Nonlinearities in Monetary Policy Transmission

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Abstract

First order approximations of a model's impulse response functions cannot capture non-linear behavior in shock transmission. Namely, it's possible that big shocks are not a scaled version of small shocks (size effect) or that responses following a positive shock do not mirror those from a negative shock (asymmetry). Using a Local Projection Instrumental Variable (LP-IV) framework, I estimate impulse responses of standard macro variables to monetary policy shocks and look for evidence of nonlinearities. Specifically, I use monetary policy surprise series as an instrument and decompose the measured shock into regimes based on how the Fed Funds Rate changed in a given month to allow for nonlinearity. I find evidence against the notion that larger shocks amplify the effects of smaller shocks and some instances of broader asymmetry. Future work will gauge how well this result holds up with other estimation approaches (e.g., VAR-based, non-parametric, Bayesian methods) and investigate if enriching standard model frictions helps produce impulse responses that align with US data.

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Introduction

Much of the evidence on the effects of monetary policy has been produced from model-based and empirical approaches that impose a linear relationship between shocks and real variables. Namely, while standard impulse response functions (IRFs) can be a non-linear function of time, it's often the case that if the impulse response to a shock s_t is $\{y_{t+h}\}$, the impulse response to αs_t is simply $\{\alpha y_{t+h}\}$. This rules out non-linearity from a shock's *size* (big and small don't have the same effect) and *sign* (positive and negative don't have symmetric effects). To produce any meaningful policy recommendations, it must be determined whether this simplification is consequential.

The first stage of this project will consist of estimating IRFs from US data of standard macro variables to monetary shocks in a way that allows for non-linearity. This will be accomplished by using monetary surprise measures that are well-established in the literature (e.g., Romer and Romer, 2004; Nakamura and Steinsson, 2018), in combination with specifying regimes that correspond to the relative size and sign of change in the Federal Reserve's target federal funds rate in a given month. Then, we will see how well "off-the-shelf" models are able to match the nonlinearities we do observe. By construction, typical formulation and solution methods for standard models produce near or exactly linear IRFs. To make this model comparison exercise consequential, we modify the default constraints faced by firms (e.g., price and wage setting rigidities) and households (e.g., investment adjustment costs) to accommodate potential asymmetries, which also shed light on the extent to which the status quo structure dictates the results these models produce. Finally, we will consider further departures from the representative agent and full information paradigm to account for and ultimately rationalize what we observe.

The results gathered so far imply a substantial degree of non-linearity. For both negative and positive shocks, we find evidence of size effects for consumption, output (industrial production), and inflation (CPI growth). Specifically, we find evidence that modest, expansionary changes to monetary policy increase our macro variables of interest relatively more than a large change. Relativity in this context means that the effects of a small interest rate cut (a movement smaller than 10% of the Fed's previous target) are proportionally larger than a big cut. We also find that larger, counteractions changes have relatively less effect on inflation, while simultaneously producing a stronger depression in the level of consumption and output. To put these results in perspective, Table 1 gives a comparison in levels for a horizon of 12 months. For sign effects, we find evidence that there are asymmetries between a big cut and a big hike but the evidence for small changes is inconclusive.

Table 1: Difference in YoY growth between large shock and scaled small shock

	Cut Size Effect	**Hike Size Effect**
Consumption	-3.5%	-2.2%
Output	-8.4%	-3.8%
Inflation	-2%	0.9%

All estimates significant at 90% level

The bedrock of the parametric approach will be a Local Projection Instrumental Variables (LP-IV) framework advanced by Jordà et al. (2015) and fleshed out by Stock and Watson (2018), which offers several advantages over alternatives. For deciding between a LP or a vector autoregressive estimation (VAR), Plagborg-Møller and Wolf (2021) clarifies that in finite samples, this decision comes down to a trade-off between flexibility (LP) and efficiency (VAR). Notable advantages for LP are the insensitivity to the presence of unit roots or non-stationary variables as both outcome and control (Plagborg-Møller and Montiel Olea, 2021; Plagborg-Møller et al., 2024) and the ability to relax the assumptions imposed by VAR structure (namely, invertibility and recursiveness). For deciding between LP and LP-IV, the various monetary shock series that have been developed still have unresolved interpretability issues (e.g., Brennan et al., 2024), but what is consistent across all approaches is that they are developed in order to capture relevant changes in monetary policy while maintaining exogenous variation. Thus, it's more appropriate to treat these shock series as instruments. Moreover, by instrumenting actual changes to the interest rate target, we can argue the coefficients produced in our estimation are representative of the effects of monetary policy in general, rather than just policy surprises. Finally, we could in principle use a different shock series for each regime of our decomposition, so we can simply use whichever one is the strongest instrument for a given regime. Doing so with a pure LP estimation would yield incomparable parameters.

The main disadvantage of LP-IV relative to LP is the inability to incorporate state dependence. It should be noted that the virtually all past approaches claiming to estimate impulse responses from state-dependent local projection estimation (as well as many VAR-based approaches) likely suffer from substantial bias for non-marginal shock sizes (Gonçalves et al., 2024). Jordà (2023) proposes a fix using a very specific type of interaction term framework, but it cannot be extended to LP-IV without suffering from the curse of dimensionality. In any event, Gonçalves et al. (2024) provide a simple non-parametric procedure to properly estimate state-dependent effects, which we can augment with instruments and additivity to account for sample size[1] and shock interpretability issues. Because the sensitivity to state dependence should be taken seriously (e.g., large cuts tend to happen when the expected trajectory of output is downward sloping regardless of policy), this is an important benchmark. Another previously referenced disadvantage of LP is the relative size of standard errors. We can consider Bayesian extensions to our approach in the spirit of Ferreira et al. (2024). Moreover, I plan to try all described estimation procedures to provide a frame of referenced. So far, the LP and state-dependent LP results have yielded qualitatively the same results for nearly all variables and various shock series[2].

[1] Sample size is a constraining issue in general, given the need to include lagged outcome and control variables for all specifications. This, in addition to the desire to include the entire zero lower bound episode and subsequent tightening, prevents the use of series with arguably superior identification strategies such as Aruoba and Drechsel (2023), Acosta (2023) and Miranda-Agrippino and Ricco (2021)

[2] Bauer and Swanson (2023) and Bu et al. (2021), in addition to those previously mentioned. The shock series mentioned in footnote 1 are also considered in the litany of ancillary estimation results, namely LP without IV.

Related Literature: This work connects to a vast empirical literature attempting to assess the effects of monetary policy using data rather than specifying a general equilibrium model. Most papers use a version of a LP or VAR specification and deal with reverse causality issues with "monetary surprise" data from a previous effort (e.g., Romer and Romer, 2004) to identify unanticipated changes in monetary policy. Ramey (2016) provides a survey of the most common approaches, with Plagborg-Møller and Wolf (2021) clarifying the finite sample setting accounts for most of the differences. Moreover, Ramey (2016) documents prevalent "puzzles", implications of impulse responses that conflict with standard intuition, that exist for different pairings of method and monetary surprise measure. The guidance suggests the bias in VARs can be prohibitive in our application. In general, there is a great degree of ambiguity about what conclusions to draw about the empirical impulse responses to monetary shocks – one can find a well-cited paper suggesting that fundamental macro variable x responds in y direction for any combination of x and y. Another benefit to the framework I'm using is my main purpose largely abstracts from the notion of puzzles by focusing on *relative* effects, which carries a general lack of strong prior beliefs because it has not been extensively documented in past theoretical or applied analysis of monetary policy transmission.

Broadly speaking, the group of popular methods has remained the same over the past decade. But because of recently revealed shortcomings much of the literature relating to bias in estimates (Gonçalves et al., 2024; Herbst and Johannsen, 2024), bias in standard errors (Plagborg-Møller and Montiel Olea, 2021; Herbst and Johannsen, 2024), and general identification (Stock and Watson, 2018; Jordà, 2023), there is a need to provide new results that account for these considerations, which will also give insight into the usability of what already exists. This work will also be one of a very small group to explicitly focus on nonlinearities. Barnichona and Matthes (2018) estimate impulse responses through a vector moving average representation with some structural restrictions and present overwhelming evidence of sign asymmetries. Consistent across 3 identification strategies, they find that the effects of rate hikes and cuts move unemployment and inflation in the *same* direction, with the specification restricting nonlinearities yielding much different conclusions. Despite the moderate body of evidence pointing to LPs as being more appropriate for recovering reliable point estimates of monetary policy effects, Lee (2023) is the only preexisting work to try to allow for any non-linearity in a LP to my knowledge. Of course, the issue of LP vs. VAR remains an unsettled question – Stock and Watson (2018), for instance, conclude that inevitability is a relatively innocuous assumption for this application. However, the monetary shocks identified by Debortoli et al. (2023), which to my knowledge is the most general VAR-based approach in the literature (e.g., relaxes ordering assumption, permits general nonlinear functions of variables as controls), are highly counterfactual, anecdotally suggesting at least one of the standard assumptions is highly non-trivial to impose.

The route I am taking is not without its own potential pitfalls. As previously referenced, LP-IV cannot feasibly incorporate state dependence. Per Jordà (2023), this is because for each control variable, we need an interaction term with what we are instrumenting. Given that at a minimum we need to include lagged control variables with a healthy number of lags (Plagborg-Møller and Montiel Olea, 2021), this creates an infeasible number of instruments. Further, Gonçalves et al. (2024) shows excluding these terms would induce significant bias when considering large shock sizes, meaning their recommendation of a non-parametric approach is a logical pairing with our baseline LP-IV. A separate issue that interacts with the LP-IV specification is the validity of the instruments themselves. Jarocinski and Karadi (2020) and Acosta (2023) present evidence that when using monetary policy surprise measures, it may be important to not assume that Fed announcements (and monetary surprise measures in general) only affect people's beliefs about interest rates, i.e., they argue it's important to account for a "Fed information effect". Koo et al. (2024) are the first to document formally how this affects inference when using impulse responses generated by LP-IV. The monetary policy surprise literature has yet to reach a consensus on several key issues, crucially including how justifiable different identification strategies are across the array of shock series you can choose from, which adds another reason to consider a non-parametric approach.

After a careful empirical treatment, the next step is to take our fact finding to models themselves, so this research also adds to the literature on model-based accommodations of nonlinearities. One well-documented cause of model nonlinearities is the effective lower bound (ELB). In particular, the standard New Keynesian model has several counterintutive implications about optimal policy when the economy is sitting at the bound (e.g., Eggertsson, 2011; Christiano et al., 2011; Wieland, 2019). However, Bonciani and Oh (2023) find that many of these "paradoxes" are resolved by allowing the central bank to conduct a wider array of open market operations, as was common during the ELB episode of the 2010s. There has been in general a lot of attention paid to the idea that tight and loose monetary policy do not have mirroring effects (e.g., Coibion, 2012; Angrist et al., 2016; Tenreyro and Thwaites, 2016). For instance, some posit that monetary policy is less effective during business cycle downturns because it's easier to supress rather than stimulate economic activity (e.g., encouraging vs. discouraging borrowing), a phenomena known as "pushing on a string". One associated source of asymmetry could relate to the evidence, dating as far back as Keynes (1936) and Tobin (1972), that there are relatively more frictions of revising prices and wages downward. Kim and Ruge-Murcia (2009) is the canonical reference for introducing more costly downward price and wage adjustment asymmetry into a New Keynesian model, but they assume a non-stochastic monetary policy rule. Lee (2023), the closest companion paper, uses an asymmetric investment constraint and simpler downward wage adjustment asymmetry and finds both sign and size asymmetries. Future work will extend beyond menu cost models, especially in light of Oh (2020) finding that under uncertainty shocks (unexpected increases in the second moments of exogenous processes), in particular that Calvo pricing yields more non-linear behavior resulting from these shocks compared to Rotemberg.

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