0.1,\ 0.027, 0.01, 0.005\}$.

- Serial correlation of money growth ν, we follow CEE $\nu = 0.5$.

3 The Impulse Response Functions for Inflation.

The policy we are simulating is a one off 1% shock in ξ at $t = 0$. In this section, all reported simulations adopt benchmark values $\gamma = 0.1$ and $\nu = 0.5$.

3.1 The Problem : Standard Taylor and Calvo Models.

- 

- Feature 1 and 2: No. Feature 3 Yes (for usual values of ω).

- Simple Taylor: $T = 2, 4, 6$ and 8. The maximum inflation response in Taylor's model is indeed delayed for a few quarters and it reaches its peak $T - 1$ quarters after the first period in which the shock occurs.

- There is a hump shape of sorts, but a rather jagged one. Hence Features 1 and 2 can be met.

- However, the simple Taylor contract will only generate a hump at around two-years if the contract lasts for that length of time ($T = 8$) which is in direct conflict with the microdata PMD1.

- Furthermore, if we turn to Feature 3, inflation dies away rapidly T periods after the shock. In particular, for $T = 4$, the effects of the shock are almost gone after 15 periods; this certainly fails to meet even the weak criteion.

- Feature 1 Yes. Feature 2 (a) yes for $T = 4$ (consistent with $PMD1$). Feature 3: No.

3.2 Solution 1: Indexation in the Calvo Model.

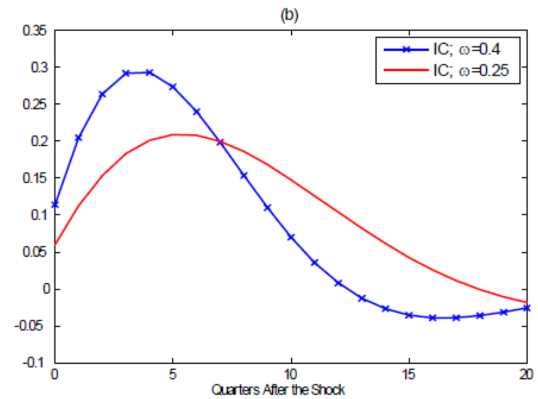
- There has been much empirical work done on the New Keynesian Phillips curve. As is well known, it does not do well in explaining the data (see for example [?]). One model that does much better empirically is the hybrid Phillips curve, which takes the form

$$\pi_t = (1-\phi)\beta E_t \pi_{t+1} + \phi\pi_{t-1} + by_t \tag{9}$$

  where $\phi \in [0,1]$ and $\phi = 0$ gives the New Keynesian Phillips curve.

- This has given rise to attempts to construct a theoretical model that can yield (9).

- The currently popular theoretical justification is to add indexation to the Calvo model (see for example CEE, S&W, Woodford: at the beginning of the contract the nominal wage is set, and for the contract duration this is updated by the previous period's inflation.



- Feature 1 Yes. feature 2 (a) Yes, (b) not quite. Feature 3: No.

- micor-data? No.*a Calvo model with full or even partial indexation implies that every firm adjusts its price every period.*

3.3 Solution 2: Distributions of Fischer Contract Lengths.

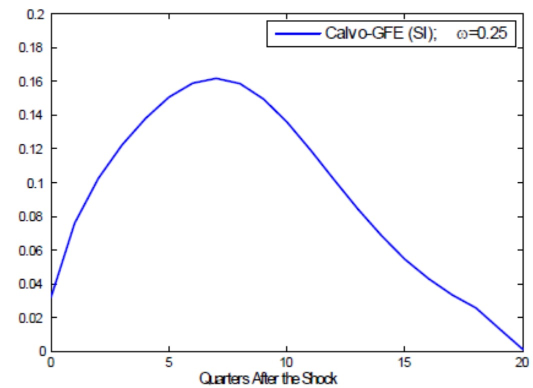
- In this section we consider a Generalized Fischer Economy (GFE): an economy with many sectors, each with a Fischer contract where the wage-setter chooses a trajectory of wages, one for each period for the whole length of the contract. The wages are thus conditional on the information the agent has when it sets the wages, so that as the contract gets older the information will be increasingly out of date.

- There are two general points that need to be understood when interpreting the Fischer contracts.

  - First, the IR functions are generated by a single innovation in the initial period. Any new contract that starts after the initial shock will be fully informed. Once all contracts have been renewed after the shock, the economy will behave as if there is full information and flexible wages/prices.

– Second *the length of the contract has no influence on the wages chosen for any specific period covered by the contract*.

- Mankiw and Reis's Sticky Information model (SI) is a GFE where the distribution of contract lengths is Calvo with their choice of $\omega = 0.25$, resulting in an average length of 7 quarters. With Fischer contracts, the Calvo reset probability is only important in generating the distribution of durations: nothing else.



- The SI model has a smooth hump, peaking at the 8th quarter, and inflation dies away slowly so that Feature 3(b) is satisfied.

- The reason for this shape is the distribution of contract lengths and in particular the longer contracts that let inflation persist. Hence, introducing heterogeneity into the Fischer model moves the model in the direction of explaining all three facts.

- With a Fischer contract, the price or wage setter tries to predict the optimal flex price or wage. Since this depends on the general price level, *the trajectory of prices builds in anticipated inflation*. The monetary policy IR has a hump shape because most firms have to wait to replan their price-plans once the new policy is in effect. Thus, for those yet to revise their plans, the pre-shock inflationary expectations are driving their prices. The Calvo distribution ensures that the hump is smooth and peaks at the required time.

- Feature 1, 2(b) and 3 YES (By construction!).

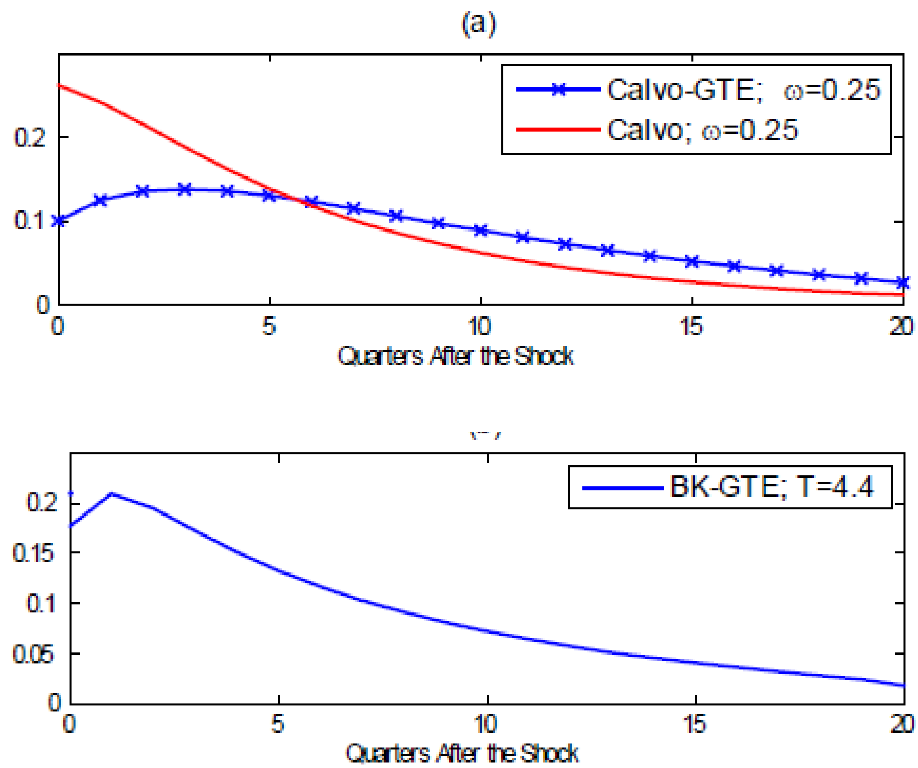
- PMD1 and 2: NO. However long or short the "contract", prices change every period which violates both PMD1 and PMD2.

3.4 Solution 3: Distributions of Taylor Contract Lengths.

- PMD2: need distribution of price-spell durations.

- GTE
  - Calvo-GTE: $a_i = \omega^2 i (1-\omega)^{-i} : i = 1...\infty$. $\omega = 0.25$.
  - $BK - GTE$.

- The inflation impulse-responses for these two distributions of contract lengths are depicted Figure 5.



- We can see immediately that adding a distribution of contract lengths has greatly improved the fit of the $IRFs$ compared to the simple Taylor contract.

- Calvo-GTE : F1 yes, F2 (a) Yes, F3 yes. $PMD1$ No, $PMD2$ a bit.

- $BK - GTE$. F1 and F3 Yes. F2: no, peaks too soon.

4 Role of the Key Parameter γ.

- We now examine how the changes in the key parameters influence the models with respect to macroeconomic Features 1-3.

- The parameter γ is important as it determines the inflationary pressure on wages and prices that results from an increase in output.

- A low value of γ means that this inflationary pressure works through more slowly so that the reaction of inflation to output growth becomes slower.

- Table 1 shows how Features 1-3 fare for each of the models at the different reference levels of γ:$0.1, 0.027, 0.01$, and 0.005.

	$\gamma = 0.1$			$\gamma = 0.05$			$\gamma = 0.027$			$\gamma = 0.01$			$\gamma = 0.005$		
	F1	F2	F3	F1	F2	F3	F1	F2	F3	F1	F2	F3	F1	F2	F3
Calvo-GTE; ω=0.40	✓		✓	✓	✓	✓✓	✓	✓	✓✓	✓	✓	✓✓	✓	✓	✓✓
Calvo-GTE; ω=0.25	✓	✓	✓✓	✓	✓	✓✓	✓	✓	✓✓	✓	✓✓	✓✓	✓	✓✓	✓✓
BK-GTE	✓		✓✓	✓		✓✓	✓		✓✓	✓	✓	✓✓	✓	✓✓	✓✓
SI; ω=0.40	✓	✓		✓	✓		✓	✓		✓	✓✓	✓	✓	✓✓	✓
SI; ω=0.25	✓	✓✓	✓✓	✓	✓✓	✓✓	✓	✓✓✓	✓✓	✓	✓✓✓	✓✓	✓	✓✓✓	✓✓
IC; ω=0.40	✓	✓		✓	✓		✓	✓		✓	✓✓	✓✓	✓	✓✓	✓✓
IC; ω=0.25	✓	✓	✓✓	✓	✓✓	✓✓	✓	✓✓	✓✓	✓	✓✓✓	✓✓	✓	✓✓✓	✓✓

γ	0.1	0.05	0.027	0.01	0.005
Calvo-GTE; ω=0.40	3	4	4	5	6
Calvo-GTE; ω=0.25	4	5	7	9	11
BK-GTE	2	2	3	7	10
SI; $\omega = 0.40$	5	6	7	9	11
SI; $\omega = 0.25$	8	11	13	16	19
IC; $\omega = 0.40$	5	6	7	9	11
IC; $\omega = 0.25$	6	8	10	13	16

Table 2: The peak response of inflation (in quarters)

- $Calvo - GTE$, we see that with $\omega = 0.25$, F1 and F3 are satisfied for all γ. The peak response meets the rapid criterion for $\gamma = 0.1$ and the moderate when $\gamma = 0.027$. This model has a distribution of contract durations, but the mean is too long. If we impose PMD1 and set $\omega = 0.4$, then the resulting Calvo distribution is much closer to the microdata on both counts. For $\gamma \leq 0.027$, the rapid peak and also the strong view of F3 are both satisfied. *Thus, the $Calvo - GTE$ is the only model with the Calvo distribution that is consistent with the microdata and also can* *satisfy the macro features* F1-3. However, the peak response will be too rapid for many macroeconomists.

- Lastly, we can look at the $BK - GTE$, which has the actual empirical distribution of contract lengths which by construction satisfies PMD1 and PMD2. For all values of γ F1 and F3 are satisfied.

- What of the peak inflation? Well, for "calibrated" $\gamma = 0.027$, the peak is at 3Q. This "almost" satisfies the rapid view

- (recall that we can follow Woodford (2003) and introduce pre-set pricing to add an extra quarter lag into the pricing decision, taking the peak response form 3 to *4Q*).

- What is more interesting is what happens when $\gamma = 0.01$. Even though the $BK - GTE$ has an average contract length of 4.4 quarters, it peaks at $7Q$. This would both satisfy the moderate view of peak inflation *and* be consistent with the microdata.

- However, as yet this can only be attained at a value of γ below the lowest "calibrated" value currently proposed.

- When there is a distribution of contract lengths, a decrease in γ will tend to delay the maximum impact if there is already a hump shape and will move the models with a distribution significantly towards explaining all three features.

5 Conclusion

- Standard Taylor and Calvo were seen as not fitting the beahviour of inflation.

- New pricing models were developed: indexation added to Calvo, the Fischer contracts (Sticky information).

- These fit the macroecnomic facts much better and are a central part of the current NNS orthodoxy.

- BUT they are in contradiction with the micro-data. Prices in these theories change every period. This is not so: there of is a distribution of durations, with a long tail of long-lived prices.

- So: use GTE. Allow for a distribution of contract lengths.

- Can go a long way to meeting the macro features of inflation in a way that is more consistent with the micro data.