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"How do US monetary policy shocks affect global inflation rate: an empirical study."

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ABSTRACT (in Italiano)

Le decisioni di politica monetaria statunitense hanno delle ripercussioni a livello dell'economia globale. Il perché queste ripercussioni esistano non è ancora perfettamente chiaro, possono infatti esserci diversi motivi per cui un movimento inaspettato del tasso di interesse sia percepito dagli agenti economici come qualcosa di sorprendente, come un fatto che accade oggi ma che inevitabilmente ha molteplici effetti su diversi cicli globali: inflattivo, monetario, economico, finanziario… Questa tesi si propone di studiare le conseguenze che uno shock di politica monetaria statunitense comporta a livello del tasso di inflazione globale, distinguendo tra uno shock genuino e uno informativo, e dando evidenza empirica the la misura dello shock utilizzata nel modello ha un effetto statisticamente significativo nel breve periodo ma tende a perdere di significatività a mano a mano che si regrediscono le variabili.

ABSTRACT

In the global economy we observe spillovers that go from the US monetary policy decisions to the rest of the world. The reason for this is not crystal clear, meaning that there could be many different channels that justify that an unexpected rise of interest rate, a shock, of monetary policy is something that surprises the agents, it happens today and can have effects on different global cycles: inflationary, economic, financial, monetary… This paper focuses on the consequences that US monetary policy shocks have on the global inflation rate, discriminating between a genuine monetary policy shock and an information shock, and providing evidence that the US monetary policy shocks' measures used in the empiric model has a statistically significant estimated effect in the short run, but tends to lose statistical significance the longer we run the models.

Section I: INTRODUCTION

When a Central Bank takes decisions regarding the policy rate to apply, it looks at some macroeconomic variables that capture the most important trends (such as the level of inflation π, the unemployment rate μ etc.) and makes choices according to what its desired level for these variables is, both in short, medium, and long run. Private agents inevitably form expectations with respect to what will the conduct of monetary policy be, therefore, as long as their expectations are matched by the new policy rate announcement, they adjust their consumption and investment levels accordingly, thus reaching the optimal equilibrium determined by the optimal levels of π, μ, y (income) and i.

For example, the fact that when the Fed decides to rise the nominal interest rate the US domestic elements tend to drop is no surprise: the US economic and financial cycle suffers, investments prolapse, and consumption follows. These notions are well known and explained by the three-equation model[1]: the central bank, in front of an undesired level of inflation/unemployment measured on the Philips Curve and caused by a shock on the demand side explained by the IS curve, move along the MR (Money Rule) curve adjusting the policy rate - according to the Taylor Rule[2] - until the desired inflation rate is reached. If, on the other hand, the undesired level of inflation is caused by a different issue, such as a negative shock on the supply side, the central bank would lower the Money Rule height and would shift the policy rate accordingly[3]. These are very general consideration regarding monetary policy behaviors. Indeed, I did not consider the shocking component of the policy rate shift, so I assumed that agents enjoyed perfect information, that they were able to form concrete expectations and that these expectations were almost always matched by the CB behaviors. Moreover, and most importantly, I was focusing on a single country, however, this paper aims to quantify the effects that an unexpected state policy rate shift (the US one) has on an aggregated variable such as the global inflation rate.

Now, before diving into the empirical model and its results, it is important to understand why I should expect a global shift in macroeconomic variables in front of a US decision. In open economy, Americans have a very strong role in terms of import and export from the rest of the world, so after a nominal interest rate rise, the global cycle suffers as well. Moreover, when the real side is put under pressure, also the financial side encounters many troubles. Indeed, the financial side is not unrelated to the real one for various reasons, such as the fact that production companies have capital divided into various financial assets (whose returns after a policy rate shocking move are studied by various papers such as Miranda - Agrippino and Rey 2020): these companies' assets are not well considered by financial markets, returns go down etc. So, in theory, if after an unexpected shift in the US policy rate the global demand drops,

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[1] The model studies the medium run effects of monetary policies and disturbances. It allows to simultaneously analyze the relationship between income y, nominal interest rate i and inflation rate π. The three equations are the IS curve that explains the negative relationship that exists between the interest rate and the income, the Philips Curve that studies income as a function of the unemployment rate (or oppositely as a function of the inflation level) and the Money Rule curve that describe the behavior and preferences of the central bank.

[2] The most general equation used to evaluate the appropriate interest rate level, it can take various forms but in the end the Fed sets the target rate like so:

$target.rate = Neutral.rate + 0{,}5 * (output.gap) + 0{,}5 * (inflation.gap)$.

[3] Generally speaking, the Central Bank could also work on the MR slope to attenuate social costs of monetary policies: when the MR's parameters α and ß are high the MR is flatter and this brings the whole system to the equilibrium faster, but society must suffer a higher unemployment rate, whereas α and ß are low the opposite happens. The sacrifice ratio is used to evaluate the different deflationary policies in these terms.

and after the global demand drops, prices fall down to, we should also be able to observe a reduction in the global inflation rate. Whether this is true or not in the data, what is the magnitude of this effect and most importantly what are the differences if we consider the genuine component or the information component of the shock, is the aim of this study.

I will proceed in steps: after a quick review of the controls and the dependent variable, Section II will provide the meaning of shocks in macroeconomics, considering how it has been defined by literature in the past and in recent times, and providing its measurement method and use in the model. Section III will depict the empirical approach: the global inflation rate at time t + h, where (h = 0, 1, 2, ..., 11), was regressed on the two shocks' proxies separately (and some controls) at time t. This approach is called Local Projection (LP). Its use will be justified, as well as its limitations and corrections. The final output, an impulse response function for both types of shocks, will be showed in Section IV where the regressions' results will be seen and analyzed, giving an interpretation of the estimated coefficients. Finally, an ending graph will compare the different behaviors of the two measures. Section V will be dedicated to conclusions.

SECTION II: DATA DESCRIPTION AND ANALYSIS

The dataset used to run the multivariate linear regressions[4] contains monthly data from January 1991 to December 2015, for a total of 300 observations of 5 variables (lags excluded). The dimension of the dataset was constrained by the number of measurements available for the monetary policy shocks (more on this later).

II.i) Global inflation and control variables

The dependent variable, the global inflation (π from now on), was downloaded from the economic time series on Fred's website (at this link https://fred.stlouisfed.org/series/OECDCPALTT01GYM). As usual, π is captured by the movements of the consumer price index for all items (CPI) for OECD countries, that measures changes in prices of goods and services purchased by the final consumers, thus evaluating the shifts in global inflation. An increase in the CPI indicates an increase in the general price level,

[4] An equation that studies the effects that more than one regressor - the independent variables X1, X2, … Xn - has on a certain dependent variable of interest Y. The relationship is assumed to be linear, but it is important to highlight that it is not always the case. We are interested in estimating the parameters of the regression, which give an idea of the causality effect of one variable on another.

i.e. inflation, while a decrease indicates deflation. The CPI is the most widely used measure of inflation, it is followed by consumers, firms, policy makers, financial markets and most importantly by the Fed when discussing the incoming decisions of monetary policy. It can also influence consumers and investors decisions. The CPI is calculated using a sample of representative products and services, and changes in their prices are monitored over time. The index that I am using in the regression is expressed in growth rate same period previous year, so it is calculated like so[5]: $\pi = \frac{\pi_t - \pi_{t-1}}{\pi_{t-1}}$

There are two control variables in the model, both downloaded from Fred's economic time series. The first one is the industrial production (INDPRO from now on, see https://fred.stlouisfed.org/series/INDPRO) which represents a proxy of the business cycle and could capture the idea of demand that shifts prices, so it embeds what could be an information about inflation. The second one is the 10-Year Treasury Constant Maturity Minus 2-Year Treasury Constant Maturity which represents the spread (T10Y2Y from now on, see https://fred.stlouisfed.org/series/T10Y2Y). It captures what is the raising of funds by firms that finance themselves in the long run versus those that finance themselves in the short run: these costs can become part of the marginal costs of firms, be charged and therefore influence inflation.

The idea behind the choice of these two controls is the following: even though I am controlling for these variables, I still find a statistically significant coefficient for the shock variable. Therefore, on the one hand we put the main regressor in a bit of difficulty, and on the other hand, we control for these two variables.

II.ii) The monetary policy shock

The last but most important variable is the measure of the monetary policy shock. As previously said, the regression ran was twofold: one with the genuine monetary policy shock as main dependent variable and one with the information shock as main dependent variable, plus all the controls. The discrimination between these two completely different types of regressors is something that concerns the most recent literature, which for instance has focused on the "Transmission of monetary policy shocks" (see Miranda - Agrippino and Ricco 2021), where the authors identify an instrument for monetary policy shock but at the same time separate its measure in two, distinguishing the genuine component from the information component.

[5] There are other ways to express the CPI index, such as percentage change from year ago, compounded annual rate of change, or indexed. I opted for this one because it makes the interpretation of results handier.

Setting aside this splitting for a moment, shocks have been a field of interest long before that paper. For instance, Ramey (2016) illustrates the challenges in the methods used to identify the correct instruments to deal with these unexpected policy rate's shifts, while Miranda - Agrippino and Rey (2020) had studied the relationship between the global financial cycle and US monetary policy shocks. Both these works did not consider the potential information component of an unexpected policy rate shift. So, since the distinction is a matter that concerns the most recent literature, it may be useful to explain what a general approach to instruments' identification for monetary policy shocks could be, to move, in a second step, to the two types of shocks upper mentioned.

For this reason, this part will be divided in three: the first one will analyze the "traditional" conception of shock while the second one will focus more on its information component. The third one will be dedicated to the way the shocks' series that I used to run the regressions had been estimated and distinguished.

II.ii.a) Monetary policy shocks before the distinction

Ramey (2016) studies all the possible empirical methods to identify shocks. These are considered in their widest conception possible, so also with respect to fiscal and technology issues. It is said that "shocks should have the following characteristics: (1) they should be exogenous[[6]] with respect to the other current and lagged endogenous variables in the model; (2) they should be uncorrelated[[7]] with other exogenous shocks; otherwise, we cannot identify the unique causal effects of one exogenous shock relative to another; and (3) they should represent either unanticipated movements in exogenous variables or news about future movements in exogenous variables." (Ramey 2016, p.5). This definition still applies to the way following studies are going to estimate the shock's series. For now, even though it does not consider purely and only the monetary shocks and it is not fully complete for the purpose of my research, I will use it for this subsection. With that said, the identification methods used for unexpected shifts in the policy rate can take various forms. I will focus on the high frequency

[6] An exogenous variable is defined as an economic variable which, within a given model, assumes a value independent of the equilibrium represented in the model itself; it is therefore a variable that affects the equilibrium represented in the model, but is not influenced by the equilibrium itself (it is the cause of the equilibrium and not its effect, but it is the effect of other variables that do not belong to the model)".

[7] Correlation is a statistical relationship between two variables where each value of the first one has a correspondent value of the second one. It does not implicate causality. In this case, the uncorrelation between the shocks and other shocks refers to the second condition in for the validity of the instruments which has to be satisfied when running an instrumental variable regression, an approach which is widely used in econometrics and that will be better depicted later on (see section II.ii.c)

identification method[8] (since it gives me the opportunity to bridge this paper with the one written in by Miranda – Agrippino and Rey, 2020) because it is employed by a lot of researchers and is also part of the identification of the shock that I am going to use in the model.

To comprehend the idea behind this approach, it is important to understand that we do not observe monetary policy shocks: when central banks decide to vary the nominal interest rate (or not to vary it at all) that move may or may not be a shock, if it is foreseeable then it is not, therefore it is not something that should lead agents to change their consumption and investments level because they have already incorporated this information and they are not surprised by the central bank. As a consequence, nothing should happen. Instead, if there is a shock, then it is not the change in itself and per se of the nominal interest rate that has a significant impact on the change in consumption, investments, etc. but we need to understand what the shock really is, how is it perceived and how to quantify it. The way Miranda–Agrippino and Rey (2020) identify the instrument for the shock could be explained like so: they appeal to information relating to US monetary policy decisions and what the financial markets think regarding these decisions. They say that if we have high frequency data so that shortly before the central bank's decision, we are able to see what the markets expect in relation to what the interest rate is after this decision, and shortly after the decision we could check if those expectations were matched or not - and most importantly how big is the difference between the ex-ante expectation and the ex-post realization - well this measurement could give a sense of the shock. According to Ramey (2016, p. 11) "because the timing is so high frequency (daily or higher), the assumptions are more plausible than those employed at the monthly or quarterly frequency".

The intuition behind their way of proceeding is the following: if private agents are very close to the decisions of a policy maker, they have already incorporated all the information about the economic system that the policy maker has. Let's take a practical example for sake of simplicity: the Fed knows that unemployment is high and inflation is low, you know it too, you are good at processing data, you are a financial operator and there are no surprises or frictions or imperfect information between parties, with that in mind you form the expectation of what the rate will be after the monetary policy decision. You are wrong. At that point, did you get it wrong because it is a surprise or because in the meantime the economy has given new

[8] This method takes into account frequently collected data, like day-by-day trade information, to find financial or economic connections. It's especially useful in situations where these connections are changing rapidly and might elude detection when data are collected daily or monthly only.
In financial and econometric studies, this technique is useful in addressing endogeneity challenges, which occur when there's a correlation between independent variables and errors. This situation could lead to distorted results. By leveraging data collected at high frequencies, experts can tap into minute-by-minute changes to trace cause-and-effect relationships.

information to the central bank and the central bank has decided to react to this information with a move in the nominal rate? The answer is the first one, because you are so close to the decision that there is nothing else the central bank learns after you have formed the expectation.

With that said, Miranda Agrippino and Rey (2020) used an identification strategy for the shock in which the choice of the high frequency instrument represents a crucial step, in the sense that the reader must believe this measure and all the following co-implications regarding financial and economic cycles that this estimate influence. To be clearer, they "use 30-min price revisions (or surprises) around FOMC announcements in the fourth federal funds futures contracts (FF4), and [they] construct a monthly instrument by summing up the high-frequency surprises within each month. Because these futures have an average maturity of three months, the price revision that surrounds the FOMC monetary policy announcements captures revisions in market participants expectations about the future monetary policy stance up to a quarter ahead" (Miranda Agrippino and Rey 2020, p. 2761).

II.ii.b) Monetary policy shocks with the distinction

The shock series in the paper cited before is not the one we are going to use in our regression. Up to date, it may not be fully complete. The strong expected result, and what was actually found, in this work and in other papers was that, at least with respect to inflation rate, whenever there was a contractionary monetary policy move (rise in the interest rate) the inflation unequivocally dropped. This is perfectly in line with the most known macroeconomic theories and models (see Section I). What had been discovered later? Miranda – Agrippino and Ricco (2021) embraced a new conception of shock, accounting for the fact that "Information asymmetries[[9]] between the public and the central bank can in fact give rise to an "information channel" for monetary policy actions […]: to informationally constrained agents, a policy rate hike can signal either a deviation of the central bank from its monetary policy rule—i.e., a contractionary monetary shock—or stronger than expected fundamentals to which the monetary authority endogenously responds". (Miranda – Agrippino and Ricco 2021, p. 75)

The intuition behind this theory is that if agents enjoyed perfect information, different identification methods would lead to the same results, yet indeed this does not occur, sometimes even resulting in price puzzles. So, due to the imperfect information between market participants and the Fed, the Miranda – Agrippino and Rey's measure is not wrong but actually contains two joint pieces of information that should be accounted separately. Their instrument

[9] A condition in which two or more individuals that engage in the same economic process do not have the same set of information at the same time. The part that is more informed has an advantage over the part which possesses less informations.

used to estimate the shock did not consider neither the information power of announcements (forward guidance[10]) nor the information asymmetries that can arise between the central bank and the public, even using the 30 minutes price revision upper mentioned.

This means that on one side we identify the genuine and classic monetary policy shock previously analyzed, on the other, the new reasoning emerging in the literature is the following: if the central bank made this surprise move, it partially may be due to the fact that they expect the economy to do well in the near future and inflation to rise at the same time, therefore they anticipate this thing to prevent inflation really manifesting, i.e. they are giving a new set of information to agents. The central bank is giving a positive information shock, they do not explicitly say that in the future the economy will do well, but it looks like they expect it and somehow agents capture and incorporate these expectations. This shock is completely different from the standard one and is supposed to be expansive.
It has been seen that the financial markets can sometimes react well and not badly to general shocks, hence the idea that it could be a shock that is seen as an information shock rather than as new data on the conduct of policy in itself. With its move, the Fed is telling market participants that it thinks the "best part" is coming, therefore agents are euphoric, the financial markets rise, consumption can increase etc. If this happens it could also be that from the point of view of global inflation this shock is indeed inflationary, not deflationary! We will check in the model's result if that is the case.

Now that the two different shocks have been depicted, we can finally give a definition of shock, or at least the definition that I will follow for the rest of the study.
Following Miranda – Agrippino and Ricco (2021), shocks are an "exogenous shifts in the policy instrument that surprise market participants, are unforecastable, and are not due to the central bank's systematic response to its own assessment of the macroeconomic outlook" (Miranda – Agrippino and Ricco 2021, p. 76). And more "a policy rate hike can be interpreted by informationally constrained agents either as a deviation of the central bank from its monetary policy rule—i.e., a contractionary monetary shock—or as an endogenous response to inflationary pressures expected to hit the economy in the near future. Despite both resulting in a policy rate increase, these two scenarios imply profoundly different evolutions for

[10] Central Banks, using the power of their announcements, can condition the future expectations of market participants regarding the incoming shifts of nominal interest rate that will influence the cost of money.

macroeconomic aggregates and agents' expectations" (Miranda – Agrippino and Ricco 2021, p. 80).

It should be clear that this definition on one side recalls the one used by Ramey (2016) with respect to the exogeneity issues, on the other side it adds the information component to the policy rate shift. The "systematic response to the macroeconomic outlook assessments" are the *classic* responses to undesired levels of inflation (to be clearer, they could be explained by the three-equation model depicted in the introduction) they are systematic, therefore they could be foreseeable. Miranda – Agrippino and Ricco (2021) think that these responses still exist but embed a new component which is the information one. Therefore, it is preferable to account separately for these two.

II.ii.c) Estimation method of monetary policy shocks measure used.

Miranda - Agrippino and the Ricco (2021) had estimated a time series that they call "information shock" that I am going to use for the model (as well as the time series regarding the genuine shocks). These two series are named MPI_INFO and MPI_FF4 respectively.

The method that they use to evaluate the measures makes use of high frequency data and puts in place an external instrument (or proxi) SVAR[11]. With respect to this last one, following the words of Ramey (2016, p. 12) "This approach takes advantage of information developed from "outside" the VAR, such as series based on narrative evidence, shocks from estimated DSGE models, or high frequency information. The idea is that these external series are noisy measures of the true shock." After assessing the relevance condition (the external instrument needs to be correlated with the shock) and the exogeneity condition[7] (the external instrument needs to be uncorrelated with other shocks) the procedure consists in three steps:

- "Estimate the reduced form system to obtain estimates of the reduced form residuals η_t
- Regress η_{2t} and η_{3t} on η_{1t} using the external instrument Z_t as the instrument. These regressions yield unbiased estimates of $b_{21}$and b_{31}. Define the residuals of these regressions to be ν_{2t} and ν_{3t}.
- Regress η_{1t} on η_{2t} and η_{3t} , using the ν_{2t} and ν_{3t} estimated in Step 2 as the instruments. This yields unbiased estimates of b_{12} and b_{13}". (Ramey 2016, p. 13).

[11] While the VAR method aims to predict the current value of each variable in the model using the past values of them and the past values of all the others, but it does not focus on causal interpretation, the SVAR adds the Structural component to it in order to investigate these causal relationships. This is done by imposing restrictions to the model in place, and since it is not always easy to base these restrictions purely on economic theory, an external instrument (exogenous) is carried out for this purpose. The intuition behind this process is similar to the IV regression, where the instrument helps to look for causal relationship while keeping them distinct from correlation.

The process followed to build the instruments for estimating the shocks in Miranda – Agrippino and Ricco is the same and "takes into account both the slow absorption of information in the economy and the signaling channel of monetary policy that arises from the asymmetry of information sets between the central bank and market participants" (Miranda – Agrippino and Ricco 2021, p. 86). In their process, the residuals obtained in the first step are instruments for the monetary policy shock, the second step just sums up monthly residuals from the step before (since FOMC meeting usually take place once a month) and the third step is the most innovative one since it counts for the "slow absorption" mentioned in the quote before and gives the final output's residual which represents the instruments that they were looking for.

In the dataset that I used, the two shocks are monthly expressed in percentage points. For example, the y1991m1 data for the genuine shock is 0,0032 this means that the private agents expected a certain shift in the interest rate, but the shift that actually occurred was bigger of 0,32 basis points[12]. The same goes for the y1991m1 value of info shock. Summed together, the two should give what the agents usually say is a "monetary policy shock", the distinction is made because the effects that we should expect from the genuine one are deflationary, while from the information one are inflationary. I will check these assumptions in Section III and IV when analyzing the model and the impulse response function and I will show the different behaviors of the shocks regarding the global inflation rate. Ideally, we would expect a permanent negative sign in the estimated coefficients of the genuine monetary policy shock, and a permanent positive sign for the one of the information shock.

Section III: THE EMPIRICAL MODEL

This section will be divided in two parts. The first one will show the empirical model the regression was ran with and how this model was selected. The second one will compare the two most used methods to understand how a particular regressor affect an endogenous variable over time and provide explanation on the choice of LP method, as well as the correction that I applied to fix the serial correlation between errors.

III.i) The model

If I have a proxy, a tool, even an imperfect measure of this shock, I could estimate a simpler model than the one that often takes place in the literature (the VAR model), since my

[12] The relationship between basis points and percentage points is the following: 1 basis point equal 0,01 percentage points.

aim isn't to estimate the shock and then see its effects on many aggregate variables but to take its measure for "granted" and check weather I find a certain linear relationship between it and the global inflation. So, I can take global inflation, regress it on itself lagged, of natural controls (such as global output and global financial cycle) and then on the measure of shocks, lag the model as many times as needed, apply ordinary least squares[13] (OLS) and follow as mono-equational approach. Because if the shock is exogenous (and it is for how it had been calculated, see more later), it allows me to talk about causality and regression allows me to see how inflation responds to this shock.
It is true that the simplest linear model to understand this relationship would be the one that regresses the dependent variable on the measure of the shock and the constant (see *equation 1*)

$$\pi_t = \beta x_t + \varepsilon_t \qquad (1)$$

but model is too simplistic since it does not consider that there could be other regressors that explain the shifts in the CPI index. In addition, it just looks at the effects day–to-day, thus it does not provide a short, medium, and long run explanation.
In order to capture these effects and to be sure that the causality relationship that we are looking for is indeed the "real" one i.e. the β of our main regressor x is statistically significant controlling for other variables, the regression, which parameters are going to be estimated, has to be more detailed.
The features that need to be added to the model in equation *(1)* in order for it to be more precise and useful are the following: first, it has to incorporate the two control variables previously described in Section II (to one of which – Industrial Production - the logarithmic transformation had been applied[14]) and, in addition to them, I added the first second and third lag of global inflation, since macro variables have a lot of persistence/memory[15] so whenever modelling them, I have to make sure this memory is captured by the model's regressors. Second it needs to provide a view of what are the effects on a monthly basis, not just day-to-day.
This approach, in the first place, led to a more complex model that contained three lags for the global inflation rate, the contemporary with three lags for the spread, and the contemporary

[13] OLS estimation is a statistical method which is carried out in order to calculate the estimated parameter of a linear regression. A regression fits well the data if its residuals are small. The magnitude of the residuals is classically measured using the sum of squared residuals (SSR), therefore OLS the estimated values for the parameters that minimize the SSR.
[14] In the context of multivariate linear regression, the logarithmic transformation is often applied to variables which are expressed in monetary terms and/or variables that assume very large values. INDPRO incorporate both cases.
[15] Meaning that inflation tends to come back slowly to its long run values when it is faced towards a shock.

with three lags for the industrial production. However, this model was over specified since I did not find any statistically significant parameter neither for the shock variable nor for the control variables (except for the first lag of global inflation) at any stage. If the output of the regression had been different, such us finding statistical evidence in the controls in each horizon, then the research would have been over, concluding that there was no statistically significant evidence in favor of X. Nevertheless, no statistical evidence was found neither for the controls nor for the main regressor in any stage, which economically speaking did not make sense, so I tried to tidy up the model.

The more stylized version that I ended using because it gave more significant results is the following (see *equation 2*):

$$\pi_t = c_h + \beta_h x_{t-h} + \gamma_h T10Y2Y_{t-h} + \gamma_h log(INDPRO)_{t-h} + \gamma_h first\_lag\_\pi_{t-k} + \varepsilon_{t-h} \quad (2)$$

$$h = 0, 1, 2, \ldots, 11$$
$$k = 1, 2, 3, \ldots, 12$$

Where π is the global inflation captured by the CPI index, c is the constant, x is the measure of the shock so it could either be the genuine component (MPI_FF4) or the information component (MPI_INFO), the other regressors are the control variables and ε is the error term.

This empirical approach that we are going to use is called Local Projection: in fact, we project the information we have at time t on inflation. The regression was run 12 times using the genuine monetary policy shock and 12 more times using the information shock. Since the parameter of interest is β_h, which express the magnitude of change in global inflation for a unit or percentage change in the measure of the monetary policy shock, I then plotted its value plus/minus its standard error on the y axis, and plotted the 12 monthly horizons on the x axis to obtain the impulse response function, on which we will make the adequate comments in the next section.

III.ii) Local Projection and Vector Auto regressive

It could now be useful to make some considerations regarding the reliability and flexibility of the Local Projections model, what are its strength and weaknesses and how I tried to minimize and correct the potential problem that could arise when adopting this kind of method.

Literature stated that there are many ways to measure the effects that a particular regressor has over time on an endogenous variable of interest, which in our case is global inflation, and to estimate impulse responses. The two most used are running a (more or less sophisticated) Vector Auto Regressive (VAR) model or running a Local Projection (LP) model.

The first method is undoubtedly more complex and advanced, the second one, despite it might seem simplistic, has solid theoretical foundations. It was introduced by Jordà (2005, p. 161) where it is clearly said that "The advantages of local projections are numerous: they can be estimated by simple least squares; they provide appropriate inference (individual or joint) that does not require asymptotic delta method approximations or numerical techniques for its calculation; they are robust to misspecification of the DGP; and they easily accommodate experimentation with highly non- linear specifications that are often impractical or infeasible in a multivariate context.. Therefore, these methods are a natural alternative to estimating impulse responses from VARs." On the other hand, it is also worth to note that Marcellino, Stock and Watson (2006, p. 499) stated that "iterated forecasts typically outperform the direct forecasts" where the Local Projection has some analogy with the direct forecasting, while the iterated forecasts could be reconducted to the VAR method. As Ramey (2016, p. 17) suggests, "In the forecasting context, one can forecast future values of a variable using either a horizon-specific regression ("direct" forecasting) or iterating on a one-period ahead estimated model ("iterated" forecasting)."

This just to keep in mind that the two approaches could be equally valid, as long as we pay attention to some aspects. Most importantly, the VAR could be preferable if the model perfectly captures the Data Generating Process (DGP), but whenever this does not happen (so the VAR is misspecified) the more we proceed in each horizon the more the specification errors will amplify the magnitude of the model malfunctioning. This does not happen when using a Local Projection method (and this is why this approach is known to be more robust to misspecification) since for each horizon the model is re – estimated: in each step the dependent variable of interest is lagged ahead, and the model is estimated h times, either changing the control variables or keeping them the same for each regression. After having ran the model as many times as needed, the estimated parameter of the X is plotted against its horizon h times and the impulse response function (IRF) is obtained.

In my regression, the dependent variable was kept still but all the variables in the right side of the model were lagged backwards, which produces the same statistical results in the end.

To consolidate the reason why this paper opts for a LP method rather than a VAR, Ramey (2016, p. 18) said that "Because the Jordà method for calculating impulse response functions imposes fewer restrictions, the estimates are often less precisely estimated and are sometimes erratic.

Nevertheless, this procedure is more robust than standard methods, so it can be very useful as a heuristic check on the standard methods. Moreover, it is much easier to incorporate state-dependence with this method". Since what I am doing is checking whether the measure of the shock (genuine or informative) have a linear impact on π (assuming that the measure is exogenous), I could talk about causality using a linear model and a LP method.

Lastly, in equation (2) when h = 0 there are no particular issues, but as we keep moving with horizons the error term ε_{t-h} will generate serial correlation "because it will be a moving average of the foreast errors from t to t+h*"* (Ramey 2016, p. 18)

Let's take a step back. The LP method makes use of multivariate linear regression. For the purpose of explanation, I will study a simple linear regression like the one written in equation 3, same applies if the regression was multivariate.

$$Y = \alpha + \beta_1 x_1 + \varepsilon \qquad (3)$$

Where $x_1$is the explanatory variables and α, β_1 are the unknown parameters and ε is the error. There are four hypotheses about the error term of the model that need to be satisfied when running a regression like so. Two of which are worth to mention[16] when applying the Local Projection method and dealing with time series since could lead to badly specified statistical models if not properly treated: the first one is that the error term has to have constant variance i.e. the error term is homoscedastic ($Var\varepsilon_i|x_i = \sigma^2$), the second one regards the fact that errors must be uncorrelated ($\sigma_{\varepsilon_i \varepsilon_j} = 0$).

As said, the LP method can generate serially correlated errors, luckily it is possible to construct standard errors to correct the autocorrelation (and heteroskedasticity too, if needed) problem. I used standard errors consistent with heteroskedasticity and autocorrelation (HAC), this approach is attributed to Newey and West (1987) and is appropriate if the autocorrelation is restricted to a maximum number of lags.

Given a simple linear regression model like the one in equation 3, the variance of the estimated parameters is then estimated like so:

$$V(\hat{\beta}_1) = \frac{\sum_{t=1}^{T} \hat{u}_t^2 (x_t - \bar{x}) + NW}{(\sum_{t=1}^{T} (x_t - \bar{x})^2)} \qquad (4)$$

[16] The other two hypothesis I am referring to, are the following: the error term has to have zero mean (in order to obtain unbiased estimates) and the error term has to be independent from the values of the variable x (The omission of relevant variables on the right side of the equation breaks this hypothesis).

Where NW is the Newey West estimator which is evaluated like so:

$$NW = 2\sum_{l=1}^{L}.\sum_{t=l+1}^{T} w_l \hat{u}_t \hat{u}_{t-l}(x_t - \bar{x})(x_{t-l} - \bar{x}) \qquad (5)$$

Where $\hat{u}_t^2$ estimates σ_t^2, $\hat{u}_t\hat{u}_{t-l}$ estimates $\sigma_{t,t-l}$ and $w_l = 1 - \frac{l}{1+L}$ is Bartlett's Kernel.
This correction modifies the output standard errors for each regression (except for h = 0). This aspect is important for evaluating the t test for the statistical significance of the coefficients and therefore to be able to draw appropriate confidence bands in the impulse response functions' graphs (see Section IV).

Section IV: ANALYSIS OF RESULTS

As previously said, the Local Projection method allows to estimate temporal reactions of a certain variable to shocks or impulses, without having to make specific assumptions about the dynamics of the underlying process. The IRF in this context indicates how a variable reacts over time to a unit shock, but it is estimated in a slightly different way than traditional vector autoregressive (VAR) models. While in a VAR model the dynamics of the system are directly estimated, in the local projection model the reaction of a variable of interest to a shock in each individual time horizon is estimated through separate regressions.
In essence, the impulse response function in the local projection model provides a "step-by-step" view of how a variable changes in response to a shock, without making hard assumptions about the structure of the model. As a consequence, local projection models are particularly useful in situations where the dynamics are complex or not well specified, such as in understanding how global macroeconomic variables move after a state policy rate shift.

With that in mind, in this section I will sum up the main regression results comparing the one that used the genuine shock with the one that used the information shock. To help in this process I will provide the two impulse response function (see figure 1) evaluated after having run all the regressions. On the x axis I plotted the 12 horizons (months), on the y axis I plotted the β estimates against each horizon. The confidence bands are at 68%[17].

[17] They had been evaluated adding and subtracting the standard deviation from the estimated parameter. It is true that they could have also been at a higher percentage level but, as it should be clear, it is more cautious to adopt a 68% in order not to make foolish interpretations of the results. Furthermore, and most importantly, this choice is consistent with what had been said about the reliability of the estimated parameters when using a Local Projection method: since I did not make specific assumptions on the dynamics of the underlying process, the estimated parameters for the shock could be less precise.

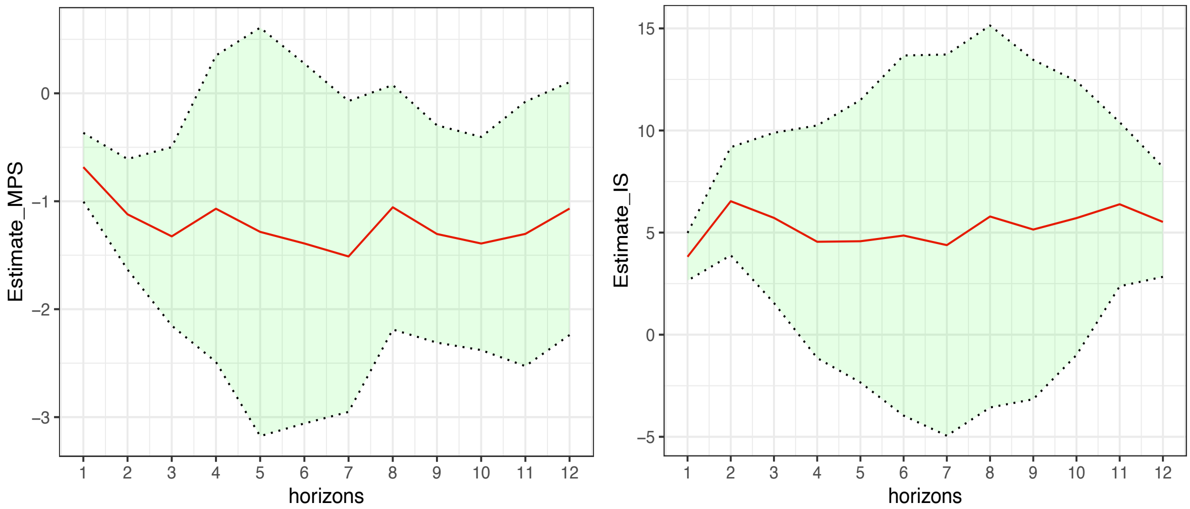

Figure 1: on the left the IRF for the genuine MPS (MPI_FF4), on the right the IRF for the IS (MPI_INFO)

The first thing to address is the sign of the estimated parameters: in all 12 horizons it is negative for the MPI_FF4 and positive for the MPI_INFO. The meaning of this should be straight forward and bears out the definition of the two components (see section II.ii.b). The genuine one is deflationary, so the global inflation lowers as the measure of the perceived shock MPI_FF4 rises. On the other hand, the informative one is indeed inflationary, so the global inflation rises as the measure of the perceived information shock rises. It is important to recall that we are looking at a general increase (or decrease) of the nominal interest rate by the central bank, so in both cases the interest rate is shifting in the same direction. We are just assuming that a shift in i could be sensed in two different ways by the private agents and, indeed, two different effects on global inflation could occur.

If on one hand it is true that the sign of the estimated parameter is consistent throughout the regressions, it is also worth to mention that the parameter is statistically significant only in the first two periods - more on this later in this section - both for the genuine component and for the information component. For this reason, and for now, I will focus on highlighting the main results of the first two horizons and I will then interpret the parameters of interest.

In the output of the MPI_FF4 first and second regression it is shown a p-value of 0,032 and 0,029 respectively, resulting in a 5% statistically significant code, while the MPI_INFO estimate is a bit more precise showing a 1% statistically significant code in the first regression and a 5% statistically significant code in the second regression, with a p value of 0,001 and 0,014 respectively. Moreover, for both the components, the control variables T10Y2Y and

INDPRO do not show any statistically significant evidence of influencing my dependent variable of interest. This aspect underlines the robustness of the parameters found. On the other hand, the first lag of global inflation is actually very significant in both stages and for both parameters; this feature should not necessarily be considered as negative because, from an economic point of view, it would be silly not to expect global inflation to be unaffected by its level of the previous month, rather I consider this result as confirmation that the monetary policy shock cannot and must not be the only component that influences the global inflation rate, but a component which, together with others, contributes to its determination.

Let's now give an interpretation of the estimated coefficients β obtained in these first two horizons.

Generally speaking, in multivariate linear regression β is the effect of one unit change in the explanatory variable X on the dependent variable (Y), holding all other explanatory variables constant. Therefore, I will adopt this approach considering as constants all the control variables:

- The first horizon shows a coefficient of -0,68 for the MPI_FF4 and +3,82 for the MPI_INFO.
    - Let's take for example the 1991m1 MPI_FF4 data, which is equal to 0,0032 percentage points (so 0,32 basis point): for a unit increase in shock (measured in basis points) the CPI index decreases of -0,68 basis points.
    - The same goes for the MPI_INFO for which we will look at the same data of 1991m1 which is equal to 0,0077 percentage points (so 0,77 basis points): for a unit increase in the shock (measured in basis points) the CPI index will now increase of 3,82 basis points.
    - The previous two example considered a positive shock both for the genuine and the information component, meaning that agents expected *i* and the central bank delivered a higher *i*. In front of a negative shock the effects are the same as described before, just reversed.
- The second horizon shows a coefficient of -1,12 for the MPI_FF4 and of +6,53 for the MPI_INFO. The reasoning behind the interpretation is the same, the only difference is that this time the inflation rate is lagged forward (or the shock is lagged backwards) so that I am able to evaluate how much a shock today influence the inflation one month later. The fact that both coefficients are bigger than the previous ones is reasonable since a contractionary move cannot be expected to produce effects immediately, agents need to have time to react to that move and to transfer this behavior to every market participant, including firms and final consumers.

Figure 2 helps to further investigate the differences between the behaviors of the two components: I plotted on the same graph the two red lines above in figure 1 to make the comparison handier.

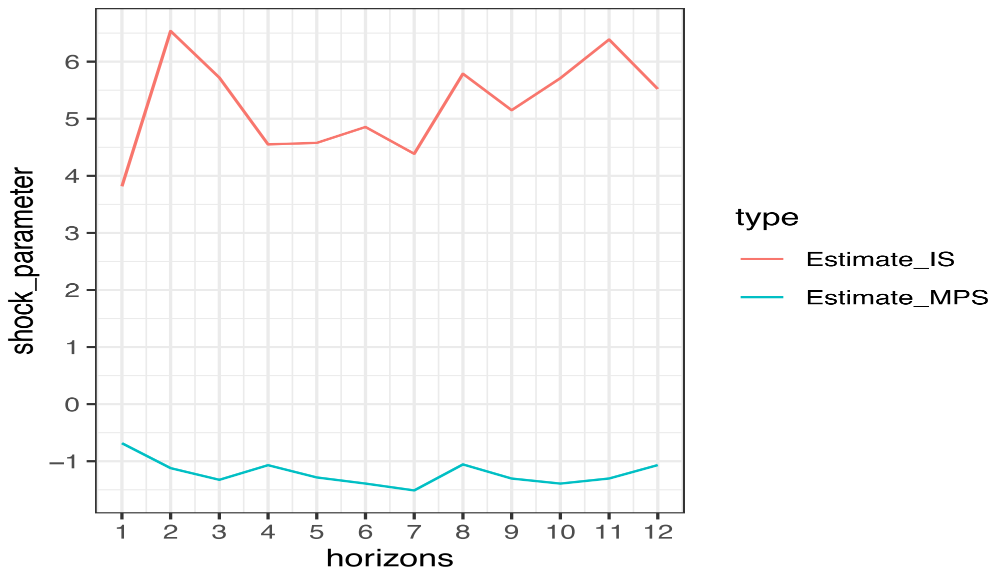

Figure 2: direct comparison between the MPI_FF4 estimated parameters (light blue line) and the MPI_INFO estimated parameters (red line)

Statistically speaking I did not find a component that performed way better that the other one, the information one is a bit more precise overall but not that much, however, as shown in the graph above, the magnitude of the effects of the MPI_INFO is higher (in absolute value) than the one of the MPI_FF4. This could be since a shock, in general, is something that strikes the agents unexpectedly: after having made the adequate considerations, they hoped for a certain *i* and they were given a different one. This, especially in the short run, could have unpredictable effects such as an inflationary outcome in front of a contractionary monetary policy move. I'm not saying that this model explains that the economy works in the opposite way to what we are all used to, in fact the most authoritative studies (see Miranda Agrippino e Ricco 2021, Miranda Agrippino and Rey 2020, and more) confirm – luckily - the opposite, i.e. that a restrictive monetary policy has deflationary effects: “We find that a monetary tightening is unequivocally contractionary, with deterioration of domestic demand, labor and credit market con- ditions as well as of asset prices and agents’ expectations” (Miranda Agrippino e Ricco, 2020, page 1). Basically, it is important to distinguish between two aspects: on one side the discrimination of the monetary policy shock and the study of its effects, as shown they concern the short (very short indeed) run and they loose statistical significance over time, on the other a contractionary monetary policy that, shocking or not, aims to lower inflation (not necessarily the day after the policy) and succeed in doing so.

With that said, when central banks decide what the new level for the interest rate will be, they have to be conscious that their choices and announcements could give rise to an information channel (see section II.ii.b), therefore, they should undoubtably be cautious in setting the interest rate level because that information channel that arises from their policies embeds short and rapid effects on one side, but these exists indeed, and could produce undesired outcomes if not well accounted for.

As said, besides these first two stages, from horizon 3 to horizon 8 the regressions did not show any statistically significant parameter, not only for the shock variable but also for all the other controls, including the first lag of global inflation. More adequate considerations will be dedicated later to the third quarter of the year, for now, I could say that in the medium run this model is not able to capture the effects of the monetary tightening, neither the genuine component nor the information component. This aspect is not necessarily negative since certain models, such as the three-equation one, were created specifically to study medium-term fluctuations and agree in giving an unambiguous answer to the lowering and raising of the interest rate by the central bank, without taking into consideration the informational component of monetary policy.

Lastly, from horizon 9 to 12, both the regressions showed an increasing importance in the estimates of the two parameters INDPRO and T10Y2Y: the estimated parameter for these variables was statistically significant at a 5% confidence level and in the 12^{th} horizon even at 1%. This result is in line with the risky price theory (adjustment costs), these costs are the one that a firm has to sustain when facing a certain change (whether it concerns capital, labor, production…) so they can take various forms for a business and they can provoke a delay in response to policy shocks. Indeed, for companies it could be very expensive to cut production overnight so they engage on a longer process of diluting costs, once they reach the new optimal production level with respect to the current economic situation, that level of production will have an impact on the costs and sales of that company. To conclude, another interesting aspect to notice is the fact that for the genuine component the confidence bands are somewhat larger and consistent after the second horizon, on the information component the confidence bands tend to widen a lot, to then squeeze in the end, indeed the regression 12 for the MPI_INFO had a significant coefficient (at 5%) not only for the controls but also for the shock.

Section V: CONCLUSIONS

What are the effects of a monetary policy shock on agents' consumption and investment decisions and ultimately on the inflation rate? Although this is an area of research that has been widely explored and studied in the most recent literature and beyond, it cannot be said with certainty that it has been fully understood, or at least that all its mechanisms and facets have been discerned. What we are sure of is that a restrictive monetary policy is unequivocally deflationary, with stringent medium-term effects on economic activity, prices, lending, etc. In addition, wanting to make a somewhat broader argument than just the rate of inflation but with the understanding that all these effects are somehow interrelated, the local currency appreciates, and corporate stock prices fall. These considerations are confirmed by several recent studies. That said, the distinction between the genuine and informational components of the monetary policy shock remains a recent yet innovative and interesting. From a certain point of view it could seem counterintuitive, in a nutshell, it suggests that if private agents give more weight to the announcement and information power of the Central Bank rather than its decisions related strictly to the medium term move to maintain the equilibrium, the CB decisions could be seen as future beliefs (or forward clues) concerning a “better state of the art”, thus resulting in an euphoric reaction by financial markets and agents. With that in mind, the intuition "let's raise nominal interest rates to lower inflation rate" remains true if one looks at the medium term (because central bank’s policy rate shifts actually aims to counter attack the medium run fluctuations) but it should be treated with caution if in the short run one does not want agents to react to this decision by incorporating only its information component and thus engaging in a series of activities that are counterproductive for the Central Bank’s aims.

REFERENCES

Board of Governors of the Federal Reserve System (US), Industrial Production: Total Index [INDPRO], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/INDPRO, August 13, 2023.

Federal Reserve Bank of St. Louis (1976). *10-Year Treasury Constant Maturity Minus 2-Year Treasury Constant Maturity*. [online] FRED, Federal Reserve Bank of St. Louis. Available at: https://fred.stlouisfed.org/series/T10Y2Y.

Jordà, Ò**. (**2005). "Estimation and Inference of Impulse Responses by Local Projections." *American Economic Review*, 95 (1), pp.161–82.

Marcellino, M., Stock, J.H. and Watson, M.W. (2006). A comparison of direct and iterated multistep AR methods for forecasting macroeconomic time series. *Journal of Econometrics*, 135(1-2), pp.499–526.

Miranda-Agrippino, S. and Rey, H. (2020). U.S. Monetary Policy and the Global Financial Cycle. *The Review of Economic Studies*, 87(6), pp.2754–2776.

Miranda-Agrippino, S. and Ricco, G. (2021). The Transmission of Monetary Policy Shocks. *American Economic Journal: Macroeconomics*, 13(3), pp.74–107.

Newey, W.K. and West, K.D. (1987). Hypothesis Testing with Efficient Method of Moments Estimation. *International Economic Review*, 28(3), pp.777–787.

Organization for Economic Co-operation and Development (1971). *Consumer Price Index: All items: Total: Total for OECD - Total*. [online] FRED, Federal Reserve Bank of St. Louis. Available at: https://fred.stlouisfed.org/series/OECDCPALTT01GYM [Accessed 13 Aug. 2023].

Ramey, Valerie A**.** 2016. "Macroeconomic Shocks and Their Propagation." NBER Working Paper 21978.

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