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Are monetary surprises effective? The view of professional forecasters in Israel

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האם הפתעות מוניטריות אפקטיביות? מבט של החזאים המקצועיים בישראל.

אלכס אילק

תקציר

במאמר זה אנו מנתחים את ההשפעה של הפתעות מוניטריות של בנק ישראל על האינפלציה ועל שער החליפין של השקל בעיניים של החזאים המקצועיים בישראל במדגם מאפריל 2001 עד אוקטובר 2016. אנו משתמשים במאגר ייחודי בישראל אשר מכיל תחזיות יומיות של החזאים המקצועיים לטווחים שונים עבור משתנים עיקריים בכלכלה. על בסיס מאגר זה, אנו גוזרים הפתעות מוניטריות של בנק ישראל תוך התייחסות למועדים ספציפיים שבהם החזאים מעדכנים את התחזיות שלהם.

אנו מוצאים, שההשפעה של ההפתעות המוניטריות על שער החליפין של השקל – בעיניים של החזאים – הייתה יציבה במהלך שני העשורים האחרונים, התמסורת משער החליפין לאינפלציה ירדה באופן משמעותי אחרי שנת 2007. זאת בעיקר הודות להפסקה מוחלטת של הצמדה של מחירי השכירות בישראל לשער החליפין של השקל-דולר.

אנו גם מספקים עדות עקיפה וחלקית לכך שההשפעה של ההפתעות המוניטריות על הפעילות הריאלית בישראל לא השתנתה אחרי 2007. דהיינו, אנו לא מצאנו עדות להתגברות "ערוץ האינפורמציה" שהוצג לראשונה ע"י Nakamura ו-Steinsson (2018). זאת, למרות שהריביות הטבעיות בעולם ובישראל ירדו משמעותית בתקופה זו, ובנוסף הוקמה וועדה מוניטרית בבנק ישראל. יחד עם זאת, אנו מוצאים שאחרי הקמתה של הוועדה המוניטרית נרשמה עלייה משמעותית במידת החלקת הריבית של בנק ישראל.

לבסוף, אנו מוצאים התנהגות א-סימטרית של תחזיות של החזאים לריבית ב"י לאחר המשבר הפיננסי בארה"ב. כאשר ההפתעה המוניטרית של ב"י הייתה חיובית, החזאים עדכנו כלפי מעלה את התחזיות שלהם לריבית ב"י בעוד שנה באופן משמעותי. לעומת זאת, כאשר ההפתעה בריבית ב"י הייתה שלילית, העדכון של תחזיות לריבית כלפי מטה היה חלש.

Are monetary surprises effective?

The view of professional forecasters in Israel

Alex Ilek

Abstract

In this study we analyze the effect of the Bank of Israel (BOI) monetary surprises on inflation and the exchange rate, in the eyes of professional forecasters (PF) in Israel. We exploit a unique daily dataset in Israel containing various forecasts of the PF in sample from April 2001 to October 2016 and derive the monetary surprises of the BOI by exploiting the specific timing of expectations formation.

We found that although the PF-perceived effect of monetary surprises on the exchange rate was stable over the past two decades, the pass-through from the exchange rate to inflation significantly declined after 2007, primarily due to a full dissociation of rent prices from the shekel-dollar exchange rate. We also provide indirect and partial evidence that the effect of the BOI monetary surprises on real activity did not change after 2007. That is, we didn't find evidence that the information channel introduced by Nakamura and Steinsson (2018) intensified in Israel despite a decline in natural rates worldwide and the establishment of a monetary committee at the BOI. We found, however, that after the establishment of the monetary committee there was a significant increase in interest-rate inertia.

Finally, we found an asymmetric pattern of the PF's assessment of the CB interest rate after the global financial crisis. Following a positive surprise in the BOI interest rate, the PFs significantly updated upward their forecasts for the interest rate for the coming year. In contrast, when the monetary surprise was negative, the PFs barely updated downward their forecast for the interest rate.

JEL classification: E37, E47, E52.

Keywords: professional forecasters, monetary surprises, policy effectiveness.

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1 Introduction

Anchoring public expectations in an inflation targeting regime is a primary goal of central banks in order to efficiently conduct monetary policy, because public expectations influence economic outcomes. Therefore, it is important for the central bank (henceforth, CB) to understand how the public forms its expectations, and to find the channels by which it can affect them. The central bank interest rate is a traditional channel. There are also other channels: communication with the public (press conferences of a monetary committee), regular publications by the CB (annual reports, staff forecasts, etc.), unconventional monetary policy measures (interventions in financial and foreign exchange markets), and forward guidance. The literature usually examines expectations of financial markets/surveys or expectations of professional forecasters (henceforth, PF), because all these sources somehow reflect the expectations of the general public in the economy.

There are three main approaches to public expectations in the literature. (1) Modeling the expectations formation of the public. For example, Branch and Evans (2006) and Markiewicz and Pick (2014) modeled the expectations of the PF in the US by assuming that the PF are adaptive learners. They found that the constant-gain learning algorithm explains the PF expectations the best. (2) Exploiting public expectations in the estimation of macro models. For example, Kortelainen et al. (2016) used PF expectations to estimate a DSGE model for the ECB and they found that inclusion of the PF expectations improves the empirical performance of the model and to some extent makes redundant habit formation and inflation indexation, which are usually obtained in models with model-consistent expectations. Smets et al. (2014) evaluated the real-time forecasting performance of the New Keynesian model estimated for the euro area and found that the model forecasts tend to be generally improved by adding PF forecasts. (3) Examining responses of public expectations to economic news. For example, Bauer (2015) tested responses of survey-based inflation expectations and PF expectations to macroeconomic news, and found significant responses to most types of news. Similar tests were conducted by Ghysels and Wright (2009). Nakamura and Steinsson (2018) focused on examining the impact of monetary surprises of the FED on survey expectations of output growth, as well as on nominal and real interest rates of different maturities.

Our study is closely related to the third approach. Our main goal is to examine how PF in Israel react to monetary policy surprises of the Bank of Israel. Specifically, we estimate the responses of the average PF forecasts of the key variables for one month and twelve months ahead to the average PF-perceived BOI monetary surprises.[1] Thus, both responses (to monetary surprises) and calculation of monetary surprises rely on the same source of expectations, generating consistency in our analysis. This is in contrast to, for example, Faust et al. (2007) where the measured surprises rely on survey expectations whereas the reactions to these surprises are derived from capital markets.

It is very important to investigate the average PF forecasts because they are one of the most important variables that the BOI continuously monitors and uses in conducting monetary policy. Thus, these responses can be seen as indicators of the effectiveness of the BOI policy, at least in the eyes of the PF. It is particularly interesting to compare the PF responses before and after 2007, because various prominent foreign and domestic events occurred during the second period that potentially altered the PF-perceived effectiveness of the BOI policy. We should note that the estimated elasticities here are not contaminated by risk premia, since the PF expectations do not contain such premia, in contrast to expectations derived from capital markets.

We now turn to a brief description of the background of Israeli PF and the types of forecasts they provide. The group of Israeli PF has always included only domestic members but its composition has changed over time. At the beginning of 2001 the group had only 5 members, mostly the Israeli commercial

[1] The average forecasts (of the PF), usually referred to in the literature as the consensus forecasts of the PF, are predictions of the future that are generated by combining together several separate (PF) forecasts, which may have been created using different econometric or statistical methodologies. Here we focus only on average (consensus) forecasts of the PF, because, as explained below, they are a very important indicator for the BOI's monetary policy. An examination of heterogeneity among the PF and its implication we leave for future research.

banks; in 2008 the group grew to 11 members due to the inclusion of insurance and investment companies; in 2012 the group reached a peak of 17 members but in 2014 it declined to 13 members: 4 commercial banks, 8 insurance and investment companies, and one independent forecaster. Since 2015 the group has consisted of 14 members. We exploit a daily dataset that contains various forecasts of the Israeli PF for the period from March 2001 to October 2016. This daily dataset contains the average PF forecasts for inflation, interest, and shekel-dollar exchange rates[2] (the forecasts for real activity are provided only from 2017 onward and hence they are not used in our analysis). The forecasting horizon is for months $t-1, t$, $t+1$, $t+2$, and $t+12$, as well as for the current and the next calendar year. The forecast for $t-1$ is only relevant for the CPI, which is published with a delay of half a month (see Section 2 for details).

The rest of the paper is organized as follows. Section 2 presents the cycle of expectations formation of the PF in Israel. Section 3 introduces the methodology to measure the effectiveness of monetary surprises. Section 4 presents the empirical results and Section 5 summarizes the main results.

2 The expectations formation cycle

We first explain in detail the different timing of the announcements of the BOI interest rate, the consumer price index, and the shekel-dollar exchange rate.

1. **The BOI interest rate**: On the Monday before the last Wednesday of each month, the BOI announced the interest rate for the forthcoming month.[3] That is, the interest rate for month t is already known at the end of month $t-1$. To illustrate, the interest rate for February 2012 was announced on 24 January 2012.

2. **Consumer price index (CPI)**: On the 15th of each month, the Central Bureau of Statistics (CBS) announces any change in the CPI for the previous month. That is, a change in the CPI for month t is published with a delay of half a month. To illustrate, the CPI for February 2012 is announced on March 15, 2012.

3. **The shekel-dollar exchange rate**: In contrast to the previous two variables, the exchange rate data is continuous and updated on a daily basis. To illustrate, on February 15, 2012, the exchange rate was known up to this date.[4]

It is convenient to illustrate graphically the data arrival of the three mentioned variables over time. Specifically, Figure 1 presents the cycle of the PF expectations formation split into four timings (denoted by T1–T4), such that in each timing new information arrives. The cycle spans two subsequent months, $t-1$ and t. Next we explain the four timings of the PF expectations in detail.

Timing 1 (T1) covers a time window from one day after the announcement of the CPI for month $t-2$ (on the 15th of month $t-1$) up to one day before the announcement of the interest rate for month t (at the end of month $t-1$).

Timing 2 (T2) covers a time window from one day after the interest rate announcement for month t up to the second day of month[5] t. The new data available at T2, relative to T1, includes, among other things, the interest rate for month t. The time window between timings 1 and 2 is about one week.

[2] The data is collected daily, but the PF do not necessarily update their forecasts on a daily basis. The PF update their forecasts in different timings during each month.

[3] From 2018 the BOI reduced the number of interest rate decisions per year from 12 to 8, and the timing of the interest rate decisions was changed. However, this period was not included in our analysis.

[4] More precisely, the representative exchange rates are published at 13.15–15.15 each day. On Fridays and holidays they are published at 10.15–12.15.

[5] It is evident from the data that some of the PF update their forecasts on the first or second day of each month.

Timing 3 (**T3**) covers a time window between the second day of month t up to the 14th of month t (one day before the announcement of the CPI for month $t-1$). The new data available at T3, relative to T2, includes, among other things, a realization of the exchange rate for the first half of month t.

Timing 4 (**T4**) covers a time window from one day after the announcement of the CPI for month $t-1$ (on the 15th of month t) up to one day before the announcement of the interest rate for month $t+1$. The new data available at T4, relative to T3, includes, among other things, the CPI for month $t-1$.

As can be seen from Figure 1, T4 is equivalent to T1, except that it is one month later. That is, the cycle of expectations formation is closed and repeats itself in months t and $t+1; t+1$ and $t+2; t+2$ and $t+3$; and so on.

Since our purpose is to evaluate the effect of monetary surprises on PF expectations, it is enough to consider the forecast updates from the end of T1 to the end of T2. A one-week time window after the interest rate announcement provides enough time for the PF to update their forecasts, as not all of them update their forecasts immediately after the announcement.[6] However, the time window should neither be too wide nor cover domestic and foreign news in month t and afterward, because in that case the updated forecasts would be affected by a large quantity of news, making identification of the effect of the monetary surprises difficult.[7]

There is international empirical evidence of the inattentiveness and delayed responses of PF to macroeconomic news (see for example, Coibion and Gorodnichenko (2012); Andrade and Bihan (2013); Clements (2012)). If such inattentiveness exists also among the PF in Israel, there is a potential concern that the estimated effect of monetary surprises on PF expectations is biased. There are two implications of this inattentiveness. (1) Assume that the PF forecasts that we derive one day before the BOI interest rate announcement are not based on the most updated information up to this point, but instead rely on the information, say, up to the beginning of month $t-1$ (see Figure 1). Then, the forecast update at the beginning of month t captures all information derived during month $t-1$, including the time window between the beginning of month $t-1$ and the end of timing T1 (just before the announcement of the BOI interest rate). Assume further that based on the information in this time window, the BOI decided to increase the interest rate. In this case, the forecast update of the PF and the BOI monetary surprise are driven by the same news and as a result, the effect of the monetary surprise on the forecast update is circumstantial rather than causal. (2) The other implication of the inattentiveness of PF to macroeconomic news is that even if the PF expectations at the end of T1 are based on the most updated information, but most of the PF are reluctant to update their forecasts after the BOI announcement, this can also lead to an attenuation bias in the estimated effect of the monetary surprise on the forecast update. Section 4.3 elaborates on testing for the inattentiveness of the PF in Israel and finds no robust evidence of it.

[6] This is in contrast to capital markets where the reaction to monetary surprises is measured in very narrow time window (see Nakamura and Steinsson (2018), Faust et al. (2007), and Faust et al. (2004)).

[7] Bauer (2015) notes that "long windows substantially lower the precision of the estimated sensitivities, since a host of news and noise that we cannot control for also affect agents' expectations over these intervals."

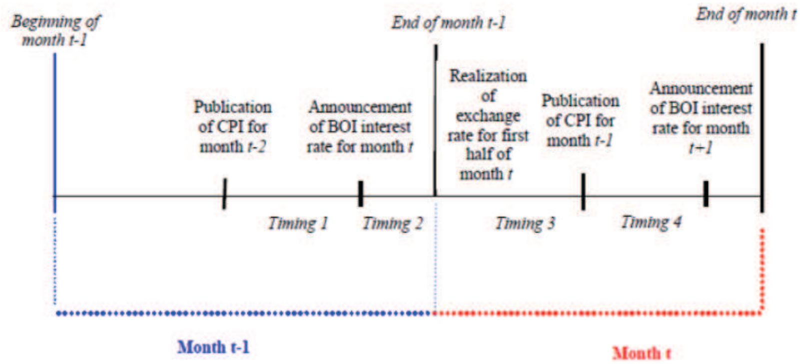

Figure 1: The cycle of expectations formation of the PF

We now return to our framework and derive the monetary surprise for month t. To do so, we exploit the PF forecast for the interest rate for month t recorded one day before the announcement, and compare it to the realization r_t. The interest rate surprise is

$$u_t^r = r_t - E_1 r_t, \tag{1}$$

where $E_1 r_t$ is the conditional expectation at the end of T1.

The series of monetary surprises (as perceived by the PF) is shown in Figure 2. It can be seen that the volatility of the monetary surprises is quite stable over the whole sample, with an SE of 0.15 b.p., except for the years 2001–2002, when large monetary surprises were generated by the BOI (for a discussion of the causes and consequence of those surprises see BOI (2002)). In the years 2001–2002 the SE of changes in the BOI interest rate was 0.84 b.p., whereas in the period 2003–2010 it fell to 0.26 b.p.. Ruge-Murcia and Riboni (2017) noticed that after 2010 the volatility of changes in the BOI interest rate declined further due to the establishment of a monetary committee.[8] The stability of the BOI monetary surprises over the whole sample, except for the years 2001–2002, along with the decline in the volatility of the BOI interest rate after 2010, can be explained by a decline in the volatility of the interest rate forecasts of the PF, which indeed significantly fell after 2010 (from 2001 up to 2010 the SE of PF expectations was 2.24 b.p., whereas after 2010 it fell to 1.12 b.p.).

[8] Ruge-Murcia and Riboni (2017) report in Table 1 that prior to the establishment of the monetary committee in 2010 the SE of the changes in the BOI interest rate was 0.472 whereas after 2010 the SE decreased to 0.141. It should be noted that although the committee was established in June 2010, it only began acting in 2011.

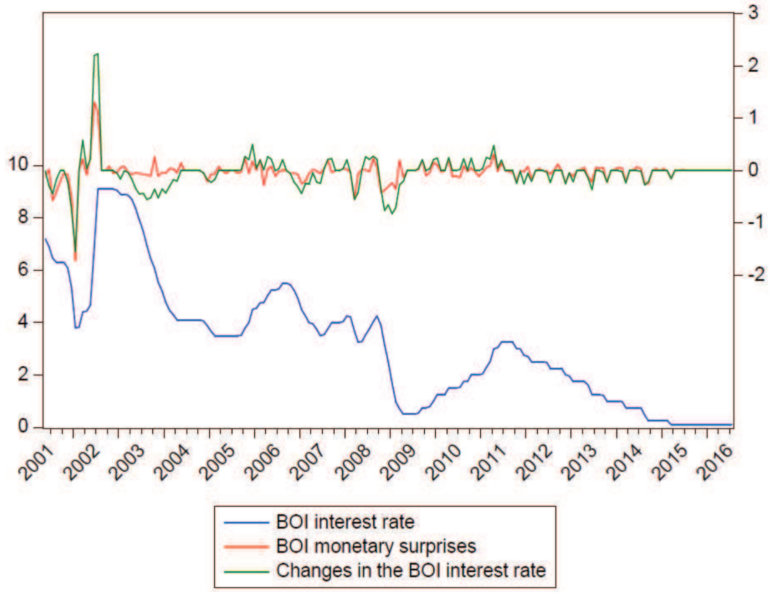

Figure 2: The BOI interest rate, its changes, and monetary surprises as perceived by the PF in Israel

3 Effectiveness of monetary surprises

3.1 Short-run elasticities w.r.t. monetary surprises

In this section we measure the effectiveness of monetary surprises by PF-perceived elasticities of inflation, exchange rate, and interest rate. Starting with inflation, we use the forecast update of the PF from the end of T1 to the end of T2:

$$E_2\pi_t - E_1\pi_t = \beta^\pi u_t^r + \xi_t^\pi, \tag{2}$$

where u_t^r is as given in eq. (1). Other news, ξ_t^π, can also affect the forecast update in this time window. The important point here is that ξ_t^π is assumed to be uncorrelated with monetary surprises and therefore, OLS and SUR estimators of β^π are consistent under this assumption (we elaborate on the estimation method in Section 4). The main justification for the orthogonality assumption is that any release of new information after the BOI announcement cannot affect the interest rate for month t, because the latter is already predetermined (but the new information can still affect the PF forecasts during T2; see Figure 1). To illustrate, an unanticipated shock to oil prices (occurring between the beginning and the end of T2) can affect the inflation expectations of the PF, but this shock is of course orthogonal to the monetary surprise.

Applying the same methodology to the shekel-dollar exchange rate forecast yields the following equation:

$$E_2 s_t - E_1 s_t = \beta^s u_t^r + \xi_t^S, \tag{3}$$

where as before the orthogonality assumption ($cov(u_t^r, \xi_t^S) = 0$) holds.

The PF-perceived short-run elasticity of the interest rate in month t w.r.t. monetary surprises is 1 by definition. Yet, it is possible to measure the effect of monetary surprises in month t on the expected interest rate in month $t+1$, which reflects to some extent inertia in the interest rate:

$$E_2 r_{t+1} - E_1 r_{t+1} = \beta^r u_t^r + \xi_t^r. \tag{4}$$

We also considered another version of eq. (4) where we also included $E_2 s_t - E_1 s_t$ and $E_2 \pi_t - E_1 \pi_t$ as explanatory variables, in addition to u_t^r. In that specification β^r has a more structural interpretation of interest-rate inertia. We obtained similar estimators of β^r under both versions, and hence we don't report them here.

3.2 Medium-run elasticities w.r.t. monetary surprises

We are also interested in measuring the PF-perceived medium-run elasticity (say, for a one-year horizon) of inflation, exchange rate, and interest rate w.r.t. monetary surprises. This is especially important for inflation, because monetary policy might affect inflation with a delay and therefore, the short-run (monthly) elasticity of inflation w.r.t. a (contemporaneous) monetary surprise might be uninformative about the effectiveness of the monetary policy.

Denote by $E_1 y_{t+12}$ the forecast of the endogenous variables for 12 months ahead (i.e., at the end of T1), where $y_{t+12} = [\pi_{t+12}, s_{t+12}, r_{t+12}]$. Denote by $E_2 y_{t+12}$ the forecast of y for 12 months ahead (i.e., at the end of T2). Using the forecast update (between the end of T1 to the end of T2) we can measure the medium-run (one-year) elasticity of the endogenous variables with respect to monetary surprises:

$$E_2 y_{t+12} - E_1 y_{t+12} = \hat{\beta}^y u_t^r + \xi_t^{y12}, \tag{5}$$

where parameter $\hat{\beta}^y$, $y = \{\pi, s, r\}$ represents the (one-year) elasticities of inflation, exchange rate, and interest rate with respect to monetary surprises, as perceived by the PF. The residual ξ_t^{y12} represents other factors affecting forecast updates, which are assumed to be uncorrelated with u_t^r.

4 Empirical setup

Our goal is to estimate eqs. (2), (3), (4), and (5). Because residuals $\xi_t^{\pi}, \xi_t^{S}, \xi_t^{r}$, and ξ_t^{y12} are potentially cross-correlated due to mutual dependence on the same news, SUR will provide more efficient estimators than OLS. However, since the regressors are the same across all equations (monetary surprises, u_t^r, and a constant term), SUR estimators are identical to the OLS estimators.

In the estimation we split the sample period into two subsamples: the first subsample is 2001.M4–2007.M12 (henceforth, Sample 1) and the second subsample is 2008.M1–2016.M10 (henceforth, Sample 2).[9] These subsamples differ in the following four aspects. (1) Until 2008 rent prices in Israel were almost fully linked to the shekel-dollar exchange rate. This had a noticeable effect on the pass-through from the exchange rate to CPI inflation, because the weight of the rent prices in the CPI was about 25%. (2) After the financial crisis of 2007–2008 a substantial decline in the natural interest rates in Israel and worldwide was recorded (see Holston et al. (2017) and Segal (2019)). (3) In 2010 there was a fundamental change in the monetary regime of the BOI: a monetary committee was established to conduct monetary policy, whereas before 2010 the governor alone set the interest rate (see Ruge-Murcia and Riboni (2017) for details). (4) From 2008 the BOI started intervening in the foreign exchange market by purchasing foreign currency.

To provide empirical support for splitting the sample in 2007, we estimate the responses of the PFs' inflation expectations for 1 month and 1 year ahead to monetary surprises by rolling regression (with time window of 5 years, with eqs. (2) and (5)), using the whole sample 2001.M4–2016.M10. Figure 3 shows the estimation results. To illustrate, the first observation in Figure 3, for 2006.M4, reflects the average PF's response to the monetary surprises in the sample 2001.M5–2006.M4, the second observation in 2006.M5 reflects the average response in the sample 2001.M6–2006.M5, and so on. The main point that emerges from Figure 3 is that before 2007-8 the responses of the inflation expectations for 1 month and for 1 year ahead

[9] The first date (2001.M4) is the period when the PF started reporting their forecasts. The last date in the sample was chosen about one and half years after the BOI interest rate reached its lowest level of 0.1%, where it stayed from March 2015 to February 2019. The estimation results up to March 2015 barely differ from those of our chosen sample.

to monetary surprises were significantly negative, as expected. However, after that period, the responses became although positive but insignificant (see Tables 1 and 2 in Section 4.1). That is, Figure 3 indicates that after 2007 the effect of the BOI monetary surprises on the PF inflation expectations weakened. Section 4.1 elaborates on this finding.

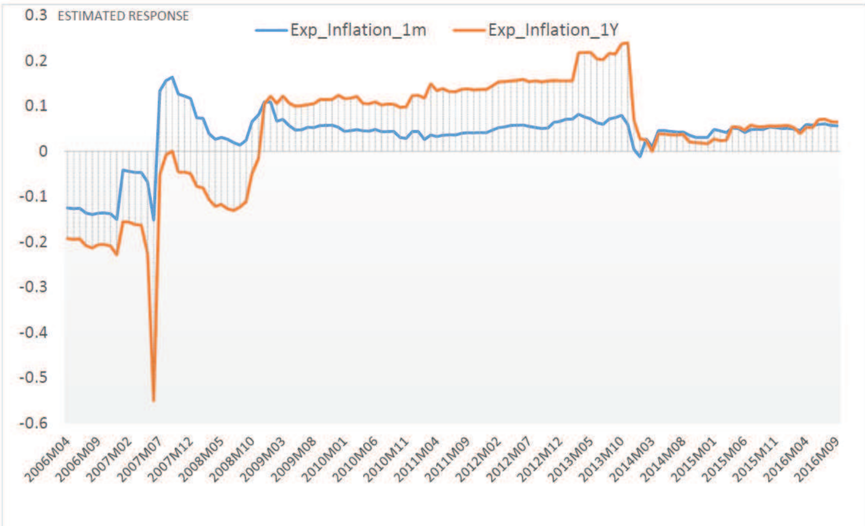

Figure 3: The estimated responses of the PFs' inflation expectations for 1 month and 1 year ahead to monetary surprises, rolling regression with window of 60 months.

Taking into account the break in 2007, estimating equations (2), (3), (4), and (5) for the subsamples yields

$$E_2 Z_t - E_1 Z_t = \left(1 - Dum^{2008}\right) \left[c_A + \Gamma_A u_t^r\right] + Dum^{2008} \left[c_B + \Gamma_B u_t^r\right] + \epsilon_t, \tag{6}$$

where $E_j Z_t = E_j[s_t, \pi_t, r_{t+1}, y_{t+12}], j = 1, 2$, the dummy Dum^{2008} equals 0 up to 2007.M12 and 1 thereafter, $\Gamma_j = [\beta^\pi, \beta^s, \beta^r, \hat{\beta}^y]$, $j = A, B$, are estimated elasticities in Sample 1 ($j = A$) and Sample 2 ($j = B$), respectively, and c_A and c_B are constant terms.

4.1 Results

Tables 1 and 2 below present the estimated short-run and medium-run elasticities, respectively. The elasticities are shown separately for Samples 1 and 2.

Table 1: Short-run elasticities (one month)[10]

The variables	Inflation	Exchange rate	Interest rate
Sample 1 (2001.M4-2007.M12)	$\beta^{\pi}=-0.12$ (0.00)	$\beta^{s}=-1.12$ (0.00)	$\beta^{r}=0.61$ (0.00)
Sample 2 (2008.M1-2016.M10)	$\beta^{\pi}=0.05$ (0.47)	$\beta^{s}=-1.11$ (0.08)	$\beta^{r}=0.78$ (0.00)
χ^2statistic [p-value] H_0:$F_B=F_A$	5.78[2%]	0.01[92%]	3.52[6%]

Remark: The upper two rows present the estimated elasticity (and its p-value, the upper and lower values in each cell, respectively). The bottom row presents the χ^2statistic (and, in brackets, its p-value), which tests whether there was a significant difference in the estimated elasticities between Samples 1 and 2.

Table 2: Medium-run elasticities (one year)

The variables	Inflation	Exchange rate	Interest rate
Sample 1 (2001.M4-2007.M12)	$\hat{\beta}^{\pi}=-0.19$ (0.00)	$\hat{\beta}^{s}=-0.54$ (0.06)	$\hat{\beta}^{r}=0.40$ (0.00)
Sample 2 (2008.M1-2016.M10)	$\hat{\beta}^{\pi}=0.12$ (0.23)	$\hat{\beta}^{s}=-0.82$ (0.17)	$\hat{\beta}^{r}=0.61$ (0.00)
χ^2statistic [p-value] H_0:$F_B=F_A$	7.29[1%]	0.17[68%]	3.51[6%]

Remark: The upper two rows present the estimated elasticity (and its p-value, the upper and lower values in each cell, respectively). The bottom row presents the χ^2statistic (and, in brackets, its p-value), which tests whether there was a significant difference in the estimated elasticities between Samples 1 and 2.

The key result from Tables 1 and 2 is that the impact of monetary surprises on inflation, in the eyes of the PF, significantly weakened after 2007, both in the short-run and in the medium-run (the difference is significant at a p-value of 2%).[11] Specifically, in Sample 1 the short-run elasticity is -0.12 and it increases to a positive value close to zero in Sample 2, although it is not significantly different from zero. The medium-run elasticity also increases from -0.19 in Sample 1 to 0.12 in Sample 2. In fact, the one-year positive elasticity of inflation we obtain here is similar to that obtained in Nakamura and Steinsson (2018) from the US capital market.[12] Thus, there is a significant decline in the effect of monetary surprises on inflation after 2007. Our main goal is to explain this reduction.

In a small open economy, like Israel, the CB has two main channels by which it can affect the economy through the interest rate. The first channel is by affecting the current and expected nominal exchange rate,

[10] The estimation results in Sample 1 are strongly affected by the period 2001–2002, where the BOI sharply and unexpectedly changed the interest rate several times (see Figure 2). That is, the estimated parameters for Sample 1 minus the years 2001–2002 (i.e., 2003.1–2007.12) are quite different from the estimated parameters for all of Sample 1 (2001.1–2007.12). Most importantly, the structural break in the pass-through from the monetary surprises to inflation between Sample 2 and Sample 1, as described previously, is not robust unless the years 2001–2002 are included. However, including these years in the estimation helps identify the causal effect of the BOI monetary surprises on PF expectations, especially in this period of frequent monetary surprises.

[11] This difference is significant also when we consider various samples around the original sample, either when we end Sample 2 sooner (say, in 2014) or start it later (say, in 2011). We also checked the hypothesis under which, in Sample 2, $\beta^{\pi}=-0.12$ (monthly elasticity) and $\beta^{\pi}=-0.19$ (annual elasticity), as estimated in Sample 1. These equality hypotheses were strongly rejected.

[12] Nakamura and Steinsson (2018) examined the reaction of break-even inflation for different horizons in the US capital market to monetary surprises. As in our analysis of Sample 2, Nakamura and Steinsson (2018) found the reaction of break-even inflation to be positive but insignificant for a majority of horizons.

and the second channel is by affecting current and expected real activity. Both channels have an effect on inflation and inflation expectations. We will try to examine shifts in these two channels, from the point of view of the PF in Israel.

The effect of monetary surprises on the shekel-dollar exchange rate

From Tables 1 and 2 it can be seen that the effect of monetary surprises on the nominal exchange rate is quite similar in both subsamples: the short-run elasticity is about -1 and the medium-run elasticity is about -0.54 (in Sample 2 the medium-run elasticity is higher but it is not statistically different from the value in Sample 1 at p-value of 68%).[13] Despite the similar effect of monetary surprises on the exchange rate in the two subsamples, the PF-perceived effect of the exchange rate on inflation is much smaller in Sample 2 compared to Sample 1. The main reason for this decline is that rent prices in Israel were no longer linked to the nominal exchange rate after 2007, whereas before that the shekel-dollar exchange rate explained almost all variation in the rent prices.[14] We should clarify one point: the calculation of rent prices for month t by the CBS relies on data from two consecutive months, $t-1$ and t. This means that before 2007, a depreciation of the shekel-dollar exchange rate in month t, say of 1%, increased rent prices in month t by 0.4% (the effect of depreciation in month $t-1$ was predetermined[11]). Since the weight of rent prices in CPI is about 25%, the depreciation of 1% had to increase the CPI in month t by 0.1% – the value that explains the difference in monthly elasticity between Sample 1 and Sample 2 (see Table 1). A similar explanation applies also to the effect of the exchange rate on annual inflation. Cukierman and Melnick (2015) provide a comprehensive analysis of the noticeable drop in the pass-through from the exchange rate to inflation in Israel due to de-dollarization of rent prices. While we do not claim that the different behavior of rent prices after 2007 was the unique factor behind the reduction of the pass-through from the exchange rate to inflation in Israel, it is highly probable that it was the major factor. The opposite (expanding) effect on the pass- through during the last years of our sample period may have been caused by increased competition due to the higher exposure of domestic consumers to online purchases from abroad, because the price for consumers is affected by the exchange rate (see discussion in BOI (2016)). However, the numerical evaluation of this effect exceeds the scope of the present analysis.

The effect of monetary surprises on real activity

We now turn to the second main channel through which the monetary interest rate affects inflation, namely, the channel of real activity (output gap). Since no forecasts of real activity were provided by the PF in Israel during our sample period, we cannot conduct a direct empirical examination of possible changes in the effect of monetary surprises on real activity. However, we will examine an indirect indicator of such changes, as explained later. There are many possible factors that can change the impact of monetary surprises on real activity, such as shifts in the degree of the economy's openness, in the preferences of agents, and in other fundamental parameters of the economy. Nevertheless, here we focus on a very specific angle that in our opinion was the most relevant during the sample period. Our hypothesis is that the effect of monetary surprises on monetary stance,[15] and in turn, on real activity declined in Israel after 2007 due to two factors: (1) the sharp and steady decline in natural rates worldwide after the global financial crisis,[16] and (2) the decline in classic monetary shocks (such as Klein-type shocks as in 2001–2002; see details in BOI (2002)) due to the establishment of the monetary committee in 2011. Appendix A shows theoretically how

[13] The estimated elasticity of the exchange rate to monetary surprises is similar to the value obtained in Faust et al. (2007).

[14] In the 1999–2007 period, changes in the shekel-dollar exchange rate (Δs_t) explained about 90% of changes in rent prices (π_t^H) (seas. adj.) in Israel, where the sum of elasticities was 0.82, i.e., $\pi_t^H = \underset{(0.00)}{0.42}\Delta s_t + \underset{(0.00)}{0.40}\Delta s_{t-1}, R^2 = 0.90$ (p-value in parentheses). After 2007 the effect of the exchange rate on rent prices almost disappeared, i.e., $\pi_t^H = \underset{(0.15)}{0.028}\Delta s_t + \underset{(0.17)}{0.02}\Delta s_{t-1}, R^2 = 0.08$.

[15] Monetary stance is the difference between the CB (real) interest rate and the natural rate of interest.

[16] See Segal (2019) for a comprehensive review of the evolution of the natural rate in Israel. See Holston et al. (2017) for a comprehensive review of the evolution of natural rates in several countries.

changes in the source of monetary surprises, as perceived by the public, affects the monetary stance, and in turn, the ability of the CB to stabilize real activity. Then, it examines empirically the hypothesis described above. The framework in Appendix A relies on the "information channel" of monetary policy that was introduced by Nakamura and Steinsson (2018).[17] We make two basic assumptions here: (1) the public perceives that the CB possesses some extra information about the real natural rate in the economy, and (2) the public doesn't know whether to attribute monetary surprises to changes in the CB's natural interest rate or to classic monetary shocks (which can stem, for example, from changes in the CB's preferences, or from reactions of the CB to new economic variables). The main result from the empirical analysis in Appendix A is that our hypothesis is not validated by the Israeli data. Specifically, we didn't find any intensification of the "information channel" of monetary policy after 2008, which suggests that the ability of the BOI monetary surprises to affect real activity was stable throughout those years.

Nominal rigidities and interest-rate inertia

In this subsection we highlight some additional interesting results from Tables 1 and 2. There is some evidence that PF believe in the existence of price rigidity in the Israeli economy. First, from the estimated elasticities (implied by the PF forecasts) we see that a higher nominal interest rate leads also to a higher real interest rate, because the expected inflation not only rise but, in fact, declines (the real interest rate is also higher in Sample 2, since the elasticity of inflation is below unity). At the same time, a higher nominal interest rate also generates appreciation of the nominal exchange rate (for both horizons), which in turn leads to real appreciation, because the (expected) nominal appreciation exceeds the reduction in (expected) inflation. Thus, it seems that from the perspective of the PF, purchasing power parity does not hold, at least in the short-to-medium run.

Another interesting point is that since 2007, interest-rate inertia significantly increased in the eyes of the PF.[18] This result is consistent with finding of Ruge-Murcia and Riboni (2017) who also documented higher inertia in Israel in the second sample and attributed it to the establishment of the monetary committee (and more generally to status quo bias).

4.2 Robustness test for estimated elasticities

We now run robustness checks on the results in Tables 1 and 2 to see whether the assumption of constant elasticities is erroneous. To do so, we relax the restriction of constant elasticities in eq. (6) and allow elasticities to depend on the sign and size of the monetary surprises. Accordingly, we estimate the following nonlinear equation:

$$E_2 Z_t - E_1 Z_t = \left(1 - Dum^{2008}\right)\left[c_A + \digamma_A u_t^r + \frac{1}{2}\Upsilon_A (u_t^r)^2\right] + Dum^{2008}\left[c_B + \digamma_B u_t^r + \frac{1}{2}\Upsilon_B (u_t^r)^2\right] + \epsilon_t, \quad (7)$$

where $\digamma_j = [\beta^\pi,\ \beta^s, \beta^r, \hat{\beta}^y]$, $\Upsilon_j = [\Upsilon^\pi, \Upsilon^s \Upsilon^r, \hat{\Upsilon}^y]$, and $j = A, B$. The estimation results are presented in Tables 3 and 4 below. The overall picture is similar to the case of constant elasticities: there is a reduction in the effect of the monetary surprises on inflation along with a notable increase in interest-rate inertia. This raises an interesting point concerning the reaction of the expected path of the BOI interest rate to monetary surprises after 2007. The Bank of Israel report (see BOI (2016)) describes in detail the real-time evolution of the public's assessment of the expected path of the BOI interest rate after 2007 (see Figure 3.14 there). It shows that initially, after each reduction in the BOI interest rate, the PF viewed the interest rate reduction as temporary, and expected that the interest rate would increase during the coming year. But over time the PF began to lower their forecasts and perceived the decline in the nominal rate as permanent

[17] Nakamura and Steinsson (2018) showed that a positive monetary surprise caused the expected output to rise rather than fall, contrary to what we would expect from a standard monetary shock.

[18] The higher interest-rate inertia in Sample 2 is not due the fact that the BOI interest rate was stuck at 0.1% from 2015 to 2018. However, significantly higher interest-rate inertia is obtained when we estimate the model up to 2014.

over the next years. This asymmetric pattern of the public's assessment of the CB interest rate was also observed in the US and in other countries. This asymmetric response of one-year interest rate forecast to monetary surprises can be seen in the estimated elasticity, which is dependent on the sign of monetary surprise (see Table 4).

Table 3: Short-run elasticities (one month)

Variables	**Inflation**	**Exchange rate**	**Interest rate**
Sample 1 (2001.M4-2007.M12)	$\underset{(0.00)}{\beta^{\pi}=-0.11}$; $\underset{(0.00)}{\Upsilon^{\pi}=0.14}$	$\underset{(0.00)}{\beta^{s}=-0.91}$; $\underset{(0.00)}{\Upsilon^{s}=1.81}$	$\underset{(0.00)}{\beta^{r}=0.58}$; $\underset{(0.00)}{\Upsilon^{r}=-0.26}$
Sample 2 (2008.M1-2016.M10)	$\underset{(0.80)}{\beta^{\pi}=0.02}$; $\underset{(0.60)}{\Upsilon^{\pi}=-0.26}$	$\underset{(0.56)}{\beta^{s}=-0.50}$; $\underset{(0.19)}{\Upsilon^{s}=7.12}$	$\underset{(0.00)}{\beta^{r}=0.83}$; $\underset{(0.36)}{\Upsilon^{r}=0.56}$
χ^2statistic [p-value] H_0:$F_B = F_A$	6.53[4%]	0.98[62%]	5.70[6%]

Remark: The upper two rows present the estimated elasticity (and its p-value (the upper and lower values in each cell, respectively). The bottom row presents the χ^2statistic (and, in brackets, its p-value), which tests whether there was a significant difference in the estimated elasticities between Samples 1 and 2.

Table 4: Medium-run elasticities (one year)

Variables	**Inflation**	**Exchange rate**	**Interest rate**
Sample 1 (2001.M4-2007.M12)	$\underset{(0.00)}{\hat{\beta}^{\pi}=-0.18}$; $\underset{(0.34)}{\hat{\Upsilon}^{\pi}=0.07}$	$\underset{(0.12)}{\hat{\beta}^{s}=-0.46}$; $\underset{(0.08)}{\hat{\Upsilon}^{s}=0.78}$	$\underset{(0.00)}{\hat{\beta}^{r}=0.40}$; $\underset{(0.87)}{\hat{\Upsilon}^{r}=-0.01}$
Sample 2 (2008.M1-2016.M10)	$\underset{(0.40)}{\hat{\beta}^{\pi}=0.11}$; $\underset{(0.89)}{\hat{\Upsilon}^{\pi}=-0.11}$	$\underset{(0.61)}{\hat{\beta}^{s}=-0.39}$; $\underset{(0.36)}{\hat{\Upsilon}^{s}=4.32}$	$\underset{(0.00)}{\hat{\beta}^{r}=0.87}$; $\underset{(0.00)}{\hat{\Upsilon}^{r}=2.62}$
χ^2statistic [p-value] H_0:$F_B = F_A$	7.25[3%]	0.73[69%]	13.94[0%]

Remark: The upper two rows present the estimated elasticity (and its p-value (the upper and lower values in each cell, respectively). The bottom row presents the χ^2statistic (and, in brackets, its p-value), which tests whether there was a significant difference in the estimated elasticities between Samples 1 and 2.

4.3 Testing for the inattentiveness of the PF in Israel

In Section 2 we raised a concern about the potential inattentiveness of the PF in Israel and its consequences for the estimated elasticities. In this section we examine whether the PF are inattentive (under the null hypothesis they are not inattentive). We follow the approach of Bordalo et al. (2018) and Coibion and Gorodnichenko (2015) by estimating the following regression:

$$y_{t+12} - E_2 y_{t+12} = \gamma^y (E_2 y_{t+12} - E_1 y_{t+12}) + \epsilon_{t+12}, \tag{8}$$

where $y_{t+12} - E_2 y_{t+12}$ is a one-year ahead forecast error, $y = \{\pi, s, r\}$. The explanatory variable $E_2 y_{t+12} - E_1 y_{t+12}$ is a revision (between T2 and T1) of the variable y being forecasted 12 months ahead. This revision captures the reactions of the PF to news (e.g., monetary surprises, etc.). Under the null hypothesis, the forecast error should be unpredictable, i.e., $\gamma^y = 0$. If inattentiveness exists, we would obtain $\gamma^y > 0$ (see Bordalo et al. (2018) for details). The estimation results show that the null hypothesis cannot be rejected for PF forecasts for inflation, interest, and shekel-dollar exchange rates at p-values of 58%, 89%, and 52%, respectively.[19] Nor can the null hypothesis be rejected when we estimate eq. (8) in Samples 1 and 2, separately.

As an additional test for the existence of inattentiveness, we estimate eq. (6) with a slight modification. Namely, we add an additional explanatory variable u^{π}_{t-2}, where $u^{\pi}_{t-2} = \pi_{t-2} - E\pi_{t-2}$, which is an inflation surprise for month $t-2$, and $E\pi_{t-2}$ is a PF forecast derived one day before the CPI announcement of month

[19] The p-values were calculated using Newey–West correction.

$t-2$. Notice that π_{t-2} is announced on the 15th of month $t-1$ (see Figure 1), about one week before the BOI interest rate for month t. If $E_1 Z_t$ contains the information about u^{π}_{t-2} (meaning that the PF update their forecast on time by exploiting all relevant information), the forecast update $E_2 Z_t - E_1 Z_t$ should not be affected by u^{π}_{t-2}, but should still be affected by u^{r}_{t}. Thus, we estimated the following equation:

$$E_2 Z_t - E_1 Z_t = \left(1 - Dum^{2008}\right)\left[c_A + \digamma_A u^r_t + \theta_A u^{\pi}_{t-2}\right] + Dum^{2008}\left[c_B + \digamma_B u^r_t + \theta_B u^{\pi}_{t-2}\right] + \epsilon_t. \qquad (9)$$

We tested whether all parameters in vector θ_A were equal to zero, and conducted the same test separately for θ_B.The null hypothesis was not rejected at a p-value of 61% for θ_A and at a p-value of 38% for θ_B. Finally, we also checked whether $\theta_A = \theta_B = 0$ and the null hypothesis was not rejected at a p-value of 54%. These findings provide additional support for the attentiveness of the PF, which in turn reduces to some extent the concern about potential bias in the estimators (see discussion in Section 2).

We also conducted a similar test to that shown in eq. (9), except that instead of a (lagged) inflation surprise we tested for a monetary surprise with one lag[20] (see eq. (10) below).

$$E_2 Z_t - E_1 Z_t = \left(1 - Dum^{2008}\right)\left[c_A + \digamma_A u^r_t + \theta_A u^{r}_{t-1}\right] + Dum^{2008}\left[c_B + \digamma_B u^r_t + \theta_B u^{r}_{t-1}\right] + \epsilon_t, \qquad (10)$$

where $\digamma_j = [\beta^{\pi},\, \beta^{s}, \beta^{r}, \hat{\beta}^{y}]$, $\theta_j = [\theta^{\pi},\, \theta^{s}, \theta^{r}, \hat{\theta}^{y}]$, $j = A, B$.

As discussed in Coibion and Gorodnichenko (2012), if the lagged monetary surprise is significant, it means that PF do not completely adjust their forecasts to the contemporaneous monetary surprise but also react to past monetary surprises – behavior that is in line with inattentiveness. The estimation results of eq. (10) for the PF in Israel show (see Tables 5 and 6 below) that the lagged monetary surprise in Sample 1 was found to be significant only for the inflation expectations for 1 and 12 months ahead (but not for exchange rate expectations and the interest rate expectations). In Sample 2, it was found to be significant for the exchange rate expectations and the interest rate expectations for 1 and 12 months ahead (but not for the inflation expectations). Thus, there is some inconsistency in the delayed responses of different types of expectations between Samples 1 and 2. The main results here are in line with those shown in Tables 1 and 2, indicating a significant decline in the effect of monetary surprises on inflation and a noticeable increase in the interest rate inertia after 2007, whereas the effect on the exchange rate was found to be stable over two samples.

Overall, based on the test in eq. (10), we find partial evidence of the inattentiveness of the PF in Israel, but this evidence is weak and not robust to other tests as given in eqs. (8) and (9). Additional evidence against the inattentiveness of the PF in Israel stems from the high frequency of forecast reporting that they are requested to provide: the BOI requests to provide forecasts at least twice per month,[21] some of the PF even provide forecasts on a weekly basis. The high frequency of forecast reporting serves as an incentive to the PF to keep a "hand on the pulse" with respect to the information arrival.

Table 5: Short-run elasticities (one month)

Variables	**Inflation**	**Exchange rate**	**Interest rate**
Sample 1 (2001.M4-2007.M12)	$\beta^{\pi}=-0.09$; $\theta^{\pi}=-0.07$ (0.00) (0.04)	$\beta^{s}=-0.93$; $\theta^{s}=-0.48$ (0.00) (0.18)	$\beta^{r}=0.61$; $\theta^{r}=0.00$ (0.00) (0.99)
Sample 2 (2008.M1-2016.M10)	$\beta^{\pi}=0.04$; $\theta^{\pi}=0.03$ (0.55) (0.59)	$\beta^{s}=-0.83$; $\theta^{s}=-1.75$ (0.23) (0.01)	$\beta^{r}=0.74$; $\theta^{r}=0.17$ (0.00) (0.04)
χ^2statistic [p-value] H_0:$\digamma_B + \theta_B = \digamma_A + \theta_A$	7.24[0%]	1.47[23%]	13.27[0%]

Remark: The upper two rows present the estimated elasticity (and its p-value (the upper and lower values in each cell, respectively). The bottom row presents the χ^2statistic (and, in brackets, its p-value), which tests whether there was a significant difference in the estimated elasticities (the sum of contemporaneous and lagged effects of monetary surprises) between Samples 1 and 2.

[20] Higher lags of monetary surprises were found to be highly insignificant.

[21] The PF provide their forecasts not only to the BOI by also to other institutions and companies.

Table 6: Medium-run elasticities (one year)

Variables	Inflation	Exchange rate	Interest rate
Sample 1 (2001.M4-2007.M12)	$\underset{(0.02)}{\hat{\beta}^{\pi}=-0.13}$; $\underset{(0.00)}{\hat{\theta}_{\pi}=-0.15}$	$\underset{(0.13)}{\hat{\beta}^{s}=-0.46}$; $\underset{(0.52)}{\hat{\theta}_{s}=-0.20}$	$\underset{(0.00)}{\hat{\beta}^{r}=0.37}$; $\underset{(0.26)}{\hat{\theta}_{r}=0.06}$
Sample 2 (2008.M1-2016.M10)	$\underset{(0.29)}{\hat{\beta}^{\pi}=0.11}$; $\underset{(0.52)}{\hat{\theta}_{\pi}=0.07}$	$\underset{(0.45)}{\hat{\beta}^{s}=-0.45}$; $\underset{(0.00)}{\hat{\theta}_{s}=-1.75}$	$\underset{(0.00)}{\hat{\beta}^{r}=0.57}$; $\underset{(0.05)}{\hat{\theta}_{r}=0.21}$
χ^2statistic [p-value] H_0:$\digamma_B + \theta_B = \digamma_A + \theta_A$	10.22[0%]	3.41[6%]	5.69[2%]

Remark: The upper two rows present the estimated elasticity (and its p-value (the upper and lower values in each cell, respectively). The bottom row presents the χ^2statistic (and, in brackets, its p-value), which tests whether there was a significant difference in the estimated elasticities (the sum of contemporaneous and lagged effects of monetary surprises) between Samples 1 and 2.

5 Conclusions

In this paper we examine the effectiveness of the monetary surprises of the BOI through the eyes of the professional forecasters in Israel. Several conclusions can be drawn. First, the PF-perceived effect of monetary surprises on inflation significantly declined after 2007. This mainly occurred due to a dissociation of rent prices from the shekel-dollar exchange rate, although the effect of the monetary surprises on the exchange rate was found to be stable over the whole period. We also tested the hypothesis that the information channel of BOI monetary policy intensified after 2007 due to a significant decline in the natural rates worldwide after the global financial crisis and the establishment of a monetary committee in Israel. We found no evidence supporting this hypothesis in Israel as the effect of monetary surprises on real activity did not change. We also found a significant increase in interest-rate inertia after the establishment of the monetary committee. This is because the committee brought more discipline to monetary policy decisions (due to status quo bias), which naturally increased the degree of smoothness of the BOI interest rate. Futhemore, we found only partial and not robust evidence of the inattentiveness of the PF in Israel. Specifically, the PF seem to rationally form their expectations by fully adjusting them to relevant economic news. Finally, we identified an asymmetric pattern of the PF's assessment of the CB interest rate after the financial crisis in the US. When there was a positive surprise in the BOI interest rate, the PFs significantly updated upward their forecasts for the interest rate for the coming year. In contrast, when the monetary surprise was negative, the PFs barely updated upward their forecast for the interest rate.

References

Andrade, P., Bihan, H. L., 2013. Inattentive professional forecasters. Journal of Monetary Economics 60 (8), 967–982.

Bauer, M. D., 2015. Inflation Expectations and the News. International Journal of Central Banking 11 (2), 1–40.

Beenstock, M., Ilek, A., 2010. Wicksell's classical dichotomy: Is the natural rate of interest independent of the money rate of interest? Journal of Macroeconomics 32 (1), 366–377.

BOI, 2002. Monetary Policy and Inflation. Annual Report of the Bank of Israel, chapter 3, Bank of Israel.

BOI, 2016. Monetary Policy and Inflation. Annual Report of the Bank of Israel, chapter 3, Bank of Israel.

Bordalo, P., Gennaioli, N., Ma, Y., Shleifer, A., 2018. Over-reaction in Macroeconomic Expectations. Working Paper 24932, National Bureau of Economic Research.

Branch, W. A., Evans, G. W., 2006. A simple recursive forecasting model. Economics Letters 91 (2), 158–166.

Clements, M. P., 2012. Do professional forecasters pay attention to data releases? International Journal of Forecasting 28 (2), 297–308.

Coibion, O., Gorodnichenko, Y., 2012. What can survey forecasts tell us about information rigidities? Journal of Political Economy 120 (1), 116–159.

Coibion, O., Gorodnichenko, Y., 2015. Information Rigidity and the Expectations Formation Process: A Simple Framework and New Facts. American Economic Review 105 (8), 2644–2678.

Cukierman, A., Melnick, R., 2015. The Conquest of Israeli Inflation and Current Policy Dilemmas. C.E.P.R. Discussion Paper 10955, C.E.P.R.

Elkayam, D., Segal, G., 2018. Estimated Natural Rate of Interest in an Open Economy: The Case of Israel. Bank of Israel Working Paper 2018.05, Bank of Israel.

Faust, J., Rogers, J. H., Wang, S.-Y. B., Wright, J. H., 2007. The high-frequency response of exchange rates and interest rates to macroeconomic announcements. Journal of Monetary Economics 54 (4), 1051–1068.

Faust, J., Swanson, E. T., Wright, J. H., 2004. Identifying VARS based on high frequency futures data. Journal of Monetary Economics 51 (6), 1107–1131.

Ghysels, E., Wright, J. H., 2009. Forecasting professional forecasters. Journal of Business & Economic Statistics 27 (4), 504–516.

Holston, K., Laubach, T., Williams, J. C., 2017. Measuring the natural rate of interest: International trends and determinants. Journal of International Economics 108, 559–575.

Kortelainen, M., Paloviita, M., Viren, M., 2016. How useful are measured expectations in estimation and simulation of a conventional small New Keynesian macro model? Economic Modelling 52, 540–550.

Laxton, D., Berg, A., Karam, P., 2006. A Practical Model-Based Approach to Monetary Policy Analysis-Overview. IMF Working Papers 06/80, International Monetary Fund.

Markiewicz, A., Pick, A., 2014. Adaptive learning and survey data. Journal of Economic Behavior & Organization 107, 685–707.

Nakamura, E., Steinsson, J., 2018. High-frequency identification of monetary non-neutrality: The information effect. Quarterly Journal of Economics 133 (3), 1283–1330.

Ruge-Murcia, F., Riboni, A., 2017. Collective versus individual decision-making: A case study of the Bank of Israel law. European Economic Review 93 (C), 73–89.

Segal, G., 2019. Natural Interest Rate. mimeo, Bank of Israel.

Smets, F., Warne, A., Wouters, R., 2014. Professional forecasters and real-time forecasting with a DSGE model. International Journal of Forecasting 30 (4), 981–995.

Stein, R., 2011. Estimating the expected natural interest rate using affine term-structure models: The case of Israel. Bank of Israel Working Paper 2011.03, Bank of Israel.

Appendix A: Effect of monetary surprises on real activity

Here we want to show how the uncertainty of the public as to the source of monetary surprises affects the ability of the CB to stabilize real activity. We start our analysis with a standard assumption that the CB is fully transparent about its perceived natural rate in the economy. Then, we turn to the more realistic full-opacity case, where the CB's natural rate is unknown to the public, and hence the source of the monetary surprises is unknown as well. For our analysis, we consider a simple public-perceived New Keynesian model for a small open economy à la Laxton et al. (2006), which includes the inflation equation, the demand equation, the real exchange rate equation and the policy rule of the CB:

$$\begin{aligned}
\pi_t &= \beta E_t \pi_{t+1} + (1-\beta)\pi_{t-1} + kx_{t-1} + \gamma \Delta s_t \\
x_t &= \lambda E_t x_{t+1} + \varrho x_{t-1} - \alpha[i_t - E_t \pi_{t+1} - r_t^n] + \delta(s_t - s_t^*) \\
s_t &= E_t s_{t+1} - [i_t - E_t \pi_{t+1} - rr_t^W] \\
i_t &= \hat{r}_t + f(z_{t-1}) + \zeta_t,
\end{aligned} \tag{11}$$

where π_t is the inflation, x_t is the output gap, s_t is the real exchange rate (in logs), s_t^* is the equilibrium real exchange rate (in logs), rr_t^W is the real foreign interest rate, i_t is the central bank interest rate, r_t^n is the real natural rate as perceived by the PF and $\hat{r}_t$ is the natural interest rate as perceived by the CB (which is included in its policy rule). Under full transparency $r_t^n = \hat{r}_t$, as assumed in standard New Keynesian models. Denote by ζ_t the classic monetary shock, which may reflect changes in the CB preferences of the CB, e.g., reaction of the CB to new variables, etc. Denote by $f(z_{t-1})$ the vector of predetermined variables included in the CB's policy rule, such as inflation and output gap, which is fully observed by the public. Under this assumption $f(z_{t-1})$ is not affected by changes in $\hat{r}_t$ or in ζ_t.

We consider two cases where the CB raises its interest rate:

Case 1: The CB (unexpectedly) raises i_t **only** because of the classic monetary shock ζ_t.

Case 2: The CB (unexpectedly) raises i_t **only** because it updates the natural interest rate $\hat{r}_t$.

We now return to the demand equation in eq. (11) and plug in the third equation for s_t:

$$x_t = \lambda E_t x_{t+1} + \varrho x_{t-1} - \alpha[i_t - E_t \pi_{t+1} - r_t^n] + \delta(E_t s_{t+1} - [i_t - E_t \pi_{t+1} - rr_t^W] - s_t^*).$$

To illustrate our main point in the simplest way, we assume that $Ex_{t+1} = E\pi_{t+1} = 0$, and the expected real exchange rate equals 1 implying $E_t s_{t+1} = 0$. Under this assumption:

$$x_t = \varrho x_{t-1} - \alpha[i_t - r_t^n] - \delta(i_t - rr_t^W + s_t^*).$$

Let $E_1 x_t$ represent the forecast for the output gap before the interest rate announcement:

$$E_1 x_t = \varrho x_{t-1} - \alpha[E_1 i_t - E_1 r_t^n] - \delta(E_1 i_t - rr_t^W + E_1 s_t^*),$$

where $E_1 i_t$ is the forecast for the CB interest rate, $E_1 i_t = c + f(z_{t-1})$; $E_1 r_t^n$ and $E_1 s_t^*$ are the public's assessments of the natural rate and the equilibrium real exchange rate in the economy, respectively, before the announcement.

Let $E_2 x_t$ represent the forecast for the output gap after the interest-rate announcement:

$$E_2 x_t = \varrho x_{t-1} - \alpha[i_t - E_2 r_t^n] - \delta(i_t - rr_t^W + E_2 s_t^*),$$

where $E_2 r_t^n$ and $E_2 s_t^*$ are the public's assessments of the natural rate and the equilibrium real exchange rate in the economy, respectively, after the announcement. From the last two equations, we see that the forecast update $\Delta E x_t = E_2 x_t - E_1 x_t$ is

$$\Delta E x_t = -(\alpha + \delta)[i_t - E_1 i_t] + \alpha[\Delta E r_t^n] - \delta[\Delta E s_t^*], \tag{12}$$

where $i_t - E_1 i_t$ is a monetary surprise, $\Delta E r_t^n = E_2 r_t^n - E_1 r_t^n$ is an update of the public's assessment of the natural rate, and $\Delta E s_t^* = E_2 s_t^* - E_2 s_t^*$ is an update of the public's assessment of the equilibrium real exchange rate.

Before we consider a realistic case where the source of the monetary surprise is unknown to the public, let us consider the case where the source is known.

Full transparency (FT)

Case 1: We assume that $\hat{r}_t = r_t^n = c$ (constant value) and it is known to the public. Moreover, we assume that the public perceives the CB to know the natural rate of the economy. Thus, any unexpected change in i_t will surely be attributed to a classic monetary shock ζ_t, i.e., $i_t - E_1 i_t = \zeta_t$, where $E_1 i_t = c + f(z_{t-1})$. From eq. (12) we can derive the elasticity of the forecast update for the output gap w.r.t. an unexpected increase in the CB interest rate (which is due to ζ_t):

$$\frac{\partial \Delta E x_t}{\partial (i_t - E i_t)} = -(\alpha + \delta) + \alpha \underbrace{\frac{\partial \Delta E r_t^n}{\partial \zeta_t}}_{0} - \delta \underbrace{\frac{\partial \Delta E s_t^*}{\partial \zeta_t}}_{0} = -(\alpha + \delta). \tag{13}$$

The last two expressions are equal to zero because monetary shock cannot affect the natural interest rate of the equilibrium real exchange rate.

Case 2: Now we assume that the unexpected increase in the nominal interest rate of the CB is due only to the CB's update of the natural interest rate ($\Delta \hat{r}_t \uparrow$), which is known to the public. Thus, the public observes the source of the monetary surprise, $i_t - E_1 i_t = \Delta \hat{r}_t$, knowing that $\zeta_t = 0$. The elasticity of the forecast update for the output gap w.r.t. the unexpected increase in the nominal interest rate (which is due to the CB's update of the natural interest rate) is

$$\frac{\partial \Delta E x_t}{\partial (i_t - E i_t)} = -\alpha + \alpha \underbrace{\frac{\partial \Delta E r_t^n}{\partial \Delta \hat{r}_t}}_{1} - \delta \underbrace{\frac{\partial \Delta E s_t^*}{\partial \Delta \hat{r}_t}}_{0} = 0. \tag{14}$$

The last expression is equal to zero because we assume that s_t^* is an exogenous process as in Laxton et al. (2006). From the above equation we see that the public's forecast for the output gap is not updated, because the monetary surprise has no effect on the monetary stance.

Full opacity (FO)

Now we examine the main part of the Appendix and consider a more realistic case where the PF don't know the source of the unexpected changes in the interest rate. They face the following signal-extraction problem: when the PF observe an unexpected change in the interest rate, $i_t - E_1 i_t = \Delta \hat{r}_t + \zeta_t$, where $E_1 i_t = c + f(z_{t-1})$, they don't know whether the monetary surprise is due to the change in the natural rate or to a classic monetary shock. Here we stick to the previous assumption that the CB knows the natural rate of the economy and, therefore, it is enough for the public to learn the natural rate from the CB policy rule. The public learns from $i_t - E_1 i_t$ about the natural rate by taking into account the following two equations:

$$\begin{aligned} i_t - E_1 i_t &= \Delta \hat{r}_t + \zeta_t, \quad \zeta_t \sim N(0, \Gamma) \\ \Delta \hat{r}_t &= \varepsilon_t^r, \quad \varepsilon_t^r \sim N(0, \Omega), \end{aligned} \tag{15}$$

where the first line in eq. (15) is the signal equation, which decomposes the monetary surprise into two unobserved components: the classic monetary shock and the CB's update of the natural rate. The second line is the state equation, which describes how changes in the natural rate ($\Delta\hat{r}_t$) evolve.[22] For simplicity, we assume that the news affecting the CB's update of the natural rate is white noise shocks (ε_t^r) (the PF perceive the natural rate as $\hat{r}_t = c + \varepsilon_t^r$ (c is known), where ε_t^r is "news" causing the CB to update its natural rate). We also assume that the PF either know about (conditional) variances Γ and Ω or they have an assessment of them. Using eq. (15), the PF derive the best estimator of (change) in the natural rate:

$$\Delta E\hat{r}_t = G(i_t - Ei_t), \tag{16}$$

where the signal-to-noise ratio

$$G = \frac{\Omega}{\Omega + \Gamma} < 1.$$

We now return to cases (1) and (2) and examine their implications under FO.

Case 1: $\zeta_t > 0$ and $\varepsilon_t^r = 0$ (but this is not observed by the PF).

Combining eq. (12) and eq. (16), we obtain the effect of monetary surprise on the updated forecast for the output gap:

$$\frac{\partial\Delta Ex_t}{\partial(i_t - Ei_t)} = -(\alpha + \delta) + \alpha \underbrace{\frac{\partial\Delta Er_t^n}{\partial(i_t - Ei_t)}}_{G} = -\left(\alpha(1 - G) + \delta\right). \tag{17}$$

From eq. (17) we see that in Case 1 under FO, the monetary surprise is less effective in stabilizing real activity compared to Case 1 under FT (eq. (13)).

Case 2: $\zeta_t = 0$ and $\varepsilon_t^r > 0$ (but this is not observed by the PF).

The PF learn from the monetary surprise the updated natural rate as given in eq. (16). The effect of the monetary surprise on the output gap forecast is

$$\frac{\partial\Delta Ex_t}{\partial(i_t - Ei_t)} = -(\alpha + \delta) + \alpha \underbrace{\frac{\partial\Delta Er_t^n}{\partial(i_t - Ei_t)}}_{G} = -\left(\alpha(1 - G) + \delta\right). \tag{18}$$

From eq. (18) we see that in Case 2 under FO, the monetary surprise is more effective in stabilizing real activity compared to Case 2 under FT (eq. (14)). This is because under FO, due to the uncertainty, the monetary surprise has some effect on the monetary stance, whereas under FT this effect is null.

Empirical examination of the information channel in Israel

In the previous section we have seen that the value of G (signal-to-noise ratio) influences the effect of monetary surprises on real activity. An increase in G can stem from assigning a higher weight to the monetary surprises attributed by the public to the CB's updates of the natural rate (higher Ω) or from assigning a lower weight to classic monetary shocks (lower Γ), both of which occur simultaneously. Technically, $G = \frac{\Omega}{\Omega+\Gamma}$ increases either when Ω increases and Γ is fixed, or when Γ decreases and Ω is fixed, or when Ω increases and Γ decreases simultaneously. It can be seen from eqs. (17) and (18) that for a monetary surprise of a given size (induced by a classic monetary shock or by the CB's update of the natural rate), the reaction of output gap becomes weaker[23] as $G \to 1$. Since under this assumption the effect of a monetary surprise on real activity becomes weaker, so does the ability of the CB to stabilize inflation, for a given elasticity of inflation w.r.t. output gap in the inflation equation (parameter k in eq. (11)).

[22] The specification of the state equation (second line in eq. (15)) is consistent with a random walk of the natural rate as found empirically in the estimates of natural rates in Israel and abroad.

[23] A similar point concerning the smaller effect of monetary surprise on output when the information channel is dominant was also raised by Nakamura and Steinsson (2018) on page 1315.

To examine possible changes in G in the Israeli economy, at the first stage we examine the evolution of conditional variance Ω over time by considering different estimates of natural rates in Israel and abroad.[24] The first measure (notation, TR) is derived from the BOI policy rule (see Elkayam and Segal (2018). For our purposes this is the most interesting measure because it reflects the perceptions of the monetary committee/governor regarding the natural rate in Israel. The second measure of natural rate in Israel is presented by a forward real interest rate for 7 years of maturity expected after 3 years (notation, $FW3\_10$) and for 5 years of maturity expected after 5 years (notation, $FW5\_10$) (see Beenstock and Ilek (2010)). The last measure of the natural rate is derived from an affine term-structure model (notation, ATS; see Stein (2011)).

By trying to mimic the real-time perceptions of the PF regarding the conditional variance of the natural rates, we derive real-time estimates of conditional variance of $\Delta\hat{r}_t$ using the Garch(p, k) model and natural rate estimates in Israel and abroad.[25] We use both domestic and foreign natural rate estimates for purposes of robustness, because we don't know what kind of natural rates the PF monitored during the sample period, but these estimates are common knowledge for all agents. The real-time estimators of conditional variance Ω of the natural rates in Israel and abroad are shown in Figures A1 and A2 below, respectively.[26] Starting with the estimated conditional variance of the natural rates abroad, we see that it is quite stable over the whole sample. The only exception is during the financial crisis in 2008–2009, when the variance jumped sharply but then quickly returned to the pre-crisis level. Turning to the estimated conditional variance of the natural rate in Israel, there was also a jump in the conditional variance of TR and FW_5_10 around the period of the financial crisis. The conditional variance of other versions of the natural rate is quite stable over the whole sample.

Based on these results, there is a little evidence that Ω changed after 2007 and, therefore, there is no effect on G from that side. Did Γ change after 2007? Since the volatility of monetary surprises as shown in Figure 2 (in Section 2) is not significantly different in Samples 1 and 2 (excluding the years 2001–2002), and relying on the previous result that Ω did not change after 2007, we can reasonably conjecture that also Γ was stable over the whole sample. Overall, we don't find compelling evidence that the effect of the BOI monetary surprises on real activity changed after 2007 due to the information channel of monetary policy.

[24] In Israel there are three types of natural rate estimates derived by different methodologies: Beenstock and Ilek (2010), Elkayam and Segal (2018), and Stein (2011). Segal (2019) provides an overview of these estimates. The natural rate estimates from abroad are taken from Holston et al. (2017).

[25] Real-time estimates were derived as follows: the first sample was based on the period 1995.Q1–2001.Q4, the next sample contained an additional quarter, 1995.Q1–2002.Q1, and so on, to the final sample, which includes the whole sample, 1995.Q1–2016.Q4.

[26] The Matlab code for the Garch estimation and the data of the natural interest rates in Israel and abroad are available from the author upon request.

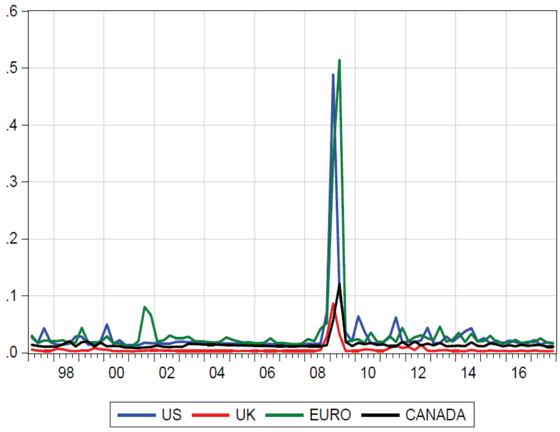

Figure A1: Real-time estimation of conditional variance of the natural rate abroad by Garch(p, k) model. Sample 1997.Q1–2016.Q4.

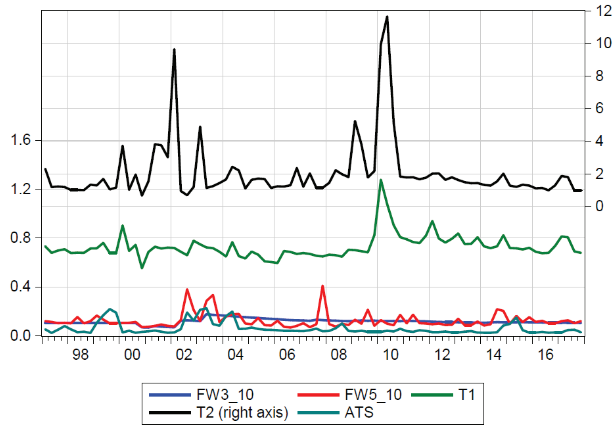

Figure A2: Real-time estimation of conditional variance of various estimates of the natural rate in Israel by the Garch(p, k) model. Sample 1997.Q1–2016.Q4.