Money and monetary policy in Israel during the last decade

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Abstract

This study examines how money and monetary policy have influenced output and inflation during the past decade in Israel by comparing two New Keynesian DSGE models. One is a baseline separable model (Galí, 2008) and the other assumes non-separable household preferences between consumption and money (Benchimol and Fourçans, 2012). We test both models by using rolling window Bayesian estimations over the last decade (2001-2013). The results of the presented dynamic analysis show that the sensitivity of output with respect to money shocks increased during the Dot-com, Intifada, and Subprime crises. The role of monetary policy increased during these crises, especially with regard to inflation, even though the effectiveness of conventional monetary policy decreased during the Subprime crisis. In addition, the non-separable model including money provides lower forecast errors than the baseline separable model without money, while the influence of money on output fluctuations can be seen as a good predictive indicator of bank and debt risks. By impacting and monitoring households' money holdings, policy makers could improve their forecasts and crisis management through models considering monetary aggregates.

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1 Introduction

The consequences and pace of the recent economic downturn, which began with the Subprime mortgage crisis in the United States and was followed by the global financial crisis (GFC), differed worldwide depending on the countries involved and their monetary policies. Nevertheless, most countries shared at least one common element: an increase in the (relative) risk aversion levels of households (Bernanke, 2009).

Risk aversion, which can be a perception, feeling, or behavior, leads to changes in both household consumption and the money held by households. The trade-off between consuming and holding money can be modeled using non-separable preferences between consumption and money holdings and testing the existence of non-separability parameters. At equilibrium, consumption equals output in simple models, and even though this non-separability parameter exists, it does not assign a significant role to money holdings with regard to output dynamics (Ireland, 2004; Andrés et al., 2006).

Despite their potential influence on output, monetary aggregates and money demand have largely been ignored in the dynamic models literature (Woodford, 2003). Indeed, Christiano et al. (2010) show that dynamic stochastic general equilibrium (DSGE) models can identify and explain business cycle dynamics as well as demonstrate how economic shocks affect the economy.[1] However, by developing the now standard New Keynesian DSGE models for the Eurozone and United States, and by excluding money shocks from their model(s), Smets and Wouters (2003, 2007) do not assign money an explicit role with regard to economic dynamics.

Nevertheless, the impact of money shocks on output is theoretically significant when risk aversion is sufficiently high relative to the non-separability parameter, as may be the case during crisis periods, and empirical tests with Eurozone or US data confirm this result (Benchimol and Fourçans, 2012; Caraiani, 2015; Benchimol and Fourçans, 2016). Indeed, comparing the out-of-sample forecasts of these non-separable models with those obtained from the baseline model *à la* Galí (2008) shows that assuming non-separability between consumption and real money holdings improves the forecasting performance of output during crises (Benchimol, 2011; Benchimol and Fourçans, 2016).

Unlike all the DSGE literature including money (Ireland, 2004; Andrés et al., 2006; Barthélemy et al., 2011), Benchimol and Fourçans (2012) introduce a microfounded money equation in the flexible-price economy, enriching

[1] For those reasons, policymaking institutions and central banks are increasingly utilizing DSGE models to assist in forecasting and policy decisions (Edge and Gürkaynak, 2010).

economic dynamics, in line with Galí (2008), and estimate the model's parameters through Bayesian estimations with several monetary policy rules and risk aversion calibrations. Benchimol (2015) also introduces the concept of flexible-price real money.

Non-separability between consumption and money introduces money-related variables into the inflation and output equations. Thus, by minimizing its loss function with respect to these two equations, the central bank has to deal with money-related variables. Yet, the objectives, independence, and autonomy of the Bank of Israel (BoI) do not directly refer to money or monetary aggregates as instruments devoted to conducting monetary policy. The main objective of the BoI is to maintain price stability while being independent of politics and administrations. Therefore, it is interesting to test a model in which consumption and money are not time-separable in household preferences and to analyze the role of money and monetary policy on Israel's output dynamics during the past decade, including many interesting stylized facts (the Dot-com, Intifada, and Subprime crises).

Most DSGE models of the Israeli economy ignore this non-separability assumption and rather consider only small open economy models without money (Binyamini, 2007; Argov and Elkayam, 2010; Argov, 2012; Argov et al., 2012). Against this background, the present study does not aim to build or use complex models in a small open economy; rather, our goal is to analyze the role of money and monetary policy by using common macroeconomic variables. The use of complex small open economy DSGE models forces us to assume and use controversial hypotheses such as the uncovered interest rate parity condition or the law of one price (Corsetti et al., 2008; Tovar, 2008), which strongly affects the results. Since our study focuses on money and monetary policy, and open economy features are assumed to be included in our macroeconomic variables, analyzing the role of money and monetary policy in the Israeli economy by using two simple closed-economy models and perspectives should provide insightful results about the past decade, as long as these DSGE models are calibrated with respect to the literature on dynamic models in Israel (Argov, 2012; Argov et al., 2012).

To achieve this goal, we compare two New Keynesian DSGE models by using Israeli data: one standard model that has separable household preferences (Galí, 2008) and another that assumes non-separability between consumption and real money holdings in household preferences (Benchimol and Fourçans, 2012). In contrast to previous authors, however, we use the Divisia monetary aggregates (Barnett, 1980) provided by the BoI. These are both theoretically and empirically superior to the standard simple-sum monetary aggregates used by Benchimol and Fourçans (2012, 2016), among others (Fourçans, 2007; El-Shagi and Giesen, 2013), which simply add up the nominal value of all the monetary assets in circulation while ignoring that these different assets yield different flows of liquidity services. At equilibrium, these assets also differ in terms of the opportunity costs (or user costs) that households and firms incur when demanding those liquidity services. Because the necessary condition for simple-sum aggregation is that all component assets be perfect substitutes (Belongia and Ireland, 2014), simple-sum aggregates are not used in our study.

Because risks in the medium or even the short run can be attenuated by the reciprocation between *good* and *bad* news, while a mix of such news also affects the results, the empirical section of this paper provides rolling window short sample Bayesian estimations in order to capture risks during short periods. The Bayesian techniques used for the estimation and evaluation of DSGE models are described in An and Schorfheide (2007), and following Canova and Sala (2009), our small sample Bayesian estimation results are robust.

The major results presented herein show that money shocks played an important role both during and after the Dot-com and Subprime crises. However, during the latter crisis, the effect of monetary policy on output and inflation increased, whereas this was not the case during and after the former. Moreover, even though the non-separable model is simple, the effect of money shocks does not reflect that of other (omitted) shocks.[2]

Further, the preference for holding money found in the present study implies a positive incentive to save that could reduce the incentive to consume. Hence, even though money does not serve any yield, holding a certain amount is often preferred to holding a lower amount of money and/or consuming. Accordingly, all these transmission channels are strongly dependent on risk perceptions. Therefore, preferences for money holding and output are more *linked* during crises relative to non-crisis periods. Indeed, in line with the findings presented by Castelnuovo (2012), the variance decomposition of output following a money shock can be seen as a good indicator of crises that are not only financial in nature.

In addition, comparing our results with a synthetic financial conditions index (FCI), which is an aggregation of several risk measures (e.g., debt, bank, foreign exchange, equities, residuals), provides interesting results. Specifically, we monitor the weekly financial and credit conditions in Israel (i.e., the FCI) by using a two-factor dynamic model,[3] which provides the overall

[2] The non-separable model was also tested by adding an ad-hoc demand shock, and it led to similar results.

[3] This model is fed by 28 variables, which are measures of the risk, leverage, and liquidity in financial markets, recorded non-simultaneously and at different frequencies (daily to quarterly). The diagnostic ability of the FCI is superior to any of the single financial

measure of systemic financial distress and idiosyncratic credit risk deviation (Michelson and Suhoy, 2014). Using distance correlations and Granger causality tests, we find that the impact of a money shock on Israeli output fluctuations causes the FCI's debt and bank risks.

Moreover, this study focuses on impulse response functions, variance decompositions, and other indicators unrelated to quantities. We find that a money demand shock plays a role in varying output through household preferences to hold rather than consume money during such periods. This shock also reinforces the idea that unconventional monetary policy is important during crises, when debt and bank risks are involved. Therefore, policy makers should pay more attention to households' money holdings, especially during crisis periods, in order to improve standard monetary policy effectiveness while monitoring money demand shocks during periods of various kinds of crises: financial (Dot-com), political (Intifada), or debt or banking crises (Subprime).

The remainder of this paper is organized as follows. Section 2 describes the methodology used for the estimations presented in Section 3. We analyze and discuss the results in Section 4, Section 5 compares our results with the FCI for Israel, Section 6 draws policy implications, and Section 7 concludes.

2 Empirical methodology

Uncertainty and risk aversion are generally relatively low in the medium and long-term, but they can be higher in the short run. Because the acquisition of short-term information is encouraged by a high degree of uncertainty (Holden and Subrahmanyam, 1996), all potentially informed investors in the economy should aim to concentrate exclusively on the short-term instead of the long-term.

To capture this phenomenon, we face a dilemma between theoretical and statistical considerations. Theoretically, only very short study periods (from one to a few years with quarterly data) are able to capture the changes in parameter values induced by short-run crises. Yet, to be reliable, statistical analyses necessitate a sufficient amount of observations, even though a specific statistical rule on the minimum number of observations necessary to carry out reliable Bayesian tests is lacking.

To overcome this issue, we choose a sample size of 24 observations (quarterly data over 6 years) for our Bayesian estimations. Indeed, Fernández-Villaverde and Rubio-Ramírez (2004) demonstrate that Bayes factors are well understood for small sample Bayesian estimations, while Benchimol and

variables used.

Fourçans (2016) produce robust results by using a sample size of 48 observations, with similar results also achieved with even smaller samples. Indeed, several studies have shown that small sample Bayesian estimates tend to outperform classical ones, even when evaluated by using frequentist criteria (Geweke et al., 1997; Jacquier et al., 2002).

The period of interest, between 2001 Q2 and 2013 Q1, should contain some higher uncertainty periods (e.g., Dot-com, Intifada, GFC). Hence, for *every* quarter of the chosen period, we run Bayesian estimations by using the 24 observations[4] *before* each respective quarter (rolling window estimation). Thus, our sample starts in 1995 Q2 in order to match our period of interest.

The values of the micro- and macro-parameters that affect the dynamics of the variables over time are provided by these estimations. The role of each shock is then analyzed by successive estimations and simulations, leading to the impulse response functions and variance decompositions of the macroeconomic variables with respect to the examined shocks.[5] We also compare the respective root mean square deviations (RMSDs) of the two models to assess their prediction performances.

3 Empirical results

3.1 Data

For both models, we use the same quarterly dataset of the Israeli economy from 1995 Q2 until 2013 Q1. For each small sample estimation, we detrend the data (all historical variables are at least $I(0)$) by using a moving window linear detrending method: thus, the respective trend is only based on the corresponding sample of observations, and detrended variables are stationary over this sample.

Inflation ($\hat{\pi}_t$) is measured as the detrended percentage change from one quarter to the previous quarter of the GDP deflator.[6] Output ($\hat{y}_t$) is measured as the difference between the log of real GDP per capita and its linear trend. The interest rate ($\hat{\imath}_t$) is the detrended central bank nominal interest rate. $\widehat{mp}_t$

[4] This short-sample can be replaced by a longer one including, for instance, 48 observations. This choice smooths our results as long as households' risk perceptions are diluted through time.

[5] These shocks are the markup shock, ε_t^p, the technology shock, ε_t^a, the monetary policy shock, ε_t^i, and, for Model 2, the money demand shock, ε_t^m. These models are detailed in the online appendix.

[6] This analysis was also conducted by using the core consumer price index (excluding food and energy) and this produced identical results.

is measured as the percentage change in real Divisia monetary aggregates per capita and its linear trend.

The growth rate of Divisia monetary aggregates is a weighted average of the growth rates of the quantities of its component assets. The weights are expenditure shares based on the products of the user costs of the component assets (prices) and the aforementioned quantities of these assets. Divisia monetary aggregates are consistent with the economic theory of aggregation for flow data, in contrast to conventional sum aggregates.[7] Our Divisia monetary aggregates contain M1, self-renewing overnight deposit (NIS, unindexed), and short-term deposit (NIS, unindexed). M1 is represented by the public's current account, unindexed deposits, and currency and coin held by the public. Here, we do not consider bills issued by the BoI (*makam*) divided by maturity periods.

All these data are extracted from BoI databases. $\hat{y}_t^f$, flexible-price output, and $\widehat{mp}_t^f$, flexible-price real money balances, are completely determined by structural shocks. As we conduct a *rolling window* estimation, it is important to note that the trend used for the detrended data is recalculated for each estimation.[8]

3.2 Estimations

We calibrate both models (for calibration procedure and discussion, see the online appendix) and estimate them by successive Bayesian estimations using the Metropolis-Hastings algorithm (Fig. 1). Fig. 1 presents the parameter means from the Bayesian estimations for both models, showing that our estimated micro-parameters are stable across the different periods. Following Iskrev (2010), all estimated parameters are identified for both models.

The implied posterior distribution of the parameters for each sample size and model is also estimated by using the Metropolis-Hastings algorithm: three distinct chains, each of 50000 draws (Smets and Wouters, 2007; Adolfson et al., 2007). Most of the average acceptance rates per chain are in the interval $[0.29; 0.36]$, concurring with the findings in the literature (Adjemian et al., 2011). Please note, however, that our purpose here is not to present all the results, as this would be a cumbersome task.[9]

[7] For detailed information about the construction of these data for Israel, see http://www.boi.org.il/en/dataandstatistics/pages/dma.aspx.

[8] Then, each subsample is detrended differently. That is why treated data and detrended subsamples are not presented here and are available upon request.

[9] The parameter estimation results, validation, and robustness tests can be provided upon request. All Student tests are above 1.96 for all short sample sizes (this analysis was also conducted with other short sample sizes such as 28, 32, 36, and 40 observations), and

The solid and dashed lines represent the results for the standard separable model (Model 1) *à la* Galí (2008) and the model under non-separable preferences (Model 2) *à la* Benchimol and Fourçans (2012), respectively.

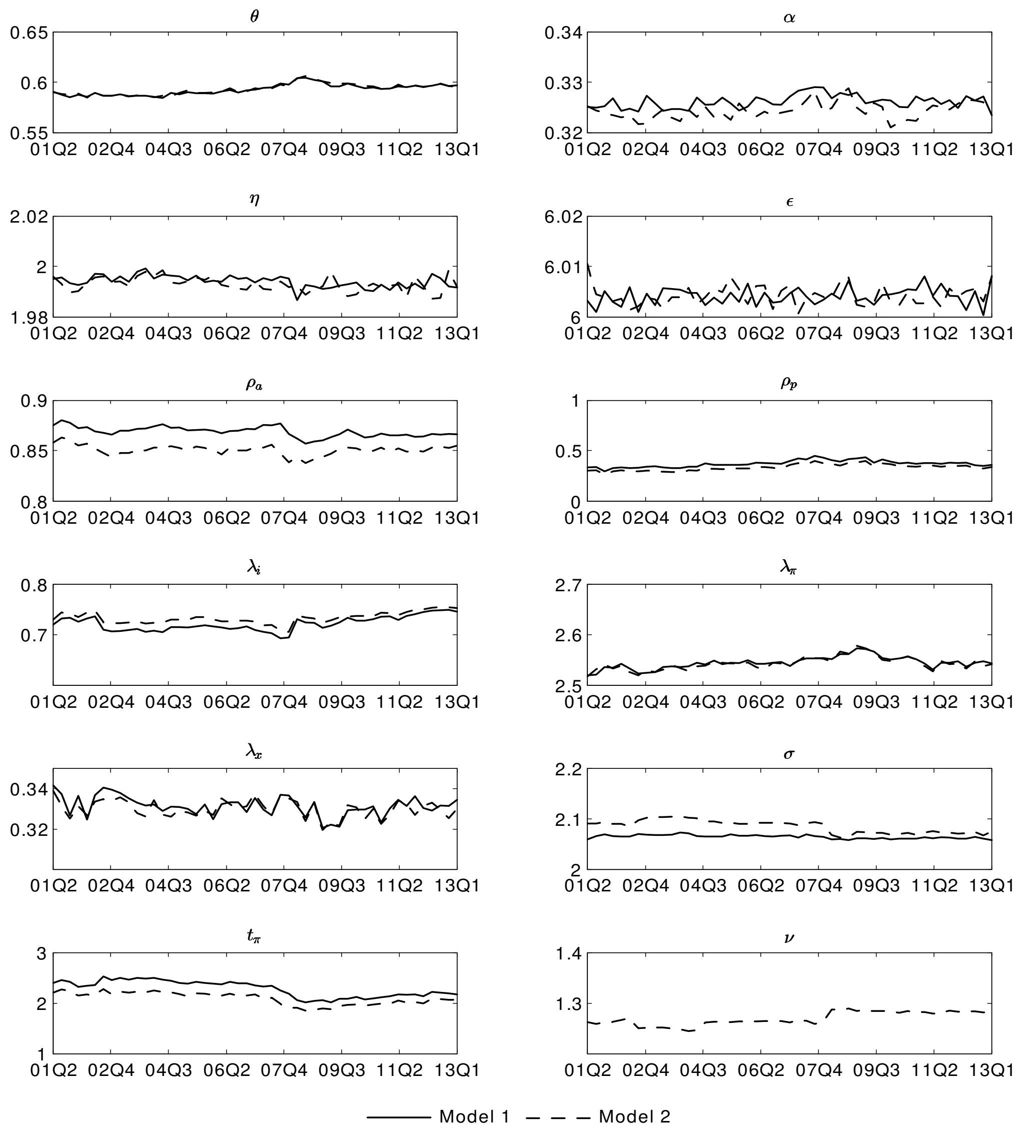

Figure 1: Micro-parameter values for both models during the past decade.

The Taylor rule parameter estimates for the past decade are displayed

parameter estimations are generally stable over time, irrespective of the short sample size, at least for the first moment (mean). Other short sample size estimations as well as the distributions of the priors and posteriors are not presented but are available upon request. We also tested Model 2 with different Taylor rules as in Benchimol and Fourçans (2012).

in Fig. 1. This figure shows that between 2007 Q3 and 2010 Q4, a specific monetary policy rule was implemented, namely a change in the smoothing parameter (λ_i) in some periods, while an increase in the inflation gap coefficient (λ_π) and a decrease in the output gap coefficient (λ_x) can be seen at the same time. Further, the estimated inflation target (t_π) is stable around 2% during the period, which is consistent with the objective of the BoI (3% - 1%), but, importantly, this decreases between 2007 Q3 and 2008 Q4, highlighting a change in monetary policy targets.

Fig. 1 shows that the Calvo (1983) parameter (θ) mean peaks during the Subprime crisis, whereas the other micro-parameters such as the share of working hours (α) in the production process, the inverse Frisch elasticity of labor supply (η), and the elasticity of substitution between individual goods (ε) remain quite stable during the past decade.

Although the relative risk aversion parameter (σ) does not change significantly, the non-separability parameter (ν), which *could* be seen as a measure of the strength of the link between consumption and money in the non-separable utility function (Model 2), increases from 2007 Q4 until 2008 Q4 (Fig. 1). During the Subprime crisis, households strengthened their link between two choices, namely whether to hold money or consume it. This parameter could also capture some of the dynamics of the crisis not captured by the risk aversion parameter alone.

The fact that high risk aversion perceptions occur only during very short periods masks the potential variations of its representative parameter (σ). Thus, compared with the relative risk aversion parameter, the non-separability parameter seems to be a better measure of behavioral changes or crisis perceptions in Model 2.

Fig. 2 shows that most of the macro-parameters sharply change during the Subprime crisis as well as during the Dot-com and Intifada crises, albeit to a lower extent. After the Subprime crisis, the macro-parameters remain stable until the end of the study period. This figure also shows that the weights of money variables on output (κ_{mp} and κ_{sm} decrease) decrease after 2008 Q3, as the weight of the nominal interest rate on money declines during that period.

The link between flexible-price output and the money shock, measured by υ^y_{sm}, also decreases during the crisis and remains stable until the end of the period.

3.3 Simulations

In this section, we compute the impulse response functions and variance decompositions of the estimated models, with respect to the corresponding

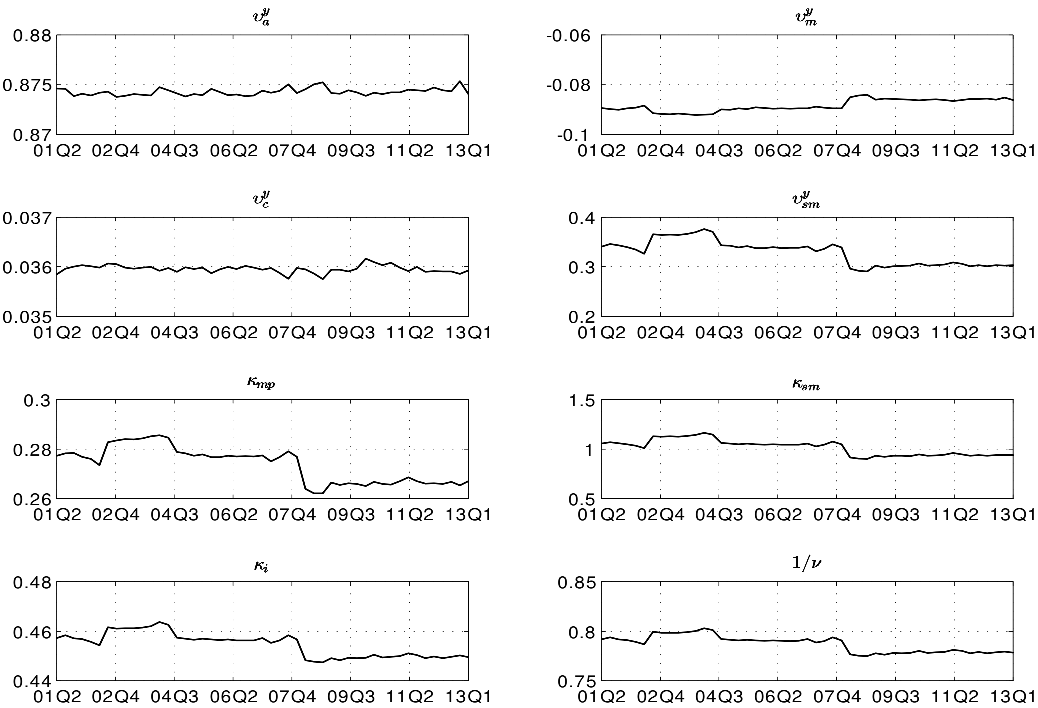

Figure 2: Macro-parameter values during the past decade (Model 2).

date.

3.3.1 Impulse response functions

As we run rolling window estimations, it is interesting to compare the responses of several key variables to the studied shocks over time.[10] Our period of interest (2001 Q2 - 2013 Q1) includes the key dates of the Dot-com crisis and GFC in Israel. Fig. 3 shows the responses of output and inflation to these shocks, Fig. 4 illustrates the responses of the interest rate and real money, and Fig. 5 presents the responses of flexible-price output and flexible-price real money to the technology and real money shocks[11]. The on-impact impulse responses for these two models are provided in the online appendix.

[10] As the results are similar in terms of dynamics over the two models, we do not present the impulse response functions of Model 1. All these results are available upon request.

[11] Because the price markup and interest rate shocks have no relevant impact on flexible-price output and flexible-price real money, we do not present the corresponding impulse response functions.

Figs. 3 to 5 as well as the on-impact impulse responses show that a structural change occurred between 2007 Q3 and 2008 Q4 for the majority of the economic variables. Similarly, another change, less structural in economic terms, occurred between 2002 Q2 and 2004 Q3, the period that corresponded to the Dot-com and Intifada crises.

As shown by Fig. 5, 2003 Q1 and 2008 Q3 are characterized by a local level of risk maximum, and this could have influenced the changes that occurred. Between 2002 Q2 and 2004 Q3, the continuation of the Intifada crisis and contraction of global demand, especially in the high-tech industry, strongly affected the Israeli economy (Bank of Israel, 2003). Moreover, between 2007 Q3 and 2008 Q4, the impact of the beginning of the Subprime mortgage defaults (2007 Q3) and collapse of Lehman Brothers (2008 Q4) in the United States was strong in both developed and developing economies including Israel, contracting global demand and reducing public wealth (Bank of Israel, 2009).

Consequently, the impact of the price markup shock on inflation and on the nominal interest rate sharply reduced compared with the other selected periods, reaching a local minimum around 2008 Q4. Then, from 2008 Q4 to 2013 Q1, the impact of the price markup shock on inflation and on the nominal interest rate increased, while the effect of this shock on real output and real money demand dropped to a local minimum around 2008 Q4. Note, however, that the impact of the price markup shock on inflation was higher during the time when the Dot-com bubble burst around 2001 Q4. Indeed, regardless of the study period, the presented results show that after a positive price markup shock, the inflation rate rises, thereby increasing the nominal interest rate and decreasing the real interest rate, output, the output gap, and real money balances.

The differences between the impulse response functions are more due to the impact responses than to the variations in the AR parameters, which remain approximately stable throughout the study period (Fig. 1). For both models, the AR parameter of the price markup shock ρ_p peaks around 2008 Q2. Note also that the AR parameter of the monetary policy shock ρ_i is assumed to be nil, as in the Israeli DSGE literature (Argov, 2012; Argov et al., 2012). In order not to give the money variable prior strength, we also set the AR parameter of the real money shock ρ_m to zero.

Fig. 3 highlights that in response to a positive technology shock, output increases but inflation decreases, resulting in a rise in real money holdings (Fig. 4) and a slight reduction in the real interest rate and the output gap. The improvement in technology is partly accommodated by the central bank, which lowers the nominal interest rate, while increasing the quantity of money in circulation. However, the responses of our economic variables to

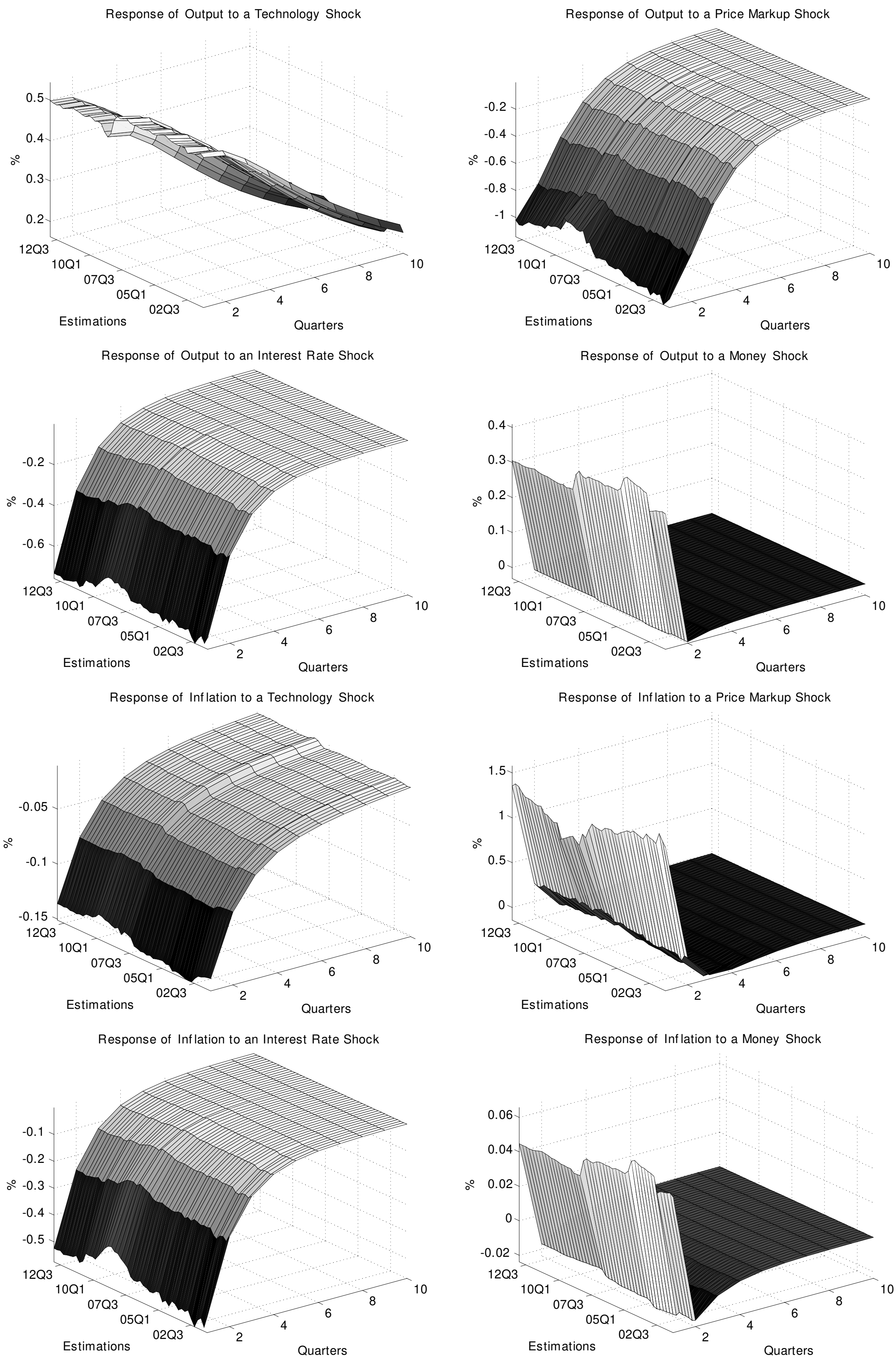

Figure 3: Responses of inflation and output over time to a one percent standard deviation shock (Model 2)

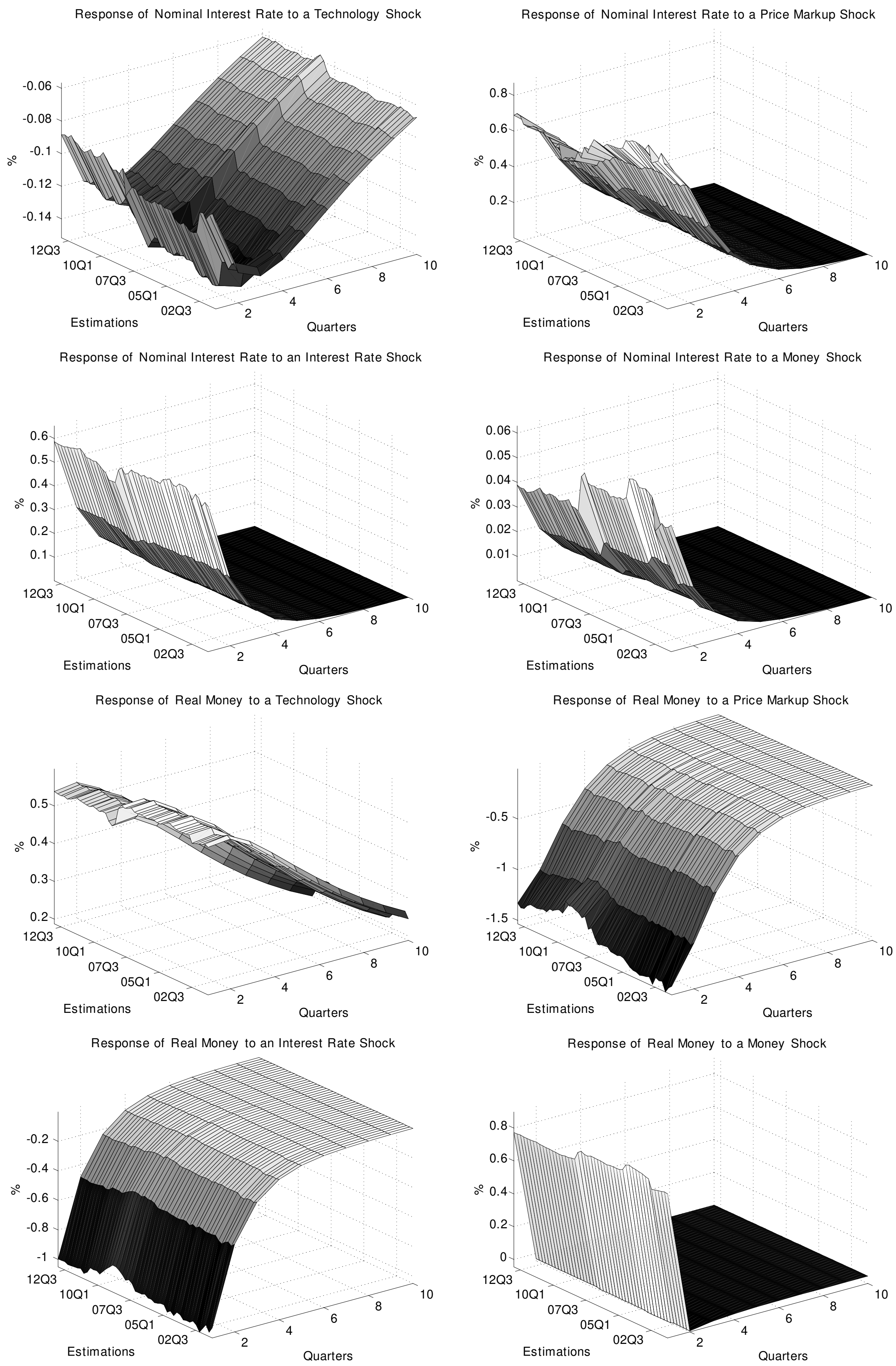

Figure 4: Responses of the nominal interest rate and real money over time to a one percent standard deviation shock (Model 2)

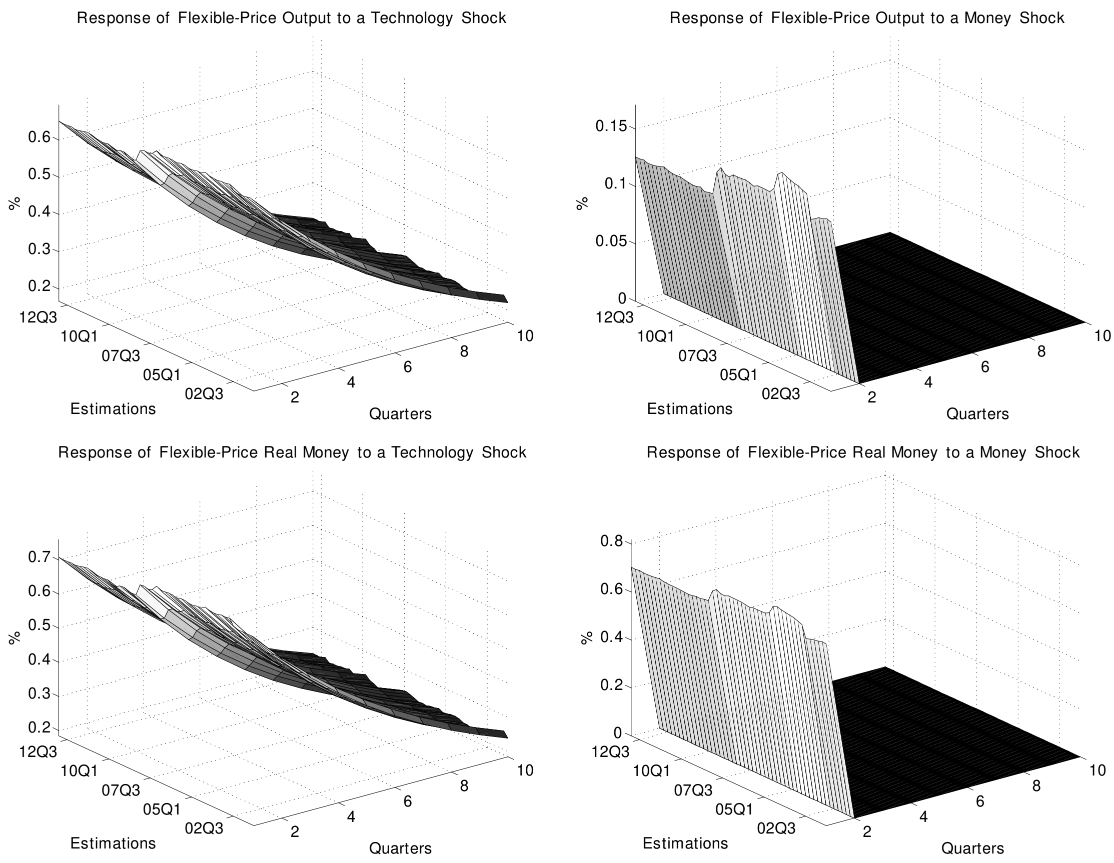

Figure 5: Responses of flexible-price output and flexible-price real money over time to a one percent standard deviation shock (Model 2)

a technology shock change over time: on-impact impulse response functions (see the online appendix) highlight that the impact sensitivity of the macroeconomic variables to a positive technology shock undergoes two important changes throughout the study period, one around 2002 Q4 and the other around 2008 Q1. Interestingly, note that the sensitivity of output and its flexible-price counterpart to a technology shock peaked during the Dot-com and Intifada crises, between 2002 Q1 and 2004 Q2, whereas their minimum sensitivity was observed around the Lehman Brothers collapse in 2008 Q4. This finding is partly explained by the overshooting of an economy affected by risk and uncertainty that had reached its highest level before the collapse of Lehman Brothers.

Fig. 3 indicates that in response to an interest rate shock (i.e., a "conventional" monetary policy shock), the inflation rate, output, the output gap, and real money balances fall (Fig. 4), whereas the nominal and real interest rates rise. Note also that the interest rate shock on inflation, output, and real money demand changes sharply during the study period. For example, the sensitivity of output and inflation to a conventional monetary policy shock reaches its lowest level around the Lehman Brothers collapse; however, this was not the case during the Dot-com and Intifada crises. The level of the sensitivity of output and inflation to the (nominal) interest rate shock is thus an indicator of the effectiveness of conventional monetary policy.

Figs. 3 to 5 also show that after a money demand shock, the nominal and real interest rates, output, and the output gap rise. Moreover, inflation increases slightly then decreases over time to its steady-state value. Interestingly, the responses of inflation, output, and the interest rates during the Dot-com and Intifada crises were more noticeable than those during the other periods. Illustrating this point, in the period after the Subprime crisis and Lehman Brothers collapse, the sensitivity of the examined macroeconomic variables was at its lowest level.

3.3.2 Variance decompositions

In this subsection, we use these estimates in order to describe the evolution of the variance decomposition of our variables over time with respect to these different shocks in the short and long runs and to compare them for both models.[12]

For Model 1, we decompose the forecast error variances for output, inflation, and the interest rate into the components attributable to each of the following three shocks: ε_t^p, ε_t^a, and ε_t^i. For Model 2, we decompose the forecast error variances for output, inflation, money, and the interest rate into the components attributable to each of the following four shocks: ε_t^p, ε_t^a, ε_t^i, and ε_t^m. The solid and dashed lines represent the historical variance decomposition of Models 1 and 2, respectively, with respect to their respective structural shocks.

Fig. 6 shows that the long-run impact of money demand on output is not very significant (less than 3%, except during the crisis peaks). In the short run, it is also low except during the Dot-com, Intifada, and Subprime crisis periods, where it peaks in 2004 Q1 (almost 8%) and in 2007 Q3 (8.3%). These considerations concern only Model 2 (Model 1 does not include money or a money shock).

Fig. 7 illustrates that the short- and long-run influence of the monetary policy shock on output increased from 2007 Q4 in Israel for both models. This result confirms the important role of interest rate shocks for determining output variance. Note, however, that the impulse responses of output to an interest rate shock (Figs. 3) are not related to the variance decompositions of output with respect to this shock (Fig. 7). The first measures the response of a variable to a shock (sensitivity), whereas the second measures the contribution level of a shock to the variance of the variable (role). Nevertheless,

[12] The variance decompositions of the variables under study, at the posterior means of their respective estimations, with respect to the structural shocks, are reported in the online appendix.

irrespective of the considered model, we find that a monetary policy shock affects output variance in line with the findings presented in the literature (Smets and Wouters, 2007).

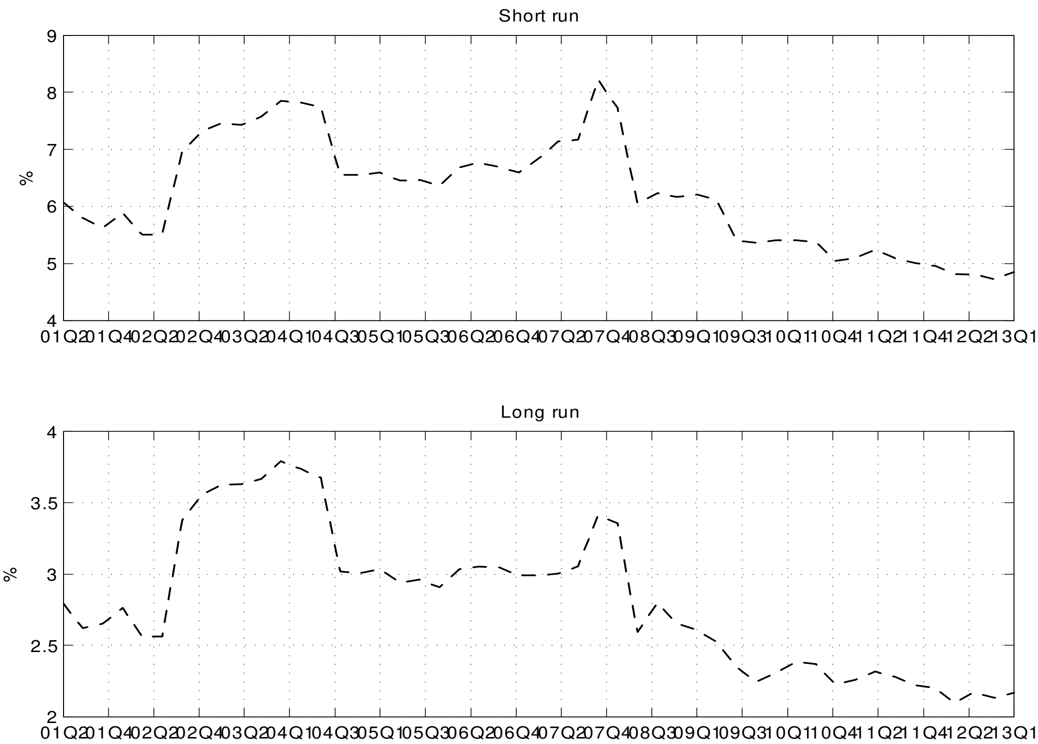

Figure 6: Variance decompositions of output with respect to the money shock for Model 2 (%).

Variance decompositions available in the online appendix shows that during the study period, the influence of monetary policy on inflation and output increases for the two models. They also indicates that technology plays an increasingly important role in the variance of output and inflation until the Subprime crisis and that the price markup shock role reaches its lowest level in explaining inflation and output variances during the Subprime crisis and GFC periods. All these variance decompositions are in line with the findings in the DSGE literature (Smets and Wouters, 2007).

Interestingly, most of these observations are not model-dependent, at least in terms of dynamics. For instance, the impact of monetary policy on output is slightly weakened by the role of money demand on output (Fig. 7). However, the dynamics are the same. Another example is the role of monetary policy on inflation, where Models 1 and 2 are almost undifferentiated.

It is important to note that these estimations and simulations were also carried out by using a preference shock instead of a markup shock, and with an additional ad-hoc (demand) shock to the output equations (see the online appendix), based on European and Israeli data. Whatever specification is used, however, the additional demand shock does not capture whether the behavior of the money demand shock and the role of money demand on our variables during the crisis is always significant and higher than that in other *less risky* periods.

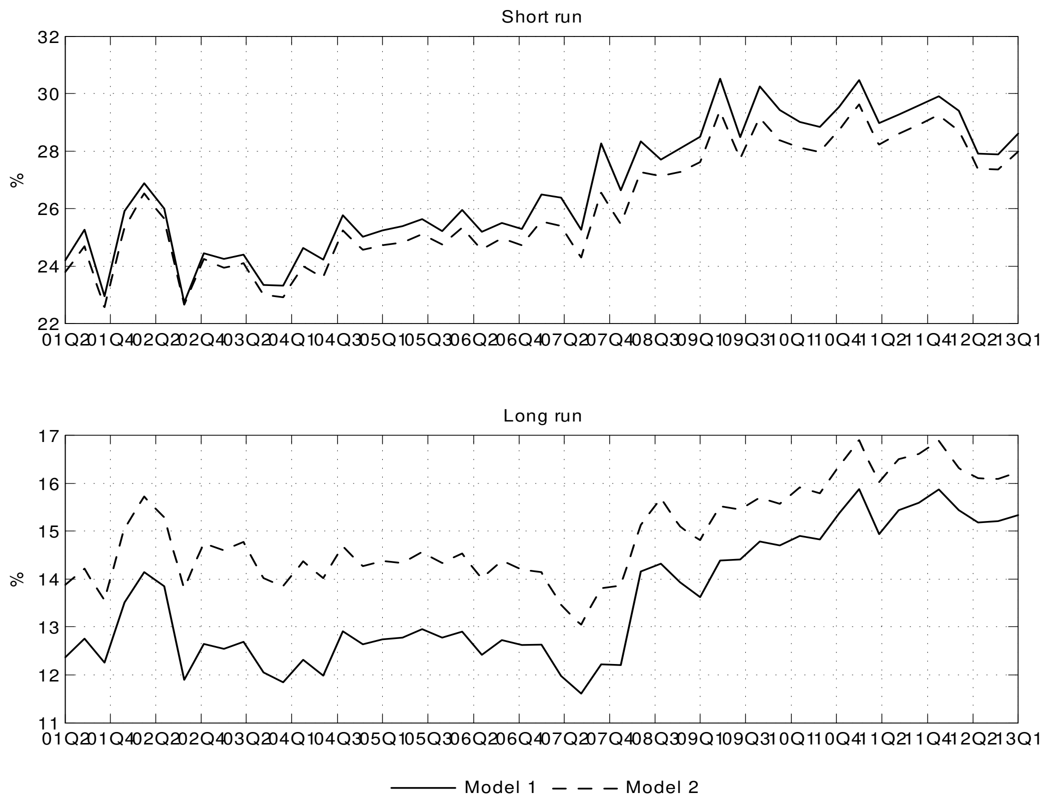

Figure 7: Variance decompositions of output with respect to the monetary policy shock for Models 1 and 2 (%).

Furthermore, Model 2 was also tested by using a money variable in the monetary policy reaction function, i.e. $\lambda_m \neq 0$ (see the online appendix). Even though this specification reinforces the role of money in the economy, the results are similar (see the online appendix for more details).

3.3.3 Comparison of forecasting performance

Finally, we perform out-of-sample DSGE forecasts over four periods (i.e., one year) in order to compare the forecasting performance of both models, after each estimation[13] (Fig. 8). To do so, we simulate our estimated models starting with a given state and analyze the trajectories of the forecasted endogenous variables.

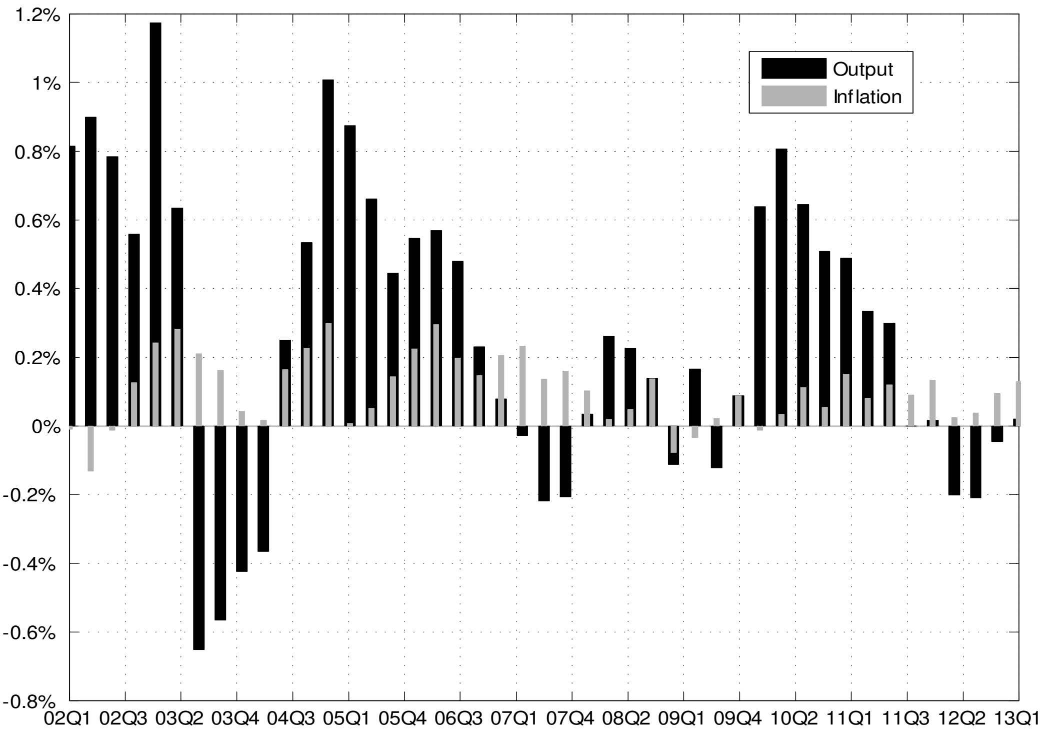

Figure 8: Comparison of output and inflation DSGE forecast errors. Model 2 is better when the bar is positive, Model 1 is better otherwise.

Specifically, from each Bayesian estimation, we simulate the out-of-sample forecasts of output and inflation over the next four periods (one year) and compare these values with the historical values to compute the RMSD of each period for both models (Fig. 8). A negative number (negative bar) implies that the non-separable model's RMSD is higher than that of the baseline model. In that case, the baseline model (Model 1) shows a better forecasting performance than the model with money (Model 2). By contrast, a positive number (positive bar) implies that the non-separable model's RMSD is lower

[13] 98 estimations, 49 for each model.

than that of the baseline model. In such a case, the non-separable model (Model 2) shows a better forecasting performance than the baseline model (Model 1).

This analysis is performed by using Metropolis-Hastings iterations on the basis of the posterior means of each estimated variable. Then, we compare the forecasts with the actual data, before comparing the two models' forecasts by calculating their respective RMSDs. In particular, by summing the corresponding RMSD absolute values for the four out-of-sample forecasts (one year), we compare these values for both models.

Fig. 8 shows that the model with money presents better predictive power for output and inflation dynamics than the baseline model, and that this is the case for most of the study period, proving Model 2 has better predictive power than Model 1 during the past decade in Israel.

4 Interpretation

As in Castelnuovo (2012), who assess money's role in the postwar U.S. business cycle by employing rolling window Bayesian estimations of a structural model of the business cycle with money, we show that money demand has an important impact on the Israeli business cycle during crises.

However, assuming non-separability between money and consumption in the utility function can be seen as a shortcut to capturing the notion of a transaction motive for holding money. In particular, the implied positive relationship between consumption and the marginal utility of money can be interpreted as follows: agents have to make more transactions in the goods market to achieve a higher level of consumption, which makes larger real holdings of the medium of exchange desirable. Accordingly, a structural crisis modifies this transmission mechanism by conferring an important role for money holdings, especially on output dynamics.

A comparison of the impulse responses and variance decompositions during the past decade in Israel allows us to explore this relationship between money, monetary policy, and output (and, to a certain extent, inflation) more in depth in order to investigate the respective roles of several shocks on the Israeli economy.

During the Dot-com and Intifada crises, as well as the Subprime crisis, money played a more significant role on output and flexible-price output dynamics than during non-crisis periods, especially in the short-term. However, while these values must thus be compared with the values presented by previous authors that show that money's role on output is limited and negligible (Ireland, 2004; Andrés et al., 2006, 2009), the impact of money on inflation variability is very small (see all the variance decompositions in the online appendix).

The peak of the role of money demand, which is equal to money supply at equilibrium, on output fluctuations corresponds to the beginning of the Subprime crisis (2007 Q3) and to the foreign exchange purchases made by the BoI (2008 Q1).

Throughout all crisis periods, the short-run impact of monetary policy on output remains high (around 23% to 31%), but its value varies notably more during the Subprime crisis, indicating its greater disruption compared with the other studied periods. The different impacts of the monetary policy shock on output fluctuations in the two models seems to be caused by the presence of the money demand shock, which influences conventional monetary policy's role on output fluctuations in the short run. In the long run, however, this gap between the models decreases, becoming negligible at the end of the study period (for other variance decompositions, see the online appendix).

The short-run impact of monetary policy shocks on inflation variability also remains high before and after each crisis period (10% to 18%), again with larger changes during the Subprime crisis (see all the variance decompositions in the online appendix). Moreover, the long-run impact of the monetary policy shock on inflation fluctuations displays similar dynamics, highlighting the leading role of the central bank in increasing its monetary policy impacts on inflation fluctuations, especially during crises. This finding also concurs with the main objective of the BoI in terms of maintaining the effectiveness of monetary policy, namely influencing the inflation rate.

Ultimately, whatever model is applied, the Subprime crisis led to structural changes in terms of how money and monetary policy affected the fluctuations in output and inflation. The role of the money demand shock is thus important during crises, as indicated by the fact that structural changes in the economy will occur several months before the peak of the crisis. Therefore, comparing this role with a financial risk-related indicator should be useful for assessing the link between risks and the role of money in the economy.

5 Money's role and financial conditions

Michelson and Suhoy (2014) propose the use of a synthetic FCI to track the comovement of financial variables. This FCI, based on 28 variables recorded at different frequencies (daily to quarterly), provides different measures for risk, leverage, and liquidity in the Israeli financial markets, with their state-space model-based methodology close to those of Aruoba et al. (2009) and

Brave and Butters (2012). Fig. 9 compares this FCI with the role of money demand in output fluctuations.

Figure 9: Comparison of the role of money demand on output and the FCI for Israel (Michelson and Suhoy, 2014)

To isolate the financial component, Michelson and Suhoy (2014) adjust these series for the past real cycle and for structural changes in the Israeli economy due to changes in the inflation environment. The index is then extracted by using the Kalman filter and applied to time series that have missing values resulting either from low-frequency data or from non-synchronous updating times. The index is finally scaled in standard deviation units and has a zero mean, corresponding to normal financial conditions, with positive (negative) values indicating tightening (loosening) conditions.

As we theoretically and empirically showed earlier, the respective roles of risk and money holdings on output variance are strongly linked. Thus, comparing an FCI that aggregates several measures of risk as well as the impact of money holdings on output fluctuations should allow us to draw interesting conclusions about correlations and causality properties.

This comparison (see Fig. 9) shows that our results are not only the consequences of financial shocks. During the study period, our indicator, the role of money on output (i.e., the variance decomposition of output with respect to the contribution of money shocks), follows the same dynamics as that presented by Michelson and Suhoy (2014). This finding means that the impact of money on output and thus on the economy is important for *deep*, or more *structural*, crises, confirming that it involves a recession, as demonstrated by the active role of a household's money holdings shocks on output fluctuations.

Castelnuovo (2012) also finds that money's role was important during the 1970s but declined thereafter and that money is important for replicating U.S. output volatility. Moreover, the risk perceptions taken into account by our Model 2 are not only related to financial markets: according to these perceptions, the influence of money demand on output fluctuations indicates that this shock provides a good predictive measure of structural changes such as recession and depression.

In the next step, following Székely et al. (2007), we use the distance correlation in order to analyze linear and non-linear dependency between the FCI, and its bank and debt components, and the role of money on output. We find that the Pearson correlation coefficient is only sensitive to linear relationships between two variables, whereas it can easily be zero for the dependent variables. Because the distance correlation assesses both linear and non-linear relationships between two variables, even non-stationary ones, it is a more complete correlation test than using the Pearson correlation coefficient.

	FCI	Bank	Debt	Forex	Equities	Resid.
Money shock's contribution to output variance	0.299	0.425	0.292	0.336	0.263	0.293

Table 1: Distance correlations between the role of money on output and the FCI and its components

Table 1 shows that our indicator, the contribution of a money shock to output variance (see Fig. 6), is not linearly or non-linearly independent of the FCI or its components. Considering this result, we apply the widely used concept of Granger causality between our indicator and the FCI and its components to ascertain the importance of the interaction between two series. One stationary variable is said to Granger cause another, given an information set, if past information about the former can improve the forecast of the latter based only on its own past information. In other words, the knowledge of one series evolution reduces the forecast errors of the other. The Granger causality test is thus a useful tool to test the predictive power of a variable on another. To achieve stationarity, and because our indicator is not cointegrated with any component of the FCI, we take our variables in differences. The lag selection process for the Granger tests is in line with those used in previous studies.[14]

The presented findings imply that our indicator causes bank and debt components, at 0.89% (F-test: 7.52) and 7.80% (F-test: 3.25), respectively.[15] Our indicator is not caused by the FCI or by one of its components. Consequently, output's variance decomposition with respect to the money shock (our indicator) seems to be a good predictive indicator of bank and debt risks.

6 Policy implications

Our dynamic analysis involves several policy recommendations. First, policy makers have to re-estimate their models at regular intervals in order to monitor parameter changes (Section 3.2). This is crucial to take new information (from the gap between the first and last released data) into account and to examine other simulations and forecasts based on these new estimations (Section 3.3).

For instance, even if a monetary policy committee does not follow its rule-based commitment for the nominal short-term interest rate, small changes

[14] We run an unrestricted VAR of the two considered variables. After checking that our estimated model is dynamically stable (inverse roots of the AR characteristic polynomial diagram), we run a sequential modified likelihood ratio (LR) test (each test at the 5% level) with a lag length criteria of four (quarterly data). The LR test provides the best lag for our Granger causality test between the two variables considered. To conserve space, we have not included the VAR estimation results, the optimal lag-length table, or the inverse roots of the AR characteristic polynomial diagram here. However, these are available upon request.

[15] The lag length is chosen to be one, which is the optimal lag length with respect to the LR lag length criterion. The lag lengths provided by other criteria (Final prediction error, Akaike, Schwarz, and Hannan-Quinn information criteria) also lead to significant Granger causality.

in the model and rule parameters could be relevant to the transmission of a shock across the economy (Section 3.3.2). In this case, a decision-making process based on old estimated parameters could lead to incorrect dynamic and transmission channel perspectives, especially during crisis periods (Kolasa, 2015).

The transmission of shocks changes over time and analyzing these policy tools with out-of-date data and estimated models can mask economic transitions (see the online appendix) and consequently, negatively impact the credibility of policy institutions.

Second, adding money to policy-making models could improve forecasting accuracy, at least during crisis periods. This recommendation is not new in the literature on the Eurozone (Benchimol, 2011; Benchimol and Fourçans, 2016) and US (Caraiani, 2015): adding non-separability between consumption and money to household preferences could improve forecasts. This raises the question of why almost all central bank DSGE models occult money.

The relevance of this question is reinforced by the fact that the DSGE models of central banks have several roles: they allow for communication with the public regarding various topics (forecast, shock transmission, economic explanation, and interpretation). Although DSGE model outputs might not be an easy way through which to communicate policy, they at least represent a good tool for economists to talk about and explore the economic situation. Therefore, by adding money to their models and thus to their communications, they could probably improve or at least complete their communications, forecasts, explanations and interpretations of economic dynamics.

Third, money variables could be good indicators of economic risk (Section 5). Most economic institutions, especially after the last GFC, put forward economic risk detection, its monitoring and management and developed foreign condition indexes.[16] Thus, obtaining more advanced indicators of debt and bank risks could be of great importance. Although our models aim to incorporate the simple perspective of the role of money on the economy, central banks should invest time and energy into developing more elaborated New Keynesian DSGE models that include money in non-separable and more elaborate estimation techniques (such as moving-window and short-sample Bayesian estimation, among others) to detect and monitor risks in their economies.

Changing the research agendas of central banks in line with our previous policy recommendations could lead to more accurate forecasts and risk monitoring as well as better communication, thereby increasing credibility.

[16] See for instance Moccero et al. (2014) for the US and Brave and Butters (2012) for the Eurozone.

Furthermore, money plays a role in economic dynamics. This finding is attributed to the fact that, unlike Eggertsson and Woodford (2003), we do not assume any household money satiation level. This strong assumption, which intends to allow the zero interest rate bound to be reached, is sometimes invoked for the sake of simplicity,[17] although this is not our purpose here (also because the zero bound was not reached during our analysis). Thus, central banks could use this money demand channel to adjust their standard monetary policies (and thus the money supply channel, because at any given time, money demand equals money supply). Although this policy stance is not new, few papers (none of which are about Israel) demonstrate this policy recommendation through such economic modeling by showing that money plays a role in economic dynamics.

7 Conclusion

This study examined the role of money and monetary policy during the past decade in Israel (2001 Q1 to 2013 Q1), with a particular focus on the GFC period and the provision of policy implications. We compared two DSGE models: a baseline model without money (Model 1), as in Galí (2008), and a model with non-separable preferences between household consumption and real money balances (Model 2), as in Benchimol and Fourçans (2012). Both models were tested by using rolling window Bayesian estimations to empirically estimate the variations in the micro- and macro-parameters over time. We also ran simulations to obtain variance decompositions from both models over the study period and to capture the short- and long-run dynamics, which are generally hidden in longer sample ranges. Our analysis shows that output fluctuations are increasingly influenced by money demand shocks during crisis periods. The impact of conventional monetary policy on output and inflation has also been affected during the past, notably increasing at the beginning of the GFC period.

The results presented herein also underscore that the impact of money on output variability diminishes significantly during crisis recovery periods. However, inflation variability does not seem to be affected directly by money variables and is rather mainly explained by monetary policy and price markup shocks in the short and long runs, in line with the findings presented thus far in the literature (Smets and Wouters, 2007; Christoffel et al., 2008).

Finally, the role of a money shock in this kind of rolling window estimation framework, where micro- and macro-parameters are re-estimated over time, can be seen as an advanced indicator of structural changes for the Israeli

[17] See, for instance, note 22 in Poilly (2010).

economy. Our results may thus help inform central banks and policymakers about the importance of money shocks as advanced indicators of *risk* (see Fig. 9). Furthermore, the results highlight the more significant role played by real money balances than generally expected during crises as well as the changing role of monetary policy.

Last, our findings imply that the contribution of money shocks to output variance causes bank and debt risks, confirming the ability of our indicator to provide central banks with relevant information on several kinds of risks.

Despite the presented findings, future researchers might consider comparing these models by using second-order estimations, which, by assigning a more explicit role to relative risk aversion (Benchimol, 2014), could improve our results. In addition, our study is limited by the assumed simplicity of the employed models relative to the assumptions of general DSGE models and New Keynesian approaches (Chari et al., 2009).

Finally, although the conclusions drawn by this study may not be useful for providing quarter-to-quarter quantitative policy advice, looking at the influence of money shocks on the variance in the main economic variables could nonetheless capture important information about economic and financial risks before they occur. The consideration of non-separability between money holdings and consumption should lead to several policy improvements, and updating information (data) in models used for policy implementation, monitoring, and communication should lead to better central bank credibility. Finally, because money plays a role in economic dynamics, we also demonstrate that central banks could use money demand/supply channels to adjust their standard monetary policies.

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