STAGGERED PRICES, SEQUENTIAL TRADE AND PRICE DISPERSION: EVIDENCE FROM MICRO DATA

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In a staggered price setting model a money supply shock leads to a persistent effect on price dispersion. In an uncertain and sequential trading model a money supply shock does not affect price dispersion. We test these predictions using datasets on prices by products and stores from recent inflationary periods in Israel.

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1. INTRODUCTION

The observation that sellers change their prices in unsynchronized jumps is consistent with a sticky price model in which prices are set in a staggered fashion as in the Taylor (1980) model. It is also consistent with an uncertain and sequential trading (UST) model.

In a UST equilibrium there is price dispersion and sellers are indifferent between quoting a relatively high price and quoting a low price because the low price implies a higher probability of making a sale. It is possible that the distribution of prices will adjust perfectly to changes in the money supply even when sellers adjust their nominal prices in jumps and in unsynchronized fashion. In particular, a seller may not change his nominal price when inflation erodes his real price because of the increase in the probability of making a sale. See for example, Eden (1994, 2001), Lucas and Woodford (1994), Bental and Eden (1996), Williamson (1996) and Woodford (1996).

Thus, the observation that sellers change their nominal price in unsynchronized jumps is not sufficient to distinguish between the staggered price-setting model and the sequential trade model. It turns out that the two models have different predictions about the response of the standard deviation of prices (across sellers of the same product) to a money supply shock. Under staggered price setting a money supply shock will have a persistent positive effect on the standard deviation of prices while under sequential price setting it will have no effect.

To build some intuition it may be useful to consider the effect of a once and for all change in the money supply. We start from an equilibrium in which the money supply has been constant for a long time and all sellers post the same price. We then increase the money supply. Under staggered price setting sellers can change prices every N periods and only a fraction $1/N$ of the sellers can change their price immediately after the change in the money supply. Therefore the change in the money supply will create a price difference between sellers who could change their nominal prices to sellers who could not. The standard deviation of prices will gradually go back to zero as all sellers adjust their prices and the economy reaches the new equilibrium. In the UST model all sellers can change their prices at any point in time and therefore the economy will reach the new equilibrium immediately after the change with no effect on the standard deviation of prices.

To distinguish between the two models empirically we therefore estimate the response of the standard deviation of prices to a price shock using datasets on prices by products and stores from high and moderate inflation periods in Israel.

This paper is related to the large literature on the relationship between inflation and relative price variability. For good surveys, see Cukierman (1983), Marquez and Vining (1984), Hartman (1991) and Weiss (1993). Most of this literature uses the variability in the rate of change of prices as a measure of price dispersion. Here we follow Reinsdorf (1994) and Eden (2001) who use measures of the variability of the level of prices.[1] Our choice of the measure of price dispersion is based on theory: We derive the implications of the above mentioned models with respect to the level measure we use. The paper is also related to Eden (2001) who test the implications of simple (S,s) type models against the UST alternative. Here we focus on staggered price setting models and derive implications about the entire impulse response functions rather than focus on contemporaneous correlations.

2. THEORETICAL IMPULSE RESPONSE ANALYSIS IN A STAGGERED PRICE SETTING MODEL

In a staggered price-setting model of the type suggested by Taylor (1980) and more recently studied by Chari, Kehoe and McGrattan (CKM, 2000), sellers can change prices every N periods. In each period a fraction $1/N$ of the sellers may change their nominal price.

To derive the implication of this assumption with respect to the response of price dispersion to a monetary shock, we start from an economy that is in a deterministic steady state with zero inflation rate and assume that this economy is experiencing a once and for all change in the money supply. For the sake of concreteness, we assume that at the initial steady state all sellers post the price of 1 and immediately after the change a fraction 1/N of the sellers post a price of 2 while the remaining fraction of (N-1)/N do not change their nominal price and post the price of 1. Let $\Delta = \ln 2$ denote the percentage change in the

[1] Recently Konieczny and Skrzypacz (2000) have used both level and rate of change measures.

nominal price of the sellers who did make a change. The rate of inflation immediately after the change is the weighted average:

$DP_t = \Delta(1/N) + 0[(N-1)/N] = \Delta/N.$

The standard deviation of the log of prices in this period is:

$SD_t = (\Delta/N)[(N-1)/N] + (\Delta - \Delta/N)(1/N) = 2(\Delta/N) - 2\Delta/N^2$

$= DP_t[2 - (2/N)]$. Assuming $N \geq 2$, this implies the following testable relationship.

Claim: Immediately after the money supply shock, the standard deviation of the log of prices (SD_t) is greater than the average rate of inflation (DP_t) and obeys the following inequalities: $DP_t \leq SD_t \leq 2DP_t$.

This claim derives the impact effect of a money supply shock and can be extended to the more general case in which the money supply follows a random walk. As was said in the introduction, the effect of the shock on the standard deviation lasts for more than one period. To get an idea about the entire effect we now derive the impulse response functions for the case in which the money supply follows a random walk and the length of the contract is two ($N = 2$) using the example in CKM. We use x_t to denote the log of the price of sellers who adjust their prices at time t and "^" to denote deviation from the steady state. CKM derive the following relationship ([38] in their paper):

(2) $$\hat{x}_t = a\hat{x}_{t-1} + (1 - a)\hat{m}_{t-1}.$$

This says that in response to a money shock at t-1, sellers who adjust prices at t will choose a price which is $(1 - a)\hat{m}_{t-1}$ higher than the steady state level. Sellers who adjust prices at t+1 will choose a price which is higher than the steady state level by $a(1 - a)\hat{m}_{t-1} + (1 - a)\hat{m}_{t-1}$. Sellers who adjust prices at t+2 will choose a price which is higher than the steady state level by $a^2(1 - a)\hat{m}_{t-1} + a(1 - a)\hat{m}_{t-1}. + (1 - a)\hat{m}_{t-1}$ and so on. When i goes to infinity, sellers who adjust prices at t+i will choose a price which is higher than the (old) steady state by $\hat{m}_{t-1}$. Thus, we may think of the response to the shock as a movement from one deterministic steady state to another.

To derive the implications with respect to the effect of the money supply shock on the standard deviation, SD, and the rate of inflation, DP, we write: $\ln M_t = \ln M_{t-1} + \varepsilon_t$ where ε_t is an i.i.d error term. We choose units so that $x_{t-1} = \ln M_{t-1} = 0$. We then assume $\varepsilon_{t-1} = \sigma$ and $\varepsilon_i = 0$ for $i \geq t$. Applying CKM formula (2) for these notations leads to:

(3)
$$x_t = (1 - a)\sigma;$$
$$x_{t+1} = a(1 - a)\sigma + (1 - a)\sigma;$$
$$x_{t+2} = a^2(1 - a)\sigma + a(1 - a)\sigma + (1 - a)\sigma;$$

where "a" is a key parameter.

The deviations of the inflation rate from the initial steady state are given by:

(4)
$$DP_t = (1/2)(x_t + x_{t-1}) - (1/2)(x_{t-1} + x_{t-2}) = (1/2)(1 - a)\sigma;$$
$$DP_{t+1} = (1/2)a(1 - a)\sigma + (1/2)(1 - a)\sigma;$$
$$DP_{t+i} = aDP_{t+i-1} \text{ for } i > 1.$$

The standard deviations of prices are given by:

(5) $$SD_t = (1/2)|x_t - x_{t-1}| = (1/2)|1 - a|\sigma;$$

$$SD_{t+i} = |a|SD_{t+i-1} \text{ for } i > 0.$$

The impulse response functions which describe the effect of the shock at t-1 are illustrated by Figures 1 and 2 under two alternative values for *a*. The first uses CKM benchmark value of $a = -0.11$. The second uses the value that Taylor uses to account for US data: $a = 0.87$.[2]

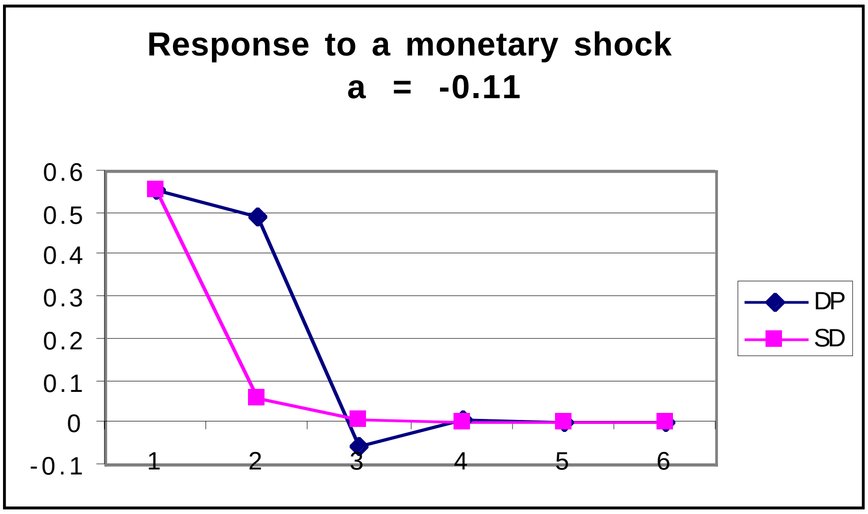


Figure 1: Theoretical impulse response functions in the staggered price model

[2] Taylor treats the parameter *a* as a structural parameter while in CKM it is a function of the underlying preferences and technology parameters. In CKM $a = (1 - \gamma^{.5})/(1 + \gamma^{.5})$ and γ is the elasticity of the equilibrium real wage rate with respect to consumption.

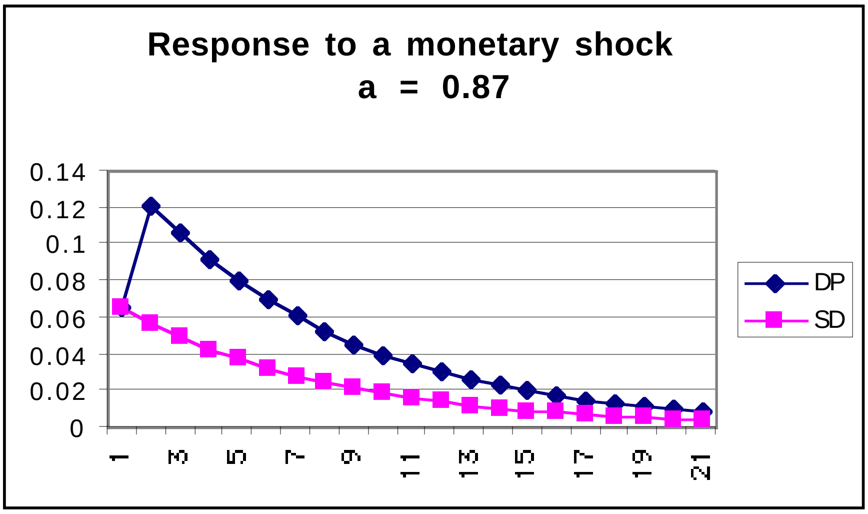


Figure 2: Theoretical impulse response functions in the staggered price model

Note that the convergence to the new steady state is much faster when *a = -0.11*. When *a = -0.11*, (3) implies that sellers who can change their price after the shock, choose a price which is higher than the (new deterministic) steady state value. When *a = 0.87* they choose a price which is much lower than the steady state value. This explains why CKM found that a shock to the money supply has very little persistent effect on output.

3. THEORETICAL IMPULSE RESPONSE ANALYSIS IN THE SEQUENTIAL AND UNCERTAIN TRADE (UST) MODEL

In Eden (1994) money follows a random walk. There is uncertainty about the amount of transfer payment that buyers will receive during trade and about the nominal amount that they will spend. The transfer process is like rain: Everyone observes the amount of transfers (helicopter money) which fall but no one knows when it will stop. It is assumed that money arrives in batches and each batch of dollars that arrive opens a new Walrasian market.

There are thus many potential markets which open sequentially and sellers allocate their output across one or more of these potential markets. Equilibrium prices are proportional to the beginning of period money supply:

(6) $$P_{st} = p_s M_t,$$

where P_{st} is the dollar price in market s and p_s is the normalized price in market s. The rate of inflation is the same for all markets and is given by:

(7) $$DP_t = \ln P_{st} - \ln P_{st-1} = \ln M_t - \ln M_{t-1} \text{ for all s.}$$

Thus prices adjust with a one period lag to changes in the money supply.

The average quoted price is given by:

(8) $$P_t = \Sigma_s\ \psi_s P_{st},$$

where ψ_s is the fraction of output allocated to market s. The variance of the log of prices is defined by:

(9) $$\mathrm{VAR}(\ln P_t) = \ \Sigma\ \psi_s(\ln P_{ts} - \ln P_t)^2.$$

We define the stationary mean and variance of normalized prices by: $\ln p = \Sigma\ \psi_s \ln p_s$ and $VAR(\ln p) = \Sigma\ \psi_s(\ln p_s - \ln p)^2$. Since M_t is common across all markets we may use (6) to write:

$$(10) \qquad VAR(\ln P_t) = VAR(\ln p) + VAR(\ln M_t) = VAR(\ln p).$$

This says that a shock to the money supply does not affect the variance of the log of dollar prices. In response to a money supply shock we should observe an increase in the inflation rate (7) but no effect on the variance. This is illustrated by Figure 3.

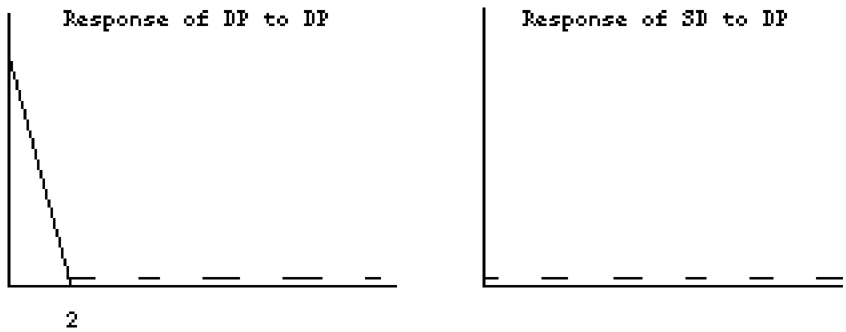


Figure 3: Theoretical impulse response functions in the UST model

It was shown that the staggered price setting model and the UST model have different predictions about the response of *DP* and *SD* to a monetary shock. In the UST model the effect of a monetary shock on the rate of inflation is only in the period after the shock and there is no effect on price dispersion. In the staggered price setting model there is a persistent effect of a monetary shock on both *DP* and *SD* and the impact effect on *SD* is quantitatively larger than the impact effect on

DP. Furthermore, in the staggered price setting model the response varies with the parameter *a*. Estimating the responses of *DP* and *SD* to a monetary shock may therefore be useful for distinguishing among competing hypotheses.

4. DATA

We use monthly data collected by Israel's Central Bureau of Statistics as inputs for computing the CPI. These are prices actually quoted to the surveyor when visiting the store (quoted price data) and not transaction weighted or unit value data. The sample periods are: 1978-1979, 1981-1982 and 1991-1992. For the first two sample periods there are data on the prices of 26 food products (mostly meat and wines). These data were used by Lach and Tsiddon (L-T) and are described in their 1992 article. The data from 1991-92 contain 115,394 monthly observations of prices by stores and products, collected from 458 stores which sold 390 different products (each store sold only a subset of the products). These data are described in Eden (2001). Here we use only 23 out of the 390 products. The 23 products which were selected are also in the earlier samples (1978-79 and 1981-82). This sub sample is called in Eden (2001) 91-92 "comparable". Here we shall simply refer to it as 91-92.

The average inflation rate across products and sellers was 4.3% per month in 1978-79, 6.3% per month in 1981-82 and 0.7% per month in 1991-92.

5. VECTOR AUTO REGRESSION ANALYSIS

The staggered price setting model suggests the following 2 variables vector auto regression relationships:

(11) $$DP_t = a_{DP} + b_{DP1}DP_{t-1} + \ldots + b_{DPq}DP_{t-q} + c_{DP1}SD_{t-1} + \ldots + c_{DPq}SD_{t-q} + \theta_t$$

(12) $$SD_t = a_{SD} + b_{SD0}DP_t + b_{SD1}DP_{t-1} + \ldots + b_{SDq}DP_{t-q} + c_{SD1}SD_{t-1} + \ldots + c_{SDq}SD_{t-q} + \varepsilon_t$$

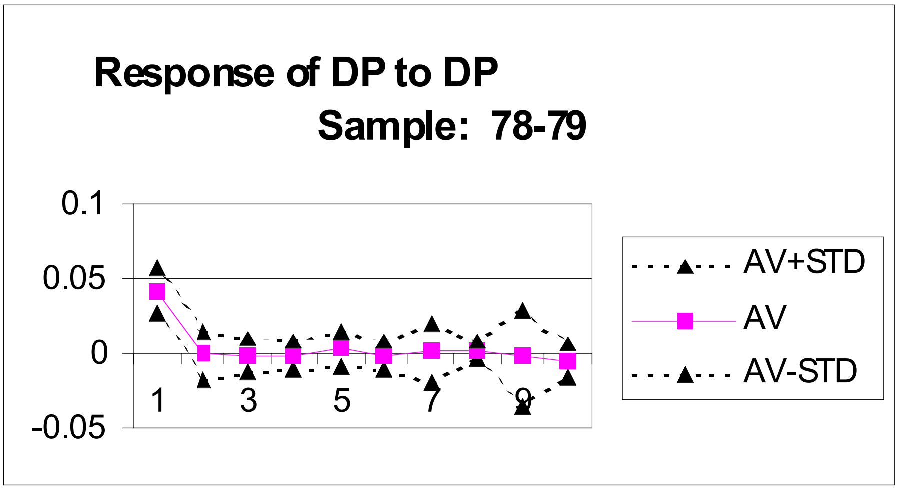
Here the *a, b, c* are coefficients and θ and ε are error terms. The error term θ in the *DP* equation may arise as a result of serially independent money supply shocks. It may also arise as a result of sampling errors: It makes a difference if we sample sellers who changed their nominal price or sellers who did not change their nominal price. Since the contemporaneous level of DP an explanatory variable in the SD equation (and serves as a proxy for the money supply shock), the error term ε in the SD equation is due to sampling errors. Since current *DP* affect the standard deviation we place *DP* first when estimating the vector auto regression (VAR). The coefficients in (11) and (12) may be product specific if we allow for product specific length of the contract (N).

Under the UST model with a random walk money supply all the coefficients b and c in (11) and (12) are zero. We therefore estimate the impulse response functions twice. We first allow for product specific coefficients and then impose the same coefficients on all products.

Allowing for product specific coefficients:

We start by running vector auto regressions for each product separately, allowing for four lags. The typical VAR had 23 observations (months) and two variables: *DP*, *SD* (in this order). We then compute the average impulse response (AV) across all the products in the sample (about 25 products per sample). This average was computed by obtaining the impulse response function in a Table form for each product and taking the average (*AV*) in each period across products. We also calculated the standard deviation (*STD*) which is the average distance from AV across the 25 products.

Figures 4 - 6 describe the the average response (*AV*) and two bounds: *AV* + *STD* is the average plus the standard deviation and *AV - STD* is the average minus the standard deviation. In all the samples the average *DP* return to the baseline in the month following the shock. The average effect of a shock to *DP* on *SD* is close to zero. These findings are consistent with the theoretical impulse response functions from the UST model (Figure 3) but not with the two versions of the staggered price setting model (Figures 1 and 2).



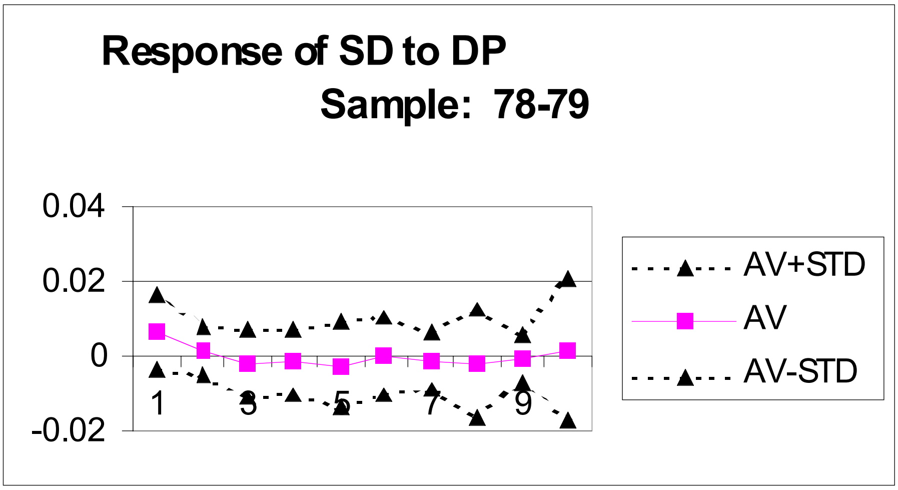
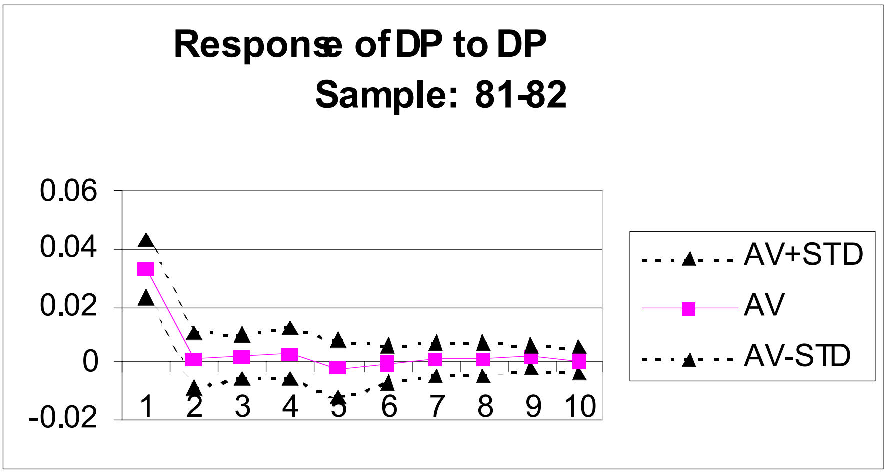


Figure 4: Average (across products) impulse response functions for the 1978-79 sample



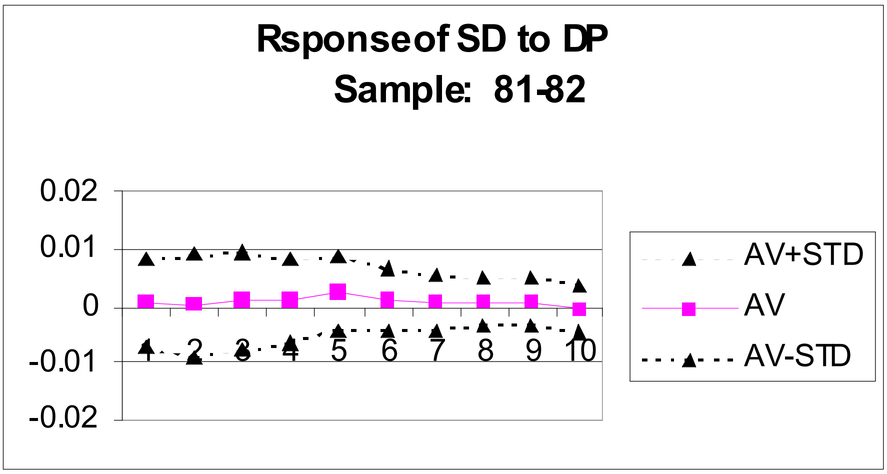
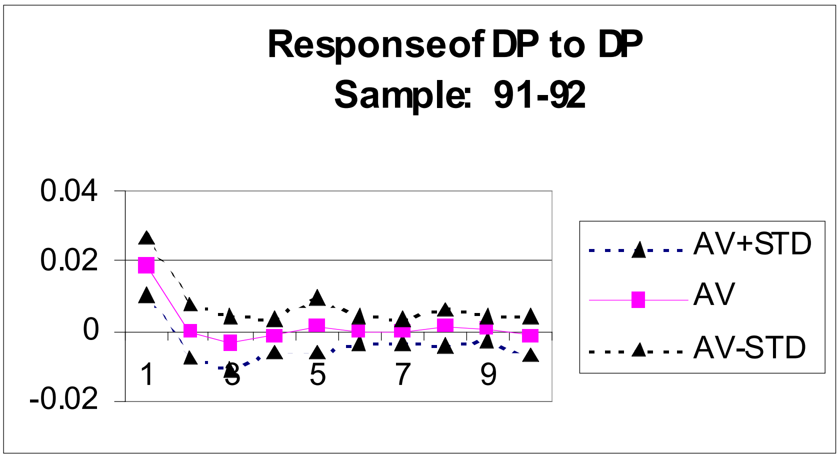


Figure 5: Average (across products) impulse response functions for the 1981-82 sample



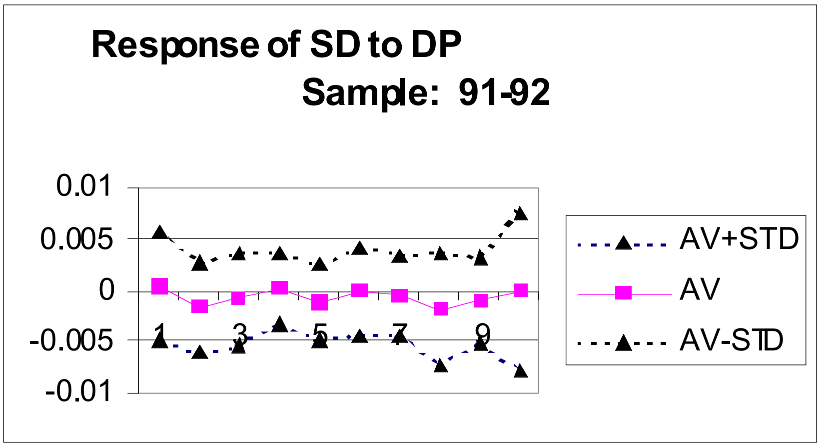


Figure 6: Average (across products) impulse response functions for the 1991-92 sample

Imposing the same coefficients on all products:

We now impose the same VAR coefficients across products. We think of an hypothetical world that lives for GT periods, where G is the number of product in the sample (about 25 goods per sample) and T is the number of months (23). In this hypothetical world agents produce one product only and each 23 months the identity of the product changes.

We create an artificial time series of about (23)(25) = 575 periods per sample and estimate two impulse response functions per sample.[3] The results of this excercise are in Figures 7 - 9. These impulse response functions look very much like the average computed in Figures 4 - 6 and may serve as a test for robustness.

6. CONCLUSIONS

We used datasets on prices by products and sellers from three inflationary periods in Israel to estimate a two variables VAR: DP (average inflation across sellers who sell the same product) and SD (the standard deviation of prices in log forms across sellers who sell the same product). We found that a shock to DP has no effect on SD and no persistent effect on DP. These findings are not consistent with a staggered price setting model of the type considered by Taylor (1980) and CKM (2000) but are consistent with a UST model of the type considered by Eden (1994).

We compared two rather basic versions of the staggered price-setting and the UST models. More general versions tend to yield less powerful predictions. In Bental and Eden (1996) a money supply shock will change the level of the beginning of next period inventories and this may (but need not) lead to a change in SD. In Calvo (1983) and in Dotsey, King and Wolman (1999) a shock to DP may occur as a result of an increase in the fraction of sellers who change their price in the

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[3] We separate each good by an appropriate number of blanks so that the lags of product i will not be taken as observations from product i-1.

Figure 7: Imposing the same coefficients on all products; 78-79

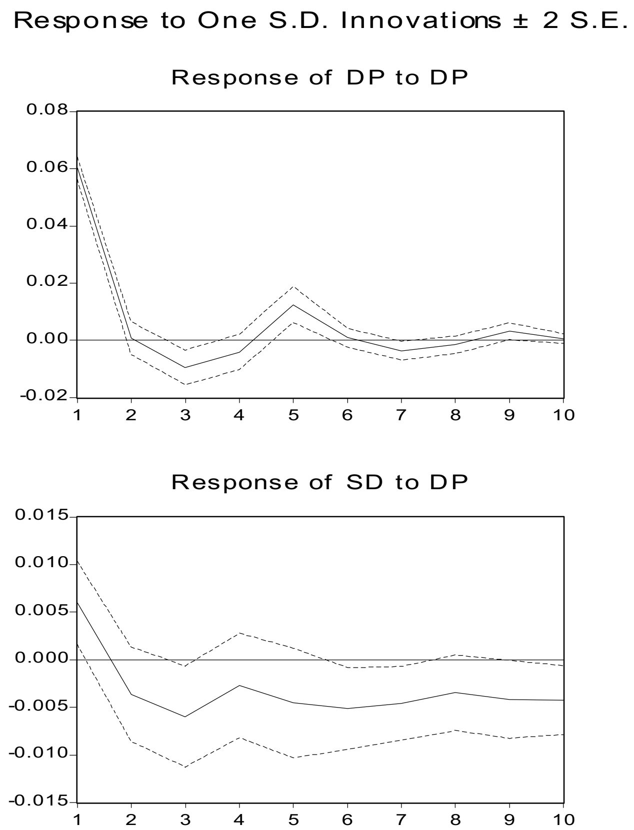


Figure 8: Imposing the same coefficients on all products; 81-82

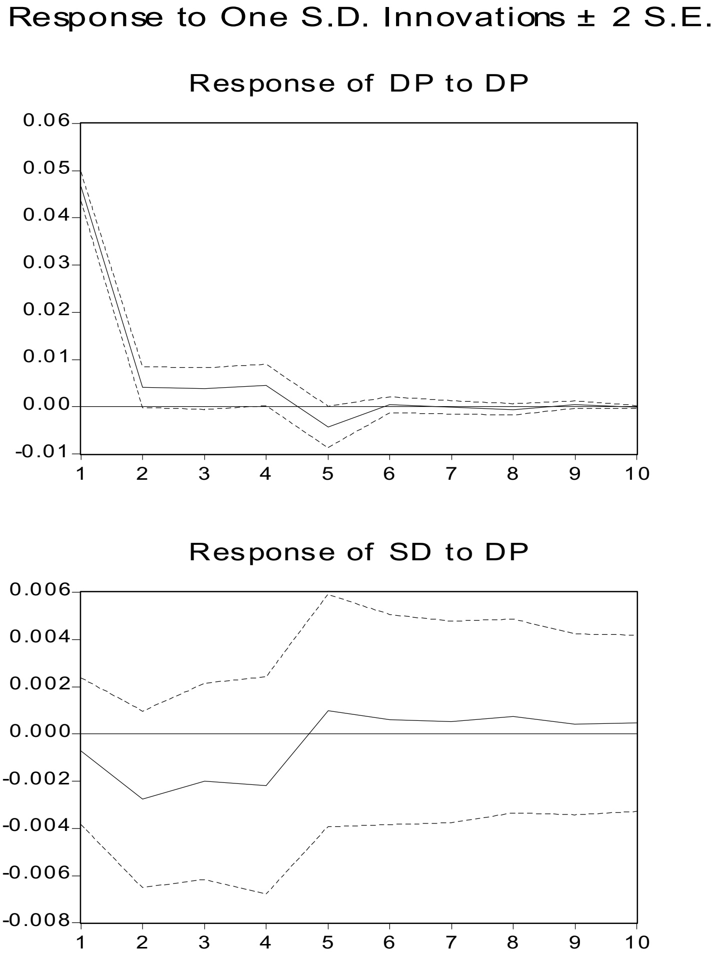
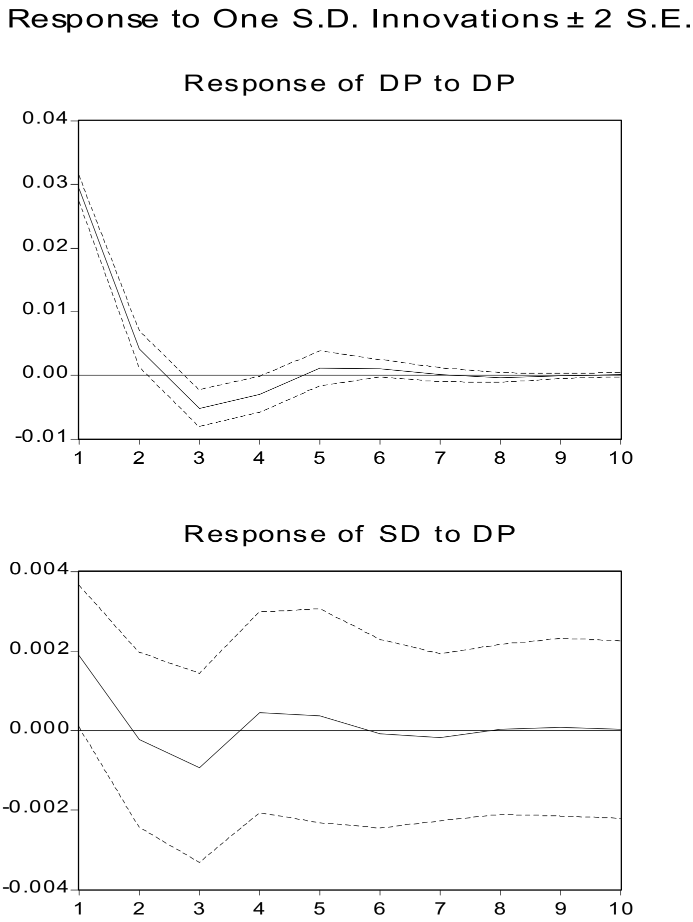


Figure 9: Imposing the same coefficients on all products: :91-92



current month. In this case if the fraction of sellers who changed their price is large we may get a negative rather than a positive response of SD to a DP shock. Dotsey, King and Wolman (1999) calibrated their model and found a positive correlation between inflation and relative price variability. Here we use data from relatively high inflation periods and therefore it seems reasonable to assume that money supply shocks dominate during these periods.

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