



Essays on monetary policy transmission¹

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INTRODUCTION

This article provides a non-technical summary of five papers that comprise my dissertation. The papers empirically investigate topics like effects of monetary policy on prices, habit formation in consumption, nowcasting the economy, and real-time data properties of macro aggregates, which all can be linked to the monetary policy transmission mechanism, and could be thus of great interest for central bankers.

The first three papers use meta-analysis as a main tool to systematically analyze the empirical literature on the effects of monetary policy transmission mechanism. Meta-analysis methodology was developed in medical research to synthesize costly clinical trials and over time it proliferated to the social sciences, including economics (Stanley & Jarrell, 1989). In contrast to narrative literature surveys, meta-analysis allows for a more structured discussion about the influence that different methods have on the results. To synthesize universe of the empirical estimates of the effect of interest, one cannot simply average the collected estimates as this has two major shortcomings. The meta-analysis provides tools to address these shortcomings, and to come up with the best estimate suggested by the literature as a whole.

First, the simple average ignores possible publication selection. If some results are more likely to get published than others, the average becomes a biased estimator of the underlying impulse response. For this reason, most meta-analyses test – and, if necessary, correct – for so-called publication bias. Brodeur et al. (2016) collect 50,000 p-values reported in economics and document widespread publication bias. Ioannidis et al. (2017) survey meta-analyses conducted in economics and find that most fields suffer from the bias, as editors, referees, or authors themselves prefer statistically significant results that have an intuitive sign.

Second, the simple average ignores heterogeneity in the results of the primary studies. Since different researchers use different data and methods, and the studies are of different quality, it is unrealistic to assume that all estimates are drawn from the same population. Meta-analysis attempts to take these factors into account. In particular, in addition to controlling for publication bias, meta-analysis aims at capturing the role that structural-, data-, estimation-, and publication characteristics might play in the variation of empirical estimates.

The final two papers of the dissertation tackle real-time data properties, and the ability to forecast the current state of the economy in real time. In practice, crucial indicators about the state of the economy – GDP and its components – are measured imperfectly. They are available only after a significant lag, and are often subject to revisions. The fact that important macro aggregates are imprecisely measured has consequences for central bankers who must make decisions that depend vitally on the current state of the economy. The final two papers therefore aim to contribute to understanding of the real-time performance of the state-of-art nowcasting models, as well as the properties and predictability of revisions to the most important macroeconomic aggregates.

HOW TO SOLVE THE PRICE PUZZLE? A META-ANALYSIS

The first paper of the dissertation focuses on the effects of monetary tightening on the price level. It is coauthored with Tomas Havranek and Roman Horvath, and was published in the *Journal of Money, Credit, and Banking* (Rusnák, Havranek & Horvath 2013).

One of the major oddities of vector autoregressions, the most popular framework for the estimation of the effects of monetary policy, is the counterintuitive increase in prices often reported in these models after tightening monetary policy shock. This so-called price puzzle is encountered by about a half of all empirical studies, and in many of them the puzzle is even statistically significant. To investigate the issue, we gather 70 published studies using vector autoregressions to scrutinize the effects of monetary policy on prices.

Employing meta-regression analysis, a quantitative method of research synthesis, we investigate which aspects of methodology systematically contribute to reporting the price puzzle. The meta-regression analysis also shows how the characteristics of the countries examined influence the reported shape of the impulse responses and thus help explain the cross-country heterogeneity in monetary transmission. We evaluate the reported graphs of impulse responses at five time horizons (representing the short, medium, and long run) and for each horizon extract the numerical value of the impulse response. In this way we collect more than 1,000 estimates, 210 on average for each horizon; the estimates summarize evidence from 31 countries and were produced by roughly 100 researchers. We present a method



of research synthesis suitable for graphical results such as impulse responses and employ modern meta-analysis methods to examine the extent of publication selection bias (the preference of authors, editors, or referees for some particular results based on significance or consistency with theory).

Our results suggest some evidence of publication selection against the price puzzle, with the selection appearing to strengthen for responses with longer horizons after monetary contraction. The result is in line with Doucouliagos and Stanley (2008), who suggest that publication selection is likely to be stronger for research areas with less theory competition. In macroeconomics, agreement exists about the effects of monetary policy on prices in the long run: prices should eventually decrease after a monetary policy tightening. On the other hand, a smaller consensus arises regarding the exact effects of monetary policy in the short run because of the uncertainty caused by transmission lags. Published results often exhibit the price puzzle for the short run; on the contrary, results showing the price puzzle for the long run would be difficult to publish.

The results suggest that the reported impulse responses are systematically affected by study design and country-specific characteristics. Study design is important in particular for the short run: the reported short-run increase in prices after a tightening is well explained by the effects of commonly questioned aspects of methodology, such as the omission of commodity prices, the omission of potential output, or the use of Choleski identification. When these aspects of methodology are filtered out, the average impulse-response function inferred from the entire literature becomes hump-shaped with no evidence of the price puzzle.

Based on such "best-practice" impulse response the maximum decrease in prices following a one-percentage-point increase in the interest rate is 0.33% and occurs already half a year after the tightening. Our results suggest that heterogeneity between countries is important for the long-run response of prices to monetary policy action. Structural characteristics such as GDP growth, average inflation, and openness, as well as institutional characteristics such as financial development and central bank independence, determine the strength of transmission.

TRANSMISSION LAGS OF MONETARY POLICY: A META-ANALYSIS

The second paper focuses on transmission lags of monetary policy. It is coauthored with Tomas Havranek and was published in the *International Journal of Central Banking* (Havranek & Rusnak 2013).

Ideally, central bank policymakers would like to know how long it takes before their monetary policy actions fully affect the economy and what determines the delays of transmission. A common claim about the transmission mechanism of

monetary policy is that it has "long and variable" lags (Friedman, 1972; Batini & Nelson, 2001; Goodhart, 2001). This view has been acknowledged by many central banks and taken into account during their decision making: most inflation-targeting central banks have adopted a value between one and two years as their policy horizon (see, for example, Bank of England, 1999; European Central Bank, 2010). Furthermore, theoretical models usually imply transmission lags of similar length (Taylor & Wieland, 2012), nonetheless, the results of empirical studies vary substantially.

We quantitatively survey studies that employ vector autoregression (VAR) methods to investigate the effects of monetary policy shocks on the price level. We refer to the horizon at which the response of prices becomes the strongest as the transmission lag, and collect almost 200 estimates from 67 published studies. The estimates of transmission lags in our sample are indeed variable, and we analyze the sources of this variation. The meta-analysis approach allows us to investigate both how transmission lags differ across countries and how different estimation methodological aspects of the VAR modelling affect the results. By synthesizing evidence from a large number of studies that use different methods, meta-analysis can extract robust results from a heterogeneous literature.

Several researchers have previously investigated the cross-country differences in monetary transmission. These papers typically look at a small set of countries at a specific point in time; in contrast, we collect estimates of transmission lags from a vast literature that provides evidence for 30 different economies during several decades. Moreover, while some of the previous studies seek to explain the differences in the strength of transmission, they remain silent about the factors driving transmission speed.

Against this background, we aim to fill this gap and associate the differences in transmission lags with a number of country and study characteristics. Our results suggest that the transmission lags reported in the literature do vary substantially: the average lag, adjusted for misspecification in some studies, is around two and half years, with a standard deviation of year and a half. Advanced economies in our sample exhibit significantly slower transmission than other economies, and the only robust country-specific determinant of the speed of transmission is the degree of financial development. In developed countries financial institutions have more opportunities to hedge against surprises in monetary policy stance, causing slower pass through of monetary policy shocks. Among the variables that describe the methods used by primary studies, the frequency of the data used to in estimation seem matter systematically for the estimated transmission lags. Our results suggest that estimates based on monthly data instead of quarterly data are more likely to report systematically shorter transmission lags.



HABIT FORMATION IN CONSUMPTION: A META-ANALYSIS

The third paper of the dissertation focuses on habit formation in consumption. It is coauthored with Tomas Havranek and Anna Sokolova and was published in the *European Economic Review* (Havranek, Rusnak, Sokolova, 2017).

The concept of habit formation in consumption is crucial for the explanation of various stylized facts in macroeconomics and finance. Habit formation in consumption is also a key ingredient of the contemporaneous structural models used by central banks to analyze the effects of different policy measures. As shown by Fuhrer (2000), the observed inflation dynamics are consistent with a large habit formation coefficient. Moreover, habit formation helps explain various empirical stylized facts: the risk-free rate puzzle (Campbell and Cochrane, 1999), the equity premium puzzle (Abel, 1990), and the happiness puzzle (Choudhary et al., 2012). Habits in consumption can assume two forms: internal and external. Internal habit formation arises when a consumer becomes accustomed to a certain level of consumption, comparing current consumption with consumption in the previous period. In other words, the consumer's utility is no longer a function of current consumption, but one of consumption growth, with past consumption reducing present utility: more food today makes the consumer hungrier tomorrow. In contrast, external habit formation describes "keeping up with the Joneses": the consumer's utility depends on the difference between her consumption and the consumption of a reference group (such as people in the town where she lives).

Our approach does not enable us to explain variation in the true degree of habit formation; instead, our goal is to explain differences in its estimates reported in previous studies. One obstacle that we encounter is the uncertainty over which of the 31 study characteristics should be included in the model approximating the process that generates habit estimates. To address this problem we employ Bayesian model averaging (BMA; Raftery et al., 1997; Moral-Benito, 2015) – a method that estimates many regressions consisting of subsets of the potential explanatory variables and weights them by model fit and model complexity. As a robustness check we use frequentist model averaging, which does not rely on Bayesian methods.

Our results show that the difference between micro estimates (e.g. Dynan, 2000) and macro estimates (e.g. Fuhrer, 2000) remains substantial even after controlling for other aspects of study design. This finding reverberates with the results of Chetty et al. (2011), who report similar divergence between micro and macro estimates in the literature estimating the intertemporal elasticity of labor supply. Furthermore, we find that the frequency of the data used in the estimation matters: estimates from studies employing monthly data tend to be substantially smaller than those

obtained with lower frequencies, with the largest estimates being associated with the use of annual data. Further results suggest that the use of second-order approximation of the Euler equation results in smaller estimates, which could imply the importance of accounting for the precautionary saving motive when estimating habit formation. Estimates based on US data tend to be larger than those reported for Japan, Europe, and other regions. In addition, our results suggest that among the DSGE studies the ones that rely on the open-economy framework typically require higher degrees of habit formation to match the dynamics of the observables.

By contrast, we find that studies using the moments of asset returns do not report estimates that differ systematically from those obtained without the use of stock market data. In a similar vein, given the features of the data employed by the particular study, the use of the DSGE methodology itself does not result in estimates that are systematically different from those obtained by other methods. This finding suggests that reproducing empirical moments of the data within structural models requires roughly the same degree of habit formation as what would typically arise from reduced-form estimation with similar data sets.

We do not find evidence of systematic differences between the estimated magnitude of external habits and internal habits when other data and method characteristics are controlled for. The result is in line with Dennis (2009), who shows that the distinction between internal and external habits has a limited effect on the business cycle characteristics of New Keynesian models, and Kano & Nason (2014), who show that there is observational equivalence between external and internal specifications for log-linear approximation of the Euler equation under additive habits. Furthermore, we find that estimates of habits formed at the level of individual goods do not systematically differ from those of habits formed over the whole consumption bundle. In addition, studies using total non-durable consumption, food expenditures, or measures that include durable consumption come up with estimates that are roughly the same. Nonetheless, we find that the use of simple panel techniques that do not rely on instrumental variables has a systematic effect on the results. Finally, we also observe a correlation between the reported estimates and the characteristics of the journal where the study is published.

NOWCASTING CZECH GDP IN REAL TIME

In the fourth paper, we evaluate the performance of the dynamic factor model when applied to nowcasting Czech GDP, using historical vintages of real-time data. The paper was published in *Economic Modelling* (Rusnak, 2016).

Because of sizeable publication delays in the release of new data on gross domestic product (GDP), timely estimates of current-quarter GDP



(so-called nowcasts) are crucial for policymakers assessing the state of the economy in real time. Obtaining these nowcasts is not straightforward because of the peculiar structure of real-time data, which is characterized by unbalanced datasets at the end of the sample, data sampled at different frequencies, and substantial data revisions. The nowcasting framework of Giannone et al. (2008) can deal with these real-time issues by casting a dynamic factor model in a state-space framework. In addition to the ability of the framework to deal with unbalanced datasets and mixed frequencies, it can utilize a potentially large set of variables by summarizing macroeconomic comovements by a few common factors. In the fourth paper, we evaluate the performance of the dynamic factor model (DFM) when applied to nowcasting Czech GDP over the 2005–2012 period, using multiple vintages of real-time data. The model utilizes 28 headline macroeconomic variables. In addition to so-called hard data covering the production, sales, labor, and trade sectors of the economy, we include a handful of financial variables and confidence indicators. Furthermore, we add several foreign variables to account for the fact that the Czech Republic is a small open economy.

Our results suggest that the nowcasting performance of the medium-scale DFM is comparable to the official nowcasts of the Czech National Bank (CNB). In addition, we find that the simple average of the DFM and CNB nowcasts is more accurate than the nowcasts of the DFM and the CNB alone. We also find that the DFM nowcasts add value to the CNB nowcasts: conditional on the CNB nowcast, on average, GDP growth turns out to be higher when the DFM nowcast is higher. Similarly to D'Agostino & Giannone (2012) we find that the relative performance of the DFM is better at times of crisis, which are characterized by large comovements of variables. We also find that the inclusion of foreign variables is crucial: if we exclude foreign variables the performance worsens significantly, while the omission of financial variables or surveys does not result in a dramatic deterioration of the forecasting accuracy.

REVISIONS TO CZECH NATIONAL ACCOUNTS: PROPERTIES AND PREDICTABILITY

In the fifth paper, we provide stylized facts about the magnitude of revisions to the Czech national accounts. The paper is published in the *Czech Journal of Economics and Finance* (Rusnak 2013).

If data are often revised, a natural question arises of how much weight policymakers should put on the initial data releases. The pursuit of optimal policy might be compromised by an over-reaction to current data (Orphanides, 2003; Kugler et al., 2005). Indeed, policymakers regularly discuss the expected revisions to the new data in their monetary policy deliberations.

The importance of using real-time data is already well recognized in the literature on forecasting and monetary policy analysis (Robertson

& Tallman, 1998; Croushore & Stark, 2001; Croushore, 2011). Against this backdrop, several real-time databases are established (Croushore & Stark, 2001; McKenzie, 2006; Fernandez et al., 2011; Giannone et al., 2012). An increasing number of papers point out that many results obtained using revised data are sensitive to real-time data issues (Swanson & White, 1997; Amato & Swanson, 2001; Orphanides, 2001; Orphanides & van Norden, 2002; Christoffersen et al., 2002; Molodtsova et al., 2008).

The reasons why statistical offices perform revisions are discussed in McKenzie (2006). Mankiw et al. (1984) propose that the revision process might be characterized as either reflecting measurement error (revisions are then referred to as noise) or reflecting new information (revisions are referred to as news). If revisions are noise, the first release of a variable is an imperfect measure of the true variable. One is therefore able to make use of other information available at the time of the release to produce better forecast of the true value. The optimal forecast of the true value is then a weighted average of the first release value and the conditional mean of other observable data. For example, we can use the mean of the underlying variable itself (in such cases the optimal forecast of future revisions is related to the deviation of the value of the first release from the mean of the underlying variable). The larger is the variance of the measurement error, the smaller weight should be attributed to the first release observation.

If revisions contain news, they are not predictable using the information available at the time of first release. Therefore, it is optimal to put a weight of one to the value of first release and a weight of zero to other observable data. In other words, the optimal forecast of future revisions is zero. When revisions are news, the first releases are often referred to as rational or efficient forecasts of the true value of a variable.

The evidence about the properties of Czech real-time data is very scarce. The main objective of the fifth paper is to fill this void, to enhance our understanding about the size and the properties of revisions to Czech national accounts. We gather real-time vintages of Czech GDP and its components over 2003–2012 and provide evidence about their statistical properties. Moreover, in line with the above mentioned literature, we test whether the revisions to Czech national accounts can be viewed as noise or news. We therefore investigate the predictability of revisions both in-sample and in a real-time out-of-sample exercise.

Our results suggest that the revisions to real GDP and its components are largely unbiased, with the exception of a positive bias in short-term revisions to annual growth rates of exports and imports. Revisions to GDP deflator, on the other hand, are biased downward for both quarterly and annual growth rates. The revisions are rather large: the mean absolute revision to annualized quarterly GDP growth is roughly 1.4 percentage



points and roughly 0.7 for annual growth rate. Revisions for other variables are even larger. Judging by the size of revisions relative to the size of the original variables, the largest relative revisions seem to occur in consumption and gross fixed capital formation. On the other hand, exports and imports have smallest noise to signal ratio from all of the main components of GDP. Next, we find that revisions for GDP are predictable in-sample and thus the first releases cannot be characterized as news. In addition to in-sample evidence,

we also investigate whether the revisions are predictable in a real-time out-of-sample exercise. We find evidence of out-of-sample predictability for the revisions of GDP deflator, and to a lesser extent to consumption and year-on-year growth rates of exports and imports, while for other variables zero revision forecasts seems to perform better in the real-time exercises. The results from the real-time exercise should be, however, viewed with caution since the out-of-sample period is very small and covers the recent crisis period.

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