Comment

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Introduction

In this paper, Alvarez, Lippi, and Passadore ask if it matters whether we model price inertia with a time-dependent rule, as in the Calvo or Taylor models, or a state-dependent rule, as in the Ss menu-cost model. They give two answers to this question, one for small shocks to the money supply and one for large shocks. For large shocks the answer is an unambiguous "yes." State dependence leads to greater price flexibility, which mutes the response of real output. This is the familiar selection effect that plays such a large role in the papers by Caplin and Spulber (1987) and Golosov and Lucas (2007). For small shocks, the answer is a more surprising "no." The authors show that it is not so much the distinction between state and time dependence that matters for the macroeconomics of price inertia, but rather the moments of distribution of price changes, in particular the kurtosis of the steady-state distribution of price changes and the expected time between price changes. Under fairly general conditions (more on this later), these moments are sufficient to characterize the cumulative response of output to a small, permanent shock to the money supply. State and time dependence work through these moments and have no independent effects.

I will focus my comments on the small shock analysis, since this is the most innovative and surprising part of the paper. I will begin with a quick literature review, then discuss the authors' sufficient statistic approach, and conclude by assessing the limitations of the result and providing suggestions for future research.

In the search for microfoundations of price rigidity, the literature has tended to focus on two prototypical models of price inertia: models

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with time-dependent pricing rules and models with state-dependent rules. Time-dependent rules are rules in which the timing of adjustment depends only on the time since the last price change. The motivating examples are fixed-length contracts and corporate decision cycles, both of which tend to give precedence to the calendar in determining which prices are changed and when.[1] Time dependence is usually modeled as either a fixed schedule of price changes (Taylor pricing) or Poisson price changes (Calvo pricing). On the other side are state-dependent rules. These rules tend to include some cost of changing prices. The price-adjustment decision then balances this cost of adjustment against the cost of mispricing. Prices may change or not change depending on the current state of the economy. Menu-cost models are the most prominent examples.

State- and time-dependent models have long been thought to be different. Since the focus of this paper is on the differences between these models, I list a few of the main differences discussed in the literature.

- *State dependence dampens the real effects of a money shock* (Caplin and Spulber 1987; Dotsey, King, and Wolman 1999; Golosov and Lucas 2007). In time-dependent models, the set of firms that adjust their prices at any point in time are exogenously determined. In state-dependent models, the firms that adjust their prices tend to be the firms with the most to gain from price adjustment, and these firms tend to be the firms whose prices are most out of line. The average amount of mispricing is therefore less in state-dependent models. Golosov and Lucas label this the selection effect.
- *With state dependence the response of the economy to a money shock should depend on the state of the economy* (Caplin and Leahy 1991, 1997; Caballero and Engel 2007). Aggregate shocks tend to alter the number of firms contemplating price increases and price decreases. The greater the number of firms that are contemplating price increases, the greater the effect of a positive money supply shock on inflation and the lesser the effect on output. An increase in the money supply should therefore have a greater effect on inflation in a boom than in a bust. Caballero and Engel codify this in their aggregate flexibility index. Aggregate shocks do not affect the incentive to adjust in time-dependent models because the adjustment decision is exogenous. The state dependence of money shocks is correspondingly reduced.
- *Time dependence leads to frontloading of price changes* (Ball 1994; Ascari 2004; Midrigan 2011). The future matters a lot in time-dependent mod-

els since the adjusting firm may not have another opportunity to adjust its prices for some time. If the firm expects inflation at some future date, it will have an incentive to raise its prices immediately. Ball shows that this may cause the economy to expand should firms expect deflation. Firms that expect the price level to fall in the future will cut their prices today, thereby raising output. The incentive to frontload is greatly reduced in state-dependent models since a firm can simply choose to adjust when it makes sense to adjust.

- *State dependence and strategic complementarity can lead to complex outcomes* (Ball and Romer 1990; Dotsey and King 2005). Ball and Romer point out the possibility of multiple equilibria: If firms care sufficiently about relative prices, then the incentive to adjust prices may be increasing in the prices set by others. Dotsey and King show that these strategic complementarities can cause inflation to respond with a delay to a money shock as firms wait for enough other firms to contemplate price adjustment before adjusting their prices themselves.
- *The modeling of price adjustment may affect the welfare costs of inflation* (Kiley 2002; Blanco 2015). Kiley shows that Calvo pricing can lead to some very stale prices and that this can greatly increase the welfare costs of inflation. Blanco studies the welfare costs of inflation at low inflation and finds inflation less costly in menu cost models.

The current paper takes a different view of what is important about the microeconomics of price adjustment. Rather than focusing on the distinction between state and time dependence, the authors focus on the resulting moments of the price-change distribution. They provide conditions under which the cumulative effect of a money shock on output is completely characterized by the frequency of price adjustment, the kurtosis of the price-change distribution, and a utility parameter that represents the elasticity of output with respect to the real wage. State- and time-dependent rules matter because they influence these statistics.

Their key result may be summarized in a single equation. Let $\mathcal{M}$ denote the cumulative response of output to a shock to the money supply, $\mathcal{M} = \int_0^\infty y(t)dt$ where $y(t)$ is the percent deviation of output from its steady state. Then, under certain conditions, a permanent δ% shock to the money supply leads to a cumulative output response equal to:

$$\mathcal{M} = \frac{\delta}{6\varepsilon}\,\text{kurtosis}(\Delta p)E(T).$$

An example will help illustrate the use of the equation. Consider a world with Taylor pricing and suppose that prices change every four periods. It follows immediately that $E(T) = 4$. Suppose that the optimal price for each product follows an independent, driftless Brownian motion with infinitessimal variance σ^2, then the steady-state distribution of price changes is a normal density with variance $4\sigma^2$. The kurtosis of a normal distribution is equal to 3. Putting this all together, the formula predicts $\mathcal{M} = 2\delta/\varepsilon$. Figure 1 illustrates the output response. Time is continuous and price adjustment is uniformly distributed over the interval [0, 4]. The money shock hits at date zero. Since only a small fraction of firms adjust their prices every instant, the impact effect is equal to the size of the money shock times the elasticity of output with respect to mispricing, δ/ε. When a firm gets a chance to adjust, it adjusts one-for-one with the money shock. Since price changes are distributed uniformly over [0, 4], output returns linearly to trend, and since every firm adjusts by date 4, output reaches trend at date 4; $\mathcal{M}$ is the area under the curve that is easily seen to be equal to $2\delta/\varepsilon$, the value predicted by the formula.

This is a very surprising equation. Note all of the things that do not appear in their equation: the variance of the idiosyncratic shocks to firms' desired prices; the number of prices that the firm is setting; anything about the form of the decision making process; if this were a menu-cost model, the size of the menu cost or the size of the Ss bands. The output response depends on only four things. The first three are fairly straightforward: $\mathcal{M}$ naturally scales with the the size of the money shock δ, the expected time between price changes $E(T)$, and the elasticity of output with respect to mispricing $1/\varepsilon$. The final element is more mysterious. Magically, the kurtosis of the price-change distribution controls for all of the effects of selection and heterogeneity. I have no intu-

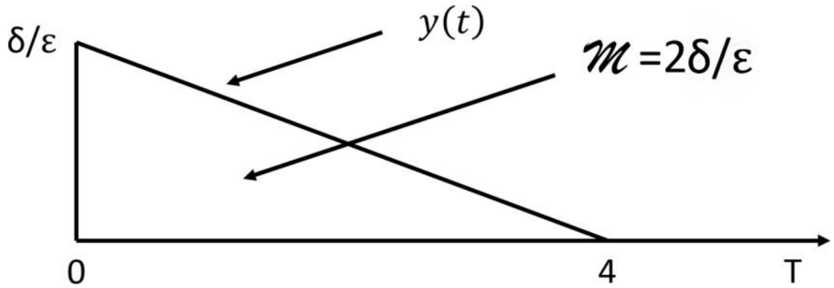

Fig. 1.

ition for this beyond the observation that larger kurtosis is associated with greater mispricing and a larger effect of money on output.

The equation is an approximation that holds under certain conditions. There are technical limitations, some of which are serious. The variance of marginal cost must be the same across products within a firm, but may differ across firms. They can handle heterogeneity in the time-dependent rules used by firms, but all firms must follow the same state-dependent rules.[2] There needs to be zero drift in marginal cost at the product level. This last requirement is in some sense the most troubling, as it would appear to be violated in the data; marginal cost is declining in some manufacturing sectors and rising in some service sectors.

Still the assumptions are no more stringent than those made in many macromodels, and the characterization of the output effects of a money shock in terms of only a few statistics is very neat and compact. I was therefore left wanting to see if their sufficient statistics worked at all in practice. Given the technical limitations, I would not expect this equation to fit the data perfectly, but it would be very nice to know if these statistics are at all informative. What is the correlation between these statistics and the real effect of a monetary policy shock? Do countries with greater kurtosis also have more potent monetary policy? What about industries? Given the large number of micropricing data sets that have been collected over the past few decades, it would be relatively simple to calculate the necessary moments. Calculating a measure of monetary policy would be more challenging, but not impossible. One could assume that ε is constant across countries. To the extent that the theory did not work one might want to begin controlling for violations of the technical assumptions, but before doing so it would be nice to know if the equation held any information in its simplest form. Simpler empirical relationships have been successfully taken to the data. I would find such an exercise much more interesting than what they actually do in the paper, which is to attempt to show that large shocks have different effects than small shocks. I see empirical work along these lines as the logical next step in their research program.

In closing, I would like to discuss the results of the paper in light of the differences between state and time dependence that are prominent in the literature discussed above. The theme of these comments is that while the assumptions that the authors make lead to very pretty results such as the equation above, these assumptions also rule out some of the potential differences between the two types of models.

First, their experiments always begin with the steady-state density.

The authors consider small shocks so that they may employ first-order approximations. Since the initial state never changes and since their approximation is linear, they can't get at the state dependence of the response of output to shocks that figures prominently in Caplin and Leahy (1991) or Caballero and Engel (2007).

Second, they can allow for lots of different types of heterogeneity, especially heterogeneity in time-dependent rules. They need this heterogeneity to be thoroughly mixed, in the sense that each type must be in their own steady state. This rules out heterogeneity that depends on the state of the economy. They cannot have time-dependent rules that depend on the aggregate state as in Ball, Mankiw, and Romer (1988), where higher inflation leads to shorter intervals between price adjustment. They cannot have the variance of idiosyncratic shocks depend on the state of the economy as in Vavra (2013). Nor can they have the time-dependent policy depend on the calendar as in Olivei and Tenreyro (2007).

Third, they make a series of assumptions so that the marginal cost of each firm is an independent Brownian motion without drift. This is a very convenient outcome since it transforms an equilibrium problem into a collection of isolated decision problems; they can solve for the pricing decisions at one firm independently from the pricing decisions of all other firms. The cost of the zero drift assumption, however, is that they do not get frontloading as in Ball (1994) or Midrigan (2011), and the strategic independence across firms means that they will not find any role for strategic complementarity as in Dotsey and King (2005).

Finally, their sufficient statistic approach does not pin down welfare. This is easy to see because the statistics are independent of so many things, in particular the variance of the idiosyncratic shocks.

In sum, this is very interesting research. The authors have made great progress on a very technically difficult problem. The simple characterization that they find is at once surprising and provocative. I look forward to seeing where they go in the future.

Endnotes

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1. The authors also appeal to imperfect information, but there are problems with this interpretation. Imperfect information itself does not lead to the type of fixed prices we see in the data. Instead, firms change their prices in every period in response to their imperfect perception of how the world is changing. One needs to add auxiliary assump-

tions such as assuming the optimal price is a martingale or adding a fixed cost of price adjustment on top of the imperfect information. The former is unrealistic. The latter might as well be called a state dependence (unless one locks managers in a box so that they have no ability to see and respond to current news).

2. To see why heterogeneity in state dependence is a problem, consider an economy that is really the sum of two completely separate economies. Suppose that each has an Ss pricing policy but that the size of the Ss bands are different. Each economy separately would have kurtosis of 1 since the price-change density is a two-point density. The combined economy, however, would have a kurtosis of greater than one, since the price-change density would be a four-point density. The equation would predict that the two sectors individually were less rigid than the combined economy, even though there is no connection between the sectors.

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