Transmission Lags of Monetary Policy: A Meta-Analysis*

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Abstract

The transmission of monetary policy to the economy is generally thought to have long and variable lags. In this paper we quantitatively review the modern literature on monetary transmission to provide stylized facts on the average lag length and the sources of variability. We collect 67 published studies and examine when prices bottom out after a monetary contraction. The average transmission lag is 29 months, and the maximum decrease in prices reaches 0.9% on average after a one-percentage-point hike in the policy rate. Transmission lags are longer in developed economies (25–50 months) than in post-transition economies (10–20 months). We find that the factor most effective in explaining this heterogeneity is financial development: greater financial development is associated with slower transmission.

Keywords: Monetary policy transmission, vector autoregressions, meta-analysis

JEL Codes: C83, E52

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1 Introduction

Policymakers need to know how long it takes before their actions fully transmit to the economy and what determines the speed 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 embraced by many central banks and taken into account during their decision making: most inflation-targeting central banks have adopted a value between 12 and 24 months as their policy horizon (see, for example, Bank of England, 1999; European Central Bank, 2010). Theoretical models usually imply transmission lags of similar length (Taylor & Wieland, 2012), but the results of empirical studies vary widely.

In this paper 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 198 estimates from 67 published studies. The estimates of transmission lags in our sample are indeed variable, and we examine the sources of variability. The meta-analysis approach allows us to investigate both how transmission lags differ across countries and how different estimation methodologies within the VAR framework affect the results. Meta-analysis is a set of tools for summarizing the existing empirical evidence; it has been regularly employed in medical research, but its application has only recently spread to the social sciences, including economics (Stanley, 2001; Disdier & Head, 2008; Card *et al.*, 2010; Havranek & Irsova, 2011). By bringing together 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. Ehrmann (2000) examines 13 member countries of the European Union and finds relatively fast transmission to prices for most of the countries: between 2 and 8 quarters. Only France, Italy, and the United Kingdom exhibit transmission lags between 12 and 20 quarters. In contrast, Mojon & Peersman (2003) find that the effects of monetary policy shocks in European economies are much more delayed, with the maximum reaction occurring between 16 and 20 quarters after the shock. Concerning cross-country differences, Mojon & Peersman (2003) argue that the confidence intervals are too wide to draw any strong conclusions, but they call for further testing of the heterogeneity of impulse responses. Boivin *et al.* (2008) update the results and conclude that the adoption of the euro contributed to lower heterogeneity in monetary transmission among the member countries.

Cecchetti (1999) finds that for a sample of advanced countries transmission lags vary between 1 and 12 quarters. He links the country-specific strength of monetary policy to a number of indicators of financial structure, but does not attempt to explain the variation in transmission lags. In a similar vein, Elbourne & de Haan (2006) investigate 10 new EU member countries and find that the maximum effects of monetary policy shocks on prices occur between 1 and 10 quarters after the shock. 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.

In this paper we attempt 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 really do vary substantially: the average lag, corrected for misspecification in some studies, is 29 months, with a standard deviation of 19 months. Post-transition economies in our sample exhibit significantly faster transmission than advanced economies, and the only robust country-specific determinant of the length 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 greater delays in the transmission of monetary policy shocks. Concerning variables that describe the methods used by primary studies, the frequency of the data employed matters for the reported transmission lags. Our results suggest that researchers who use monthly data instead of quarterly data report systematically faster transmission.

The remainder of the paper is structured as follows. Section 2 presents descriptive evidence concerning the differences in transmission lags. Section 3 links the variation in transmission lags to 33 country- and study-specific variables. Section 4 contains robustness checks. Section 5 summarizes the implications of our key results.

2 Estimating the Average Lag

We attempt to gather all published studies on monetary transmission that fulfill the following three inclusion criteria. First, the study must present an impulse response of the price level to a shock in the policy rate (that is, we exclude impulse responses of the inflation rate). Second, the impulse response in the study must correspond to a one-percentage-point shock in the interest rate, or the size of the monetary policy shock must be presented so that we can normalize the response. Third, we only include studies that present confidence intervals around the impulse responses—as a simple indicator of quality. The primary studies fulfilling the inclusion criteria are listed in Table 1. More details describing the search strategy can be found in a related paper (Rusnak *et al.*, 2012), examining which method choices are associated with reporting the "price puzzle" (the short-term increase in the price level following a monetary contraction).

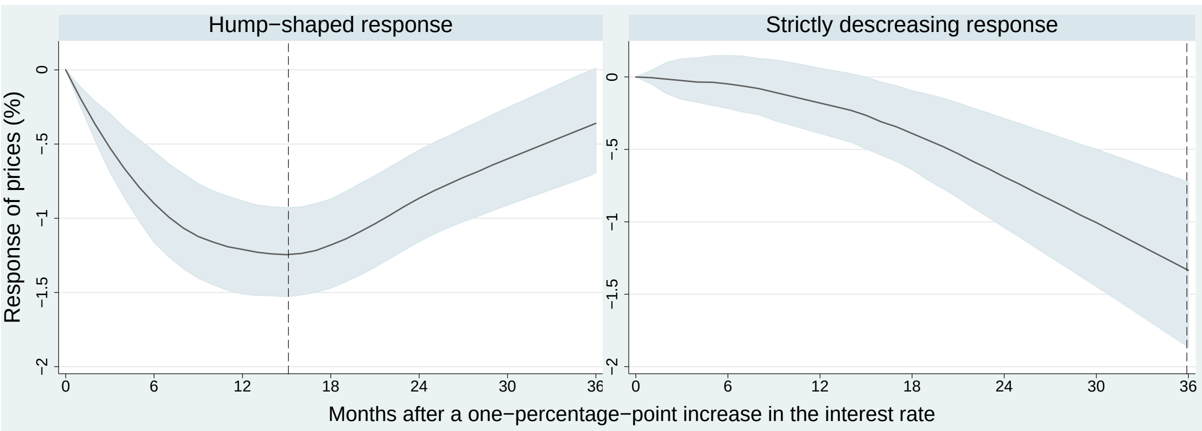
After imposition of the inclusion criteria, our database contains 198 impulse responses taken from 67 previously published studies and provides evidence on the monetary transmission mechanism for 30 countries, mostly developed and post-transition economies. The database is available in the online appendix. For each impulse response we evaluate the horizon at which the decrease in prices following the monetary contraction reaches its maximum. The literature reports two general types of impulse responses, both of which are depicted in Figure 1. The left-hand panel shows a hump-shaped (also called U-shaped) impulse response: prices decrease and bounce back after some time following a monetary policy shock; the monetary contraction stabilizes prices at a lower level or the effect gradually dies out. The dashed line denotes the maximum effect, and we label the corresponding number of months passed since the monetary

Table 1: List of primary studies

Andries (2008)	Eickmeier *et al.* (2009)	Mertens (2008)
Anzuini & Levy (2007)	Elbourne (2008)	Minella (2003)
Arin & Jolly (2005)	Elbourne & de Haan (2006)	Mojon (2008)
Bagliano & Favero (1998)	Elbourne & de Haan (2009)	Mojon & Peersman (2001)
Bagliano & Favero (1999)	Forni & Gambetti (2010)	Mountford (2005)
Banbura *et al.* (2010)	Fujiwara (2004)	Nakashima (2006)
Belviso & Milani (2006)	Gan & Soon (2003)	Normandin & Phaneuf (2004)
Bernanke *et al.* (1997)	Hanson (2004)	Oros & Romocea-Turcu (2009)
Bernanke *et al.* (2005)	Horvath & Rusnak (2009)	Peersman (2004)
Boivin & Giannoni (2007)	Hulsewig *et al.* (2006)	Peersman (2005)
Borys *et al.* (2009)	Jang & Ogaki (2004)	Peersman & Smets (2001)
Bredin & O'Reilly (2004)	Jarocinski (2009)	Peersman & Straub (2009)
Brissimis & Magginas (2006)	Jarocinski & Smets (2008)	Pobre (2003)
Brunner (2000)	Kim (2001)	Rafiq & Mallick (2008)
Buckle *et al.* (2007)	Kim (2002)	Romer & Romer (2004)
Cespedes *et al.* (2008)	Krusec (2010)	Shioji (2000)
Christiano *et al.* (1996)	Kubo (2008)	Sims & Zha (1998)
Christiano *et al.* (1999)	Lagana & Mountford (2005)	Smets (1997)
Cushman & Zha (1997)	Lange (2010)	Sousa & Zaghini (2008)
De Arcangelis & Di Giorgio (2001)	Leeper *et al.* (1996)	Vargas-Silva (2008)
Dedola & Lippi (2005)	Li *et al.* (2010)	Voss & Willard (2009)
EFN (2004)	McMillin (2001)	Wu (2003)
Eichenbaum (1992)		

Notes: The search for primary studies was terminated on September 15, 2010. A list of excluded studies, with reasons for exclusion, is available in the online appendix.

Figure 1: Stylized impulse responses



Notes: The figure depicts stylized examples of the price level's response to a one-percentage-point increase in the policy rate. The dashed lines denote the number of months to the maximum decrease in prices.

contraction as the transmission lag. In contrast, the right-hand panel shows a strictly decreasing impulse response: prices neither stabilize nor bounce back within the time frame reported by the authors (impulse response functions are usually constructed for a five-year horizon). In this case the response of the price level becomes the strongest in the last reported horizon, so we label the last horizon as the transmission lag.

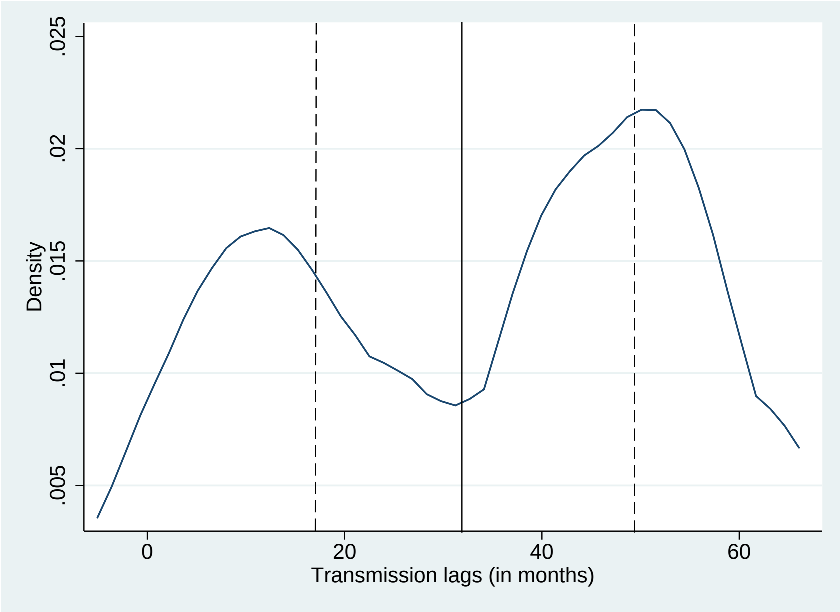
Researchers often discuss the number of months to the maximum decrease in prices in the case of hump-shaped impulse responses. On the other hand, researchers rarely interpret the timing of the maximum decrease in prices for strictly decreasing impulse responses, as the implied transmission lag often seems implausibly long. Moreover, a strictly decreasing response may indicate nonstationarity of the estimated VAR system (Lütkepohl, 2005). Nevertheless we do not limit our analysis to hump-shaped impulse responses since both types are commonly reported: in the data set we have 100 estimates of transmission lags taken from hump-shaped impulse responses and 98 estimates taken from strictly decreasing impulse responses. We do not prefer any particular shape of the impulse response and focus on inference concerning the average transmission lag, but we additionally report results corresponding solely to hump-shaped impulse responses.

Figure 2 depicts the kernel density plot of the collected estimates; the figure demonstrates that the transmission lags taken from hump-shaped impulse responses are, on average, substantially shorter than the lags taken from strictly decreasing impulse response functions. Numerical details on summary statistics are reported in Table 2. The average of all collected transmission lags is 33.5 months, but the average reaches 49.1 months for transmission lags taken from strictly decreasing impulse responses and 18.2 months for hump-shaped impulse responses. In other words, the decrease in prices following a monetary contraction becomes the strongest, on average, after two years and three quarters. Our data also suggest that the average magnitude of the maximum decrease in prices following a one-percentage-point increase in the policy rate is 0.9% (for a detailed meta-analysis of the strength of monetary transmission at different horizons, see Rusnak *et al.*, 2012).

The average of 33.5 is constructed based on data for 30 different countries. To investigate whether transmission lags vary across countries, we report country-specific averages in Table 3 (we only show results for countries for which we have collected at least five observations from the literature). We divide the countries into two groups: developed economies and post-transition economies.[1] From the table it is apparent that developed countries display much longer transmission lags than post-transition countries. The developed country with the fastest transmission of monetary policy actions is Italy: the corresponding transmission lag reaches 26.6 months. The slowest transmission is found for Japan and France, with a transmission lag equal to 51.3 months. In general, the transmission lags for developed countries seem to vary between approximately 25 and 50 months. These values sharply contrast with the results for post-transition

[1]The definition of the two groups is somewhat problematic. The Czech Republic, for example, has been considered a developed economy by the World Bank since 2006. We include the country into the second group because pre-2006 time series constitute the bulk of the data used by studies in our sample.

Figure 2: Kernel density of the estimated transmission lags



Notes: The figure is constructed using the Epanechnikov kernel function. The solid vertical line denotes the average number of months to the maximum decrease in prices taken from all the impulse responses. The dashed line on the left denotes the average taken from the hump-shaped impulse responses. The dashed line on the right denotes the average taken from the strictly decreasing impulse response functions.

Table 2: Summary statistics of the estimated transmission lags

Variable	Observations	Mean	Median	Std. dev.	Min	Max
Estimates from all impulse responses	198	33.5	37	19.4	1	60
Hump-shaped impulse responses	100	18.2	15	14.1	1	57
Strictly decreasing impulse responses	98	49.1	48	8.6	24	60

Table 3: Transmission lags differ across countries

Developed economies		Post-transition economies	
Economy	Average transmission lag	Economy	Average transmission lag
United States	42.2	Poland	18.7
Euro area	48.4	Czech Republic	14.8
Japan	51.3	Hungary	17.9
Germany	33.4	Slovakia	10.7
United Kingdom	40.4	Slovenia	17.6
France	51.3		
Italy	26.6		

Notes: The table shows the average number of months to the maximum decrease in prices taken from all the impulse responses reported for the corresponding country. We only show results for countries for which the literature has reported at least five impulse responses.

countries, where all reported transmission lags lie between 10 and 20 months. The result is in line with Jarocinski (2010), who investigates cross-country differences in transmission and finds that post-communist economies exhibit faster transmission than Western European countries. We examine the possible sources of the cross-country heterogeneity in the next section.

3 Explaining the Differences

Two general reasons may explain why the reported transmission lags vary: First, structural differences across countries may cause genuine differences in the speed of transmission. Second, characteristics of the data and other aspects of the methodology employed in the primary studies, such as specification and estimation characteristics, may have a systematic influence on the reported transmission lag.

We collected 33 potential explanatory variables. Several structural characteristics that may account for cross-country differences in the monetary transmission mechanism have been suggested in the literature (Dornbusch *et al.*, 1998; Cecchetti, 1999; Ehrmann *et al.*, 2003). Therefore, to control for these structural differences we include *GDP per capita* to represent the country's overall level of the development, *GDP growth* and *Inflation* to reflect other macroeconomic conditions in the economy, *Financial development* to capture the importance of the financial structure, *Openness* to cover the exchange rate channel of the transmission mechanism, and *Central bank independence* to capture the influence of the institutional setting and credibility on monetary transmission. These variables are computed as averages over the periods that correspond to the estimation periods of the primary studies. The sources of the data for these variables are Penn World Tables, the World Bank's World Development Indicators, and the International Monetary Fund's International Financial Statistics; the central bank independence index is extracted from Arnone *et al.* (2009). We also include variables that control for data, methodology, and publication characteristics of the primary studies. The definitions of the variables are provided in Table 4 together with their summary statistics.

Rather than estimating a regression with an ad hoc subset of explanatory variables, we formally address the model uncertainty inherent in meta-analysis (in other words, many method variables may be important for the reported speed of transmission, but no theory helps us select which ones). There are at least two drawbacks to using simple regression in situations where many potential explanatory variables exist. First, if we put all potential variables into one regression, the standard errors get inflated since many redundant variables are included. Second, sequential testing (or the "general-to-specific" approach) brings about the possibility of excluding relevant variables.

To address these issues, Bayesian model averaging (BMA) is employed frequently in the literature on the determinants of economic growth (Fernandez *et al.*, 2001; Sala-I-Martin *et al.*, 2004; Durlauf *et al.*, 2008; Feldkircher & Zeugner, 2009; Eicher *et al.*, 2011). Recently, BMA has been used to address other questions as well (see Moral-Benito, 2011, for a survey). The idea of BMA is to go through all possible combinations of regressors and weight them according to their model fit. BMA thus provides results robust to model uncertainty, which arises when little or nothing is known ex ante about the correct set of explanatory variables. An accessible introduction to BMA can be found in Koop (2003); technical details concerning the implementation of the method are provided by Feldkircher & Zeugner (2009).

Because we consider 33 potential explanatory variables, it is not technically feasible to enumerate all 2^{33} of their possible combinations; on a typical personal computer this would take several months. In such cases, Markov chain Monte Carlo methods are used to go through the most important models. We employ the priors suggested by Eicher *et al.* (2011), who recommend using the uniform model prior and the unit information prior for the parameters, since these priors perform well in forecasting exercises. Following Fernandez *et al.* (2001), we run the estimation with 200 million iterations, ensuring a good degree of convergence. Appendix A provides diagnostics of our BMA estimation; the online appendix provides R and Stata codes.

Table 4: Description and summary statistics of explanatory variables

Variable	Description	Mean	Std. dev.
Country characteristics			
GDP per capita	The logarithm of the country's real GDP per capita.	9.880	0.415
GDP growth	The average growth rate of the country's real GDP.	2.644	1.042
Inflation	The average inflation of the country.	0.078	0.145
Financial dev.	The financial development of the country measured by (domestic credit to private sector)/GDP.	0.835	0.408
Openness	The trade openness of the country measured by (exports + imports)/GDP.	0.452	0.397
CB independence	A measure of central bank independence (Arnone *et al.*, 2009).	0.773	0.145
Data characteristics			
Monthly	=1 if monthly data are used.	0.626	0.485
No. of observations	The logarithm of the number of observations used.	4.876	0.661
Average year	The average year of the data used (2000 as a base).	-9.053	7.779
Specification characteristics			
GDP deflator	=1 if the GDP deflator is used instead of the consumer price index as a measure of prices.	0.172	0.378
Single regime	=1 if the VAR is estimated over a period of a single monetary policy regime.	0.293	0.456
No. of lags	The number of lags in the model, normalized by frequency: lags/frequency	0.614	0.373
Commodity prices	=1 if a commodity price index is included.	0.626	0.485
Money	=1 if a monetary aggregate is included.	0.545	0.499
Foreign variables	=1 if at least one foreign variable is included.	0.444	0.498
Time trend	=1 if a time trend is included.	0.131	0.339
Seasonal	=1 if seasonal dummies are included.	0.146	0.354
No. of variables	The logarithm of the number of endogenous variables included in the VAR.	1.748	0.391
Industrial prod.	=1 if industrial production is used as a measure of economic activity.	0.429	0.496
Output gap	=1 if the output gap is used as a measure of economic activity.	0.030	0.172
Other measures	=1 if another measure of economic activity is used (employment, expenditures).	0.121	0.327
Estimation characteristics			
BVAR	=1 if a Bayesian VAR is estimated.	0.121	0.327
FAVAR	=1 if a factor-augmented VAR is estimated.	0.051	0.220
SVAR	=1 if non-recursive identification is employed.	0.313	0.465
Sign restrictions	=1 if sign restrictions are employed.	0.152	0.359
Publication characteristics			
Strictly decreasing	The reported impulse response function is strictly decreasing (that is, it shows the maximum decrease in prices in the last displayed horizon).	0.495	0.501
Price puzzle	The reported impulse response exhibits the price puzzle.	0.530	0.500
Study citations	The logarithm of [(Google Scholar citations of the study)/(age of the study) + 1].	1.875	1.292
Impact	The recursive RePEc impact factor of the outlet.	0.900	2.417
Central banker	=1 if at least one co-author is affiliated with a central bank.	0.424	0.495
Policymaker	=1 if at least one co-author is affiliated with a Ministry of Finance, IMF, OECD, or BIS.	0.061	0.239
Native	=1 if at least one co-author is native to the investigated country.	0.449	0.499
Publication year	The year of publication (2000 as a base).	4.894	3.889

Notes: The sources of data for country characteristics are Penn World Tables, the World Bank's World Development Indicators, and the International Monetary Fund's International Financial Statistics.

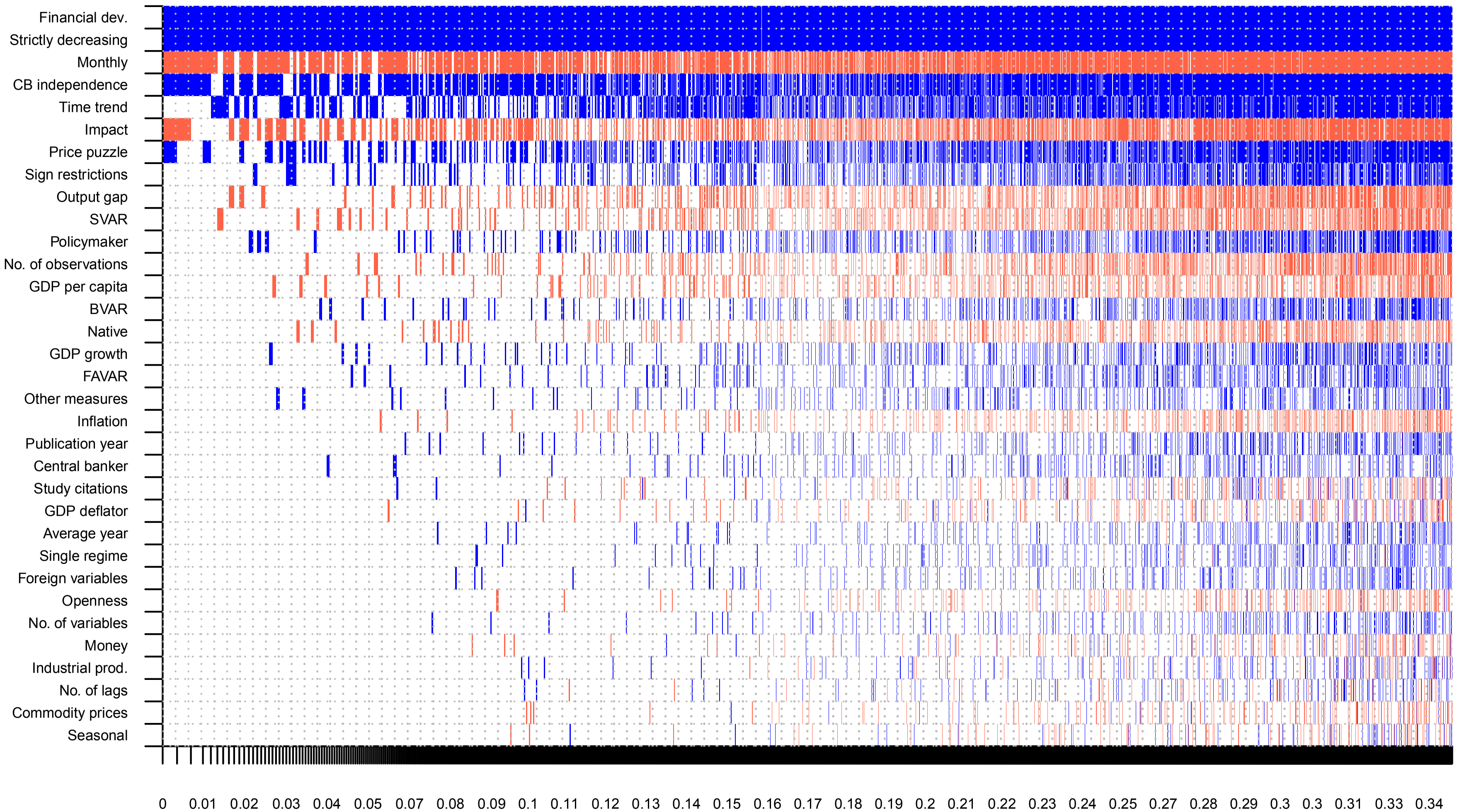
The results of the BMA estimation are reported graphically in Figure 3. The columns represent individual regression models where the transmission lag is regressed on variables for which the corresponding cell is not blank. For example, the explanatory variables in the first model from the left are *Financial development*, *Strictly decreasing*, *Monthly*, *CB independence*, *Impact*, and *Price puzzle*. The width of the columns is proportional to the so-called posterior model probabilities; that is, it captures the weight each model gets in the BMA exercise. The figure only shows the $5,000$ models with the highest posterior model probabilities. The best models are displayed on the left-hand side and are relatively parsimonious compared to those with low posterior model probabilities. Explanatory variables in the figure are displayed in descending order according to their posterior inclusion probabilities (the sum of the posterior probabilities of the models they are included in). In other words, the variables at the top of the figure are robustly important for the explanation of the variation in transmission lags, whereas the variables at the bottom of the figure do not matter much.

The color of the cell corresponding to each variable included in a model represents the estimated sign of the regression parameter. Blue (darker in grayscale) denotes a positive sign, and red (lighter in grayscale) denotes a negative sign. For example, in the first model from the left the estimated regression sign is positive for *Financial development*, positive for *Strictly decreasing*, negative for *Monthly*, positive for *CB independence*, negative for *Impact*, and positive for *Price puzzle*. As can be seen from the figure, variables with high posterior inclusion probabilities usually exhibit quite stable regression signs. Nevertheless, for a more precise discussion of the importance of individual variables (analogous to statistical significance in the frequentist case), we need to turn to the numerical results of the BMA estimation, reported in Table 5.

Table 5 shows the posterior means (weighted averages of the models displayed in Figure 3) for all regression parameters and the corresponding posterior standard deviations. According to Masanjala & Papageorgiou (2008), variables with the ratio of the posterior mean to the posterior standard deviation larger than 1.3 can be considered effective (or "statistically significant" in the frequentist case). There are only three such variables: *Financial development*, *Monthly*, and *Strictly decreasing*. First, our results suggest that a higher degree of financial development in the country is associated with slower transmission of monetary policy shocks to the price level. Moreover, when researchers use monthly data in the VAR system, they are more likely to report shorter transmission lags. The BMA exercise also corroborates that the transmission lags taken from strictly decreasing impulse responses are much longer than the lags taken from hump-shaped impulse responses; the difference is approximately 26 months.

While many of the method characteristics appear to be relatively unimportant for the explanation of the reported transmission lags, a few (for example, *Sign restrictions* or *Output gap*) have moderate posterior inclusion probabilities. Because some of the method choices are generally considered misspecifications in the literature, we use the results of the BMA estimation to filter out the effects of these misspecifications from the average transmission lag. In other words, we define an ideal study with "best-practice" methodology and maximum publication characteristics (for example the impact factor and the number of citations). Then we plug the chosen values of the explanatory variables into the results of the BMA estimation and evaluate

Figure 3: Bayesian model averaging, model inclusion



Notes: Response variable: transmission lag (the number of months to the maximum decrease in prices taken from the impulse responses). Columns denote individual models; variables are sorted by posterior inclusion probability in descending order. Blue color (darker in grayscale) = the variable is included and the estimated sign is positive. Red color (lighter in grayscale) = the variable is included and the estimated sign is negative. No color = the variable is not included in the model. The horizontal axis measures cumulative posterior model probabilities. Only the 5,000 models with the highest posterior model probabilities are shown.

Table 5: Why do transmission lags vary?

Variable	PIP	Posterior mean	Posterior std. dev.	Standardized coef.
Country characteristics				
GDP per capita	0.099	-0.447	1.647	-0.0096
GDP growth	0.087	0.111	0.444	0.0059
Inflation	0.053	-0.337	1.918	-0.0025
Financial dev.	**1.000**	**12.492**	**3.166**	**0.2630**
Openness	0.029	-0.056	0.631	-0.0011
CB independence	0.705	13.370	10.412	0.1002
Data characteristics				
Monthly	**0.730**	**-4.175**	**3.036**	**-0.1045**
No. of observations	0.127	-0.362	1.136	-0.0123
Average year	0.032	0.003	0.030	0.0012
Specification characteristics				
GDP deflator	0.035	-0.052	0.584	-0.0010
Single regime	0.031	0.039	0.395	0.0009
No. of lags	0.023	0.014	0.436	0.0003
Commodity prices	0.022	-0.009	0.246	-0.0002
Money	0.026	-0.011	0.286	-0.0003
Foreign variables	0.030	0.039	0.385	0.0010
Time trend	0.472	3.681	4.480	0.0643
Seasonal	0.020	-0.004	0.307	-0.0001
No. of variables	0.028	0.036	0.400	0.0007
Industrial prod.	0.025	0.008	0.352	0.0002
Output gap	0.189	-1.464	3.566	-0.0130
Other measures	0.059	0.199	1.038	0.0034
Estimation characteristics				
BVAR	0.096	0.337	1.278	0.0057
FAVAR	0.068	0.304	1.444	0.0034
SVAR	0.153	-0.468	1.303	-0.0112
Sign restrictions	0.200	0.954	2.232	0.0177
Publication characteristics				
Strictly decreasing	**1.000**	**26.122**	**1.798**	**0.6757**
Price puzzle	0.383	1.359	1.999	0.0351
Study citations	0.039	-0.005	0.205	-0.0003
Impact	0.423	-0.305	0.414	-0.0381
Central banker	0.044	0.075	0.497	0.0019
Policymaker	0.149	0.858	2.426	0.0106
Native	0.091	-0.221	0.865	-0.0057
Publication year	0.048	0.011	0.070	0.0022
Constant	1.000	7.271	NA	0.3752

Notes: Estimated by Bayesian model averaging. Response variable: transmission lag (the number of months past to the maximum decrease in prices taken from impulse responses). PIP = posterior inclusion probability. The posterior mean is analogous to the estimate of the regression coefficient in a standard regression; the posterior standard deviation is analogous to the standard error of the regression coefficient in a standard regression. Variables with posterior mean larger than 1.3 posterior standard deviations are typeset in bold; we consider such variables effective (following Masanjala & Papageorgiou, 2008).

the implied transmission lag.

For the definition of the "ideal" study we prefer the use of more observations in the VAR system (that is, we plug in the sample maximum for variable *No. of observations*), more recent data (*Average year*), the estimation of the VAR system over a period of a single monetary policy regime (*Single regime*), the inclusion of commodity prices in the VAR system (*Commodity prices*), the inclusion of foreign variables (*Foreign*), the inclusion of seasonal dummies (*Seasonal*), the inclusion of more variables in the VAR (*No. of variables*), the use of the output gap as a measure of economic activity (*Output gap*; *Industrial production* and *Other measures* are set to zero), the use of Bayesian VAR (*BVAR*), the use of sign restrictions (*Sign restrictions*; *FAVAR* and *SVAR* are set to zero), more citations of the study (*Study citations*), and a higher impact factor (*Impact*). All other variables are set to their sample means.

The average transmission lag implied by our definition of the ideal study is 29.2 months, which is less than the simple average by approximately 4 months. The estimated transmission lag hardly changes when FAVAR or SVAR are chosen for the definition of best-practice methodology; the result is also robust to other marginal changes to the definition. On the other hand, the implied transmission lag decreases greatly if one prefers hump-shaped impulse responses: in this case the estimated value is only 16.3 months. Moreover, if one prefers impulse responses that do not exhibit the price puzzle, the implied value diminishes by another month. In sum, when the effect of misspecifications is filtered out and one does not prefer any particular type of impulse response, our results suggest that prices bottom out approximately two and a half years after a monetary contraction.

4 Robustness Checks and Additional Results

Our analysis, based on the results of BMA, attributes the differences in transmission lags between (and within) developed and post-transition countries to differences in the level of financial development. The BMA exercise carried out in the previous section controls for methodology and other aspects associated with estimating impulse responses. Nevertheless, it is still useful to illustrate that the differences in results between developed and post-transition countries are not caused by differences in the frequency of reporting strictly decreasing impulse responses or impulse responses showing the price puzzle. To this end, we replicate Table 3 but only focus on the subsamples of impulse responses that are hump-shaped (Table 6) or that do not exhibit the price puzzle (Table 7).

The tables show that developed countries exhibit longer transmission lags even if strictly decreasing impulse responses or impulse responses showing the price puzzle are disregarded. But the difference is smaller for the subsample of hump-shaped impulse responses, where some developed countries (for example, Italy) exhibit shorter transmission lags than some post-transition countries (for example, Poland). There are two potential explanations of this result. First, compared with Table 3, now we only have approximately half the number of observations, and for some countries we are even left with less than five impulse responses, which makes

Table 6: Transmission lags differ across countries (hump-shaped impulse responses)

Developed economies		Post-transition economies	
Economy	Average transmission lag	Economy	Average transmission lag
United States	23.2	Poland	15.4
Euro area	39.5	Czech Republic	14.8
Japan	40.5	Hungary	14.4
Germany	19.4	Slovakia	5.0
United Kingdom	10.0	Slovenia	13.0
France	24.0		
Italy	9.2		

Notes: The table shows the average number of months to the maximum decrease in prices taken from the impulse responses reported for the corresponding country. Strictly decreasing impulse responses are omitted from this analysis.

Table 7: Transmission lags differ across countries (responses not showing the price puzzle)

Developed economies		Post-transition economies	
Economy	Average transmission lag	Economy	Average transmission lag
United States	40.5	Poland	14.0
Euro area	49.2	Czech Republic	8.8
Japan	57.0	Hungary	15.4
Germany	34.5	Slovakia	10.7
United Kingdom	10.0	Slovenia	17.8
France	52.8		
Italy	30.0		

Notes: The table shows the average number of months to the maximum decrease in prices taken from the impulse responses reported for the corresponding country. Impulse responses exhibiting the price puzzle are omitted from this analysis.

the average number imprecise. Second, strictly decreasing impulse responses, which are associated with longer transmission lags, are more often reported for developed economies than for post-transition economies. The reason is that shorter data spans are available for post-transition countries, which makes researchers often choose monthly data. Since monthly data are associated with shorter reported lags, researchers investigating monetary transmission in post-transition countries are less likely to report strictly decreasing impulse responses. Nevertheless, in the BMA estimation we control for data frequency as well as for the shape of the impulse response, and financial development still emerges as the most important factor causing cross-country differences in transmission lags.

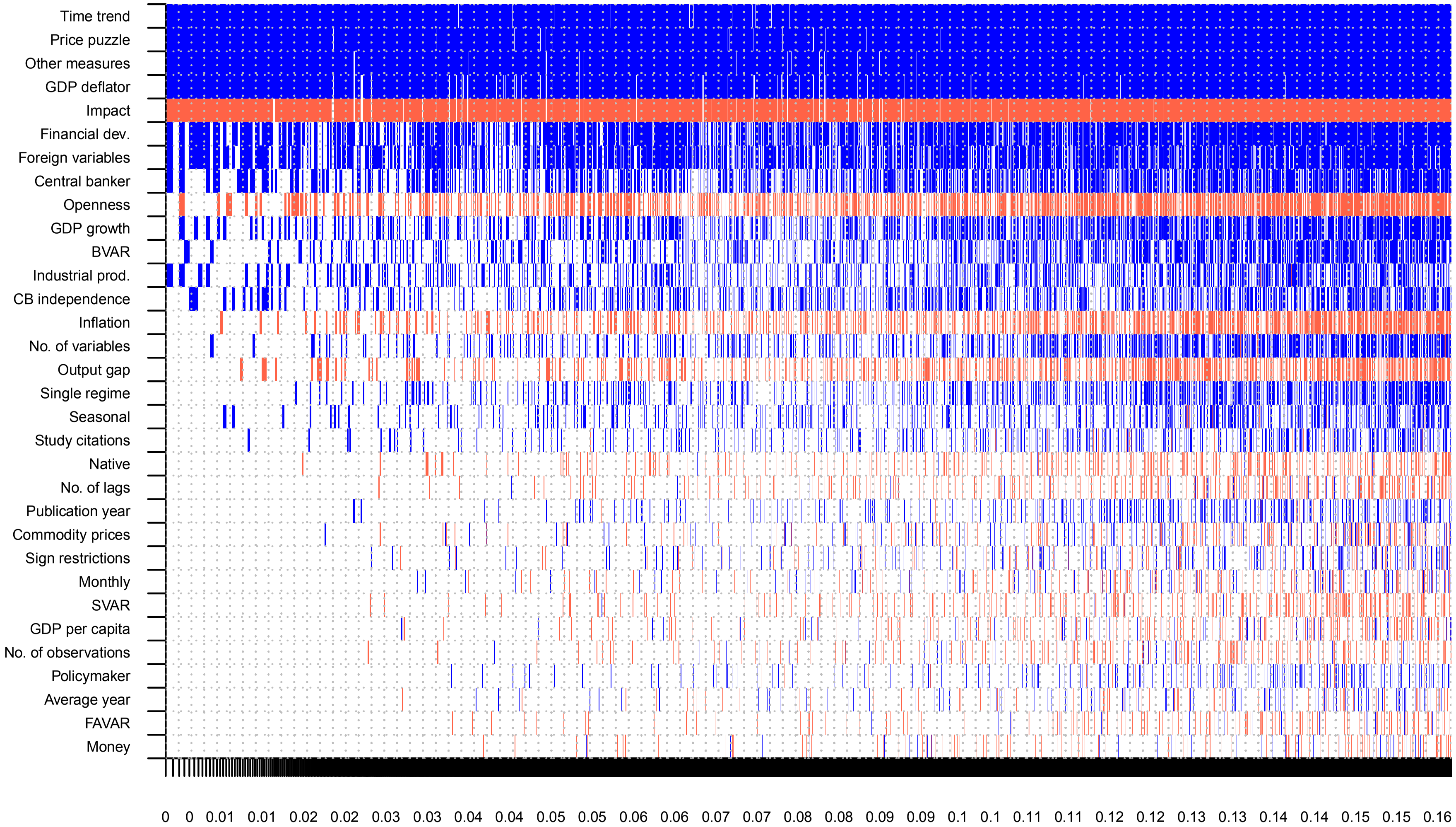
In our baseline model from the previous section we combine data from hump-shaped and strictly decreasing impulse response functions. For strictly decreasing impulse responses, however, our definition of the transmission lag (the maximum effect of a monetary contraction on prices) is influenced by the reporting window chosen by researchers. To see whether the result concerning financial development is robust to omitting data from strictly decreasing impulse response functions, we repeat the BMA estimation from the previous section using a subsample of hump-shaped impulse responses.

The results are presented graphically in Figure 4. The variable corresponding to financial development retain its estimated sign from the baseline model and still represents the most important country-level factor explaining the differences in monetary transmission lags. Compared to the baseline model, in this specification additional method variables seem to be important. The use of other measures than GDP, the output gap, or industrial production as a proxy for economic activity is associated with slower reported transmission. The choice to represent prices by the GDP deflator instead of the consumer price index on average translates into longer transmission lags. Also the inclusion of foreign variables in the VAR system makes researchers report slower transmission.

By excluding all strictly decreasing impulse responses, however, we lose half of the information contained in our data set. For this reason we consider a second way of taking into account the effect of the reporting window: censored regression. The reporting window of primary studies is often set to five years, so we use 60 months as the upper limit and estimate the regression using the Tobit model. (Changing the upper limit to three or four years, which are sometimes used as the reporting window, does not qualitatively affect the results). Unfortunately, it is cumbersome to estimate Tobit using BMA. Thus, we estimate a general model with all potential explanatory variables and then employ the general-to-specific approach. The general model is reported in Table B1 in Appendix B. The inclusion of all potential explanatory variables, many of which may not be important for explanation of the differences in transmission lags, inflates the standard errors of the relevant variables. Hence, in the next step we eliminate the insignificant variables one by one, starting from the least significant variable. As mentioned before, the general-to-specific approach is far from perfect—but in this case it represents an easy alternative to BMA.

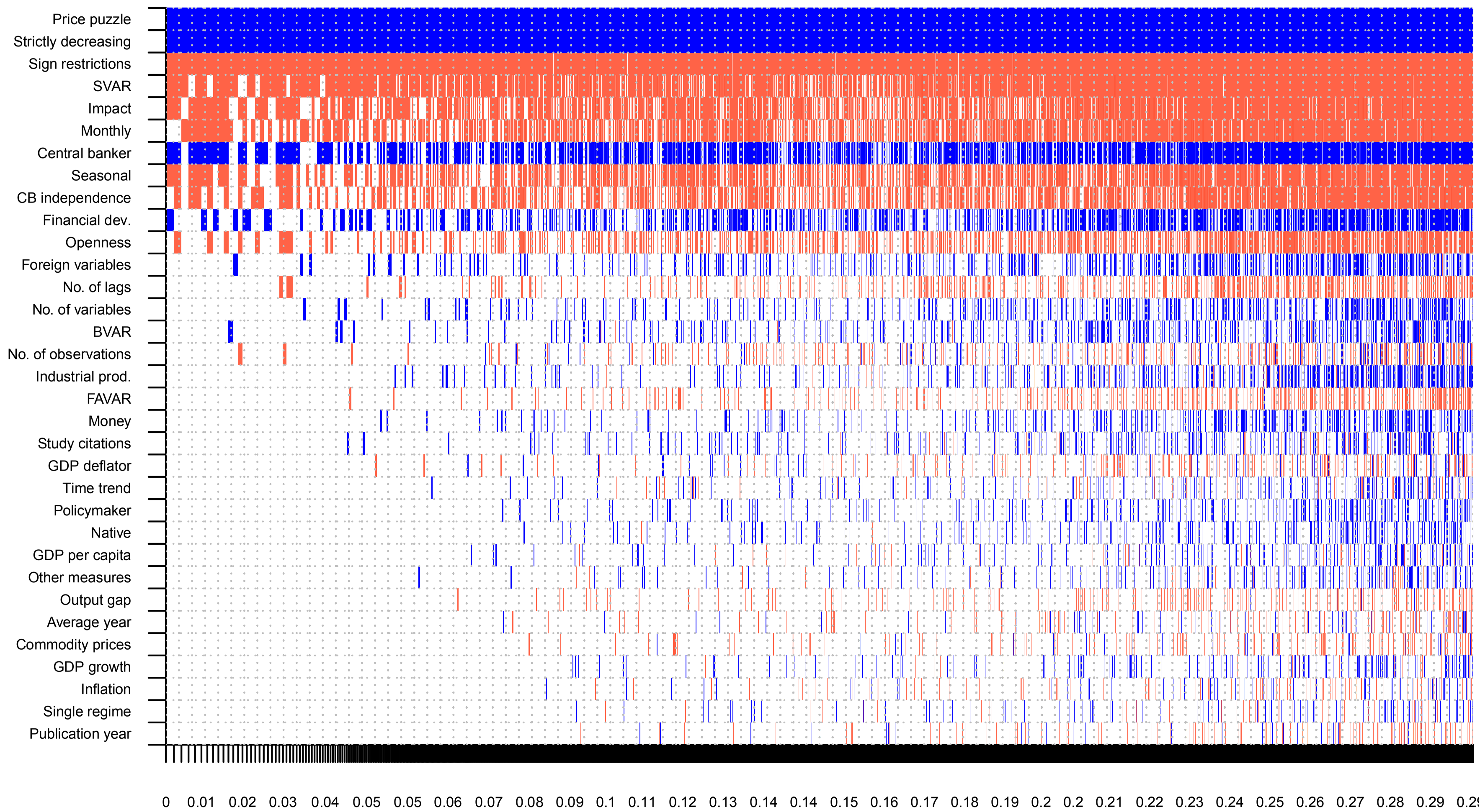
The results presented in Table 8 and Table B1 corroborate that, even using this methodology,

Figure 4: Bayesian model averaging, model inclusion (hump-shaped impulse responses)



Notes: Response variable: transmission lag (the number of months to the maximum decrease in prices taken from the impulse responses). Only transmission lags from hump-shaped impulse responses are included in the estimation. Columns denote individual models; variables are sorted by posterior inclusion probability in descending order. Blue color (darker in grayscale) = the variable is included and the estimated sign is positive. Red color (lighter in grayscale) = the variable is included and the estimated sign is negative. No color = the variable is not included in the model. The horizontal axis measures cumulative posterior model probabilities. Only the 5,000 models with the highest posterior model probabilities are shown.

Figure 5: Bayesian model averaging, model inclusion (time to -0.1% decrease in prices)



Notes: Response variable: the number of months to a -0.1% decrease in prices following a one-percentage-point increase in the policy rate. Columns denote individual models; variables are sorted by posterior inclusion probability in descending order. Blue color (darker in grayscale) = the variable is included and the estimated sign is positive. Red color (lighter in grayscale) = the variable is included and the estimated sign is negative. No color = the variable is not included in the model. The horizontal axis measures cumulative posterior model probabilities. Only the 5,000 models with the highest posterior model probabilities are shown.

Table 8: Censored regression, specific model

Response variable: transmission lag		
GDP per capita	-11.48**	(4.793)
Price puzzle	4.667**	(2.343)
Inflation	-17.25**	(8.739)
Financial dev.	21.61***	(5.375)
Openness	-12.67***	(4.670)
CB independence	29.38***	(10.64)
Monthly	-12.04***	(3.821)
No. of observations	6.526**	(2.951)
Policymaker	12.37**	(5.012)
Constant	86.58**	(43.69)
Observations	198	

Notes: Standard errors in parentheses. Estimated by Tobit with the upper limit for transmission lags equal to 60 months. The specific model is a result of the backward stepwise regression procedure applied to the general model, which is reported in Appendix B (the cut-off level for p-values was 0.1). ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

financial development is highly important for the explanation of transmission lags; in both specifications it is significant at the 1% level. The use of monthly data is associated with faster reported transmission, which is also consistent with the baseline model. In line with our results from the previous sections, Table 8 suggests that impulse responses exhibiting the price puzzle are likely to show longer transmission lags. In contrast to the baseline model, some other variables seem to be important as well: *GDP per capita*, *Inflation*, and *Openness*, among others. Because, however, the results concerning these variables are not confirmed by other specifications, we do not want to put much emphasis on these variables. The variable *Strictly decreasing*, which was crucial for the baseline BMA estimation, is omitted from the present analysis because it defines the censoring process.

So far we have analyzed the time it takes before a monetary contraction translates into the maximum effect on the price level. The extent of the maximum effect, however, varies a lot across different impulse responses. Therefore, as a complement to the previous analysis, we collect data on how long it takes before a one-percentage-point increase in the policy rate leads to a decrease in the price level of 0.1%. This number was chosen because most of the impulse response functions in our sample (173 out of 198) reach this level at some point. In contrast, if we chose a value of 0.5%, for example, we would have to disregard almost two thirds of all the impulse responses.

The results of the BMA estimation using the new response variable are reported in Figure 5. Again, the shape of the impulse response and the frequency of the data used in the VAR system seem to be associated with the reported transmission lag. Financial development still belongs among the most important country-level variables, together with central bank independence and trade openness. According to this specification, monetary transmission is faster in countries that are more open to international trade and that have a more independent central bank; these results may point at the importance of the exchange rate and expectation channels of monetary transmission. Additionally, some method variables matter for the estimated transmission lag: for example, the use of sign restrictions, structural VAR, and seasonal adjustment. Our results also suggest that articles published in journals with a high impact factor tend to present faster monetary transmission.

5 Concluding Remarks

Building on a sample of 67 previous empirical studies, we examine why the reported transmission lags of monetary policy vary. Our results suggest that the cross-country variation in transmission is robustly associated with differences in financial development. To explain the variation of results between different studies for the same country, the frequency of the data used is important: the use of monthly data makes researchers report transmission faster by 4 months, holding other things constant. This is in line with Ghysels (2012), who shows that responses from low- and high-frequency VARs may indeed differ due to mixed-frequency sampling or temporal aggregation of shocks. The shape of the impulse response matters as well. Strictly decreasing impulse responses, which may suggest that the underlying VAR system is not stationary, exhibit much longer transmission lags.

The key result of our meta-analysis is that a higher degree of financial development translates into slower transmission of monetary policy. The finding can be interpreted in the following way. If financial institutions lack opportunities to protect themselves against unexpected monetary policy actions (due to either low levels of capitalization or low sophistication of financial instruments provided by the undeveloped financial system), they need to react immediately to monetary policy shocks, thus speeding up the transmission. In financially developed countries, in contrast, financial institutions have more opportunities to hedge against surprises in monetary policy stance, causing greater delays in the transmission of monetary policy shocks.

More generally, our results imply that monetary transmission may slow down as the financial system of emerging countries develops, since financial innovations allow banks to protect better against surprise shocks in monetary policy.

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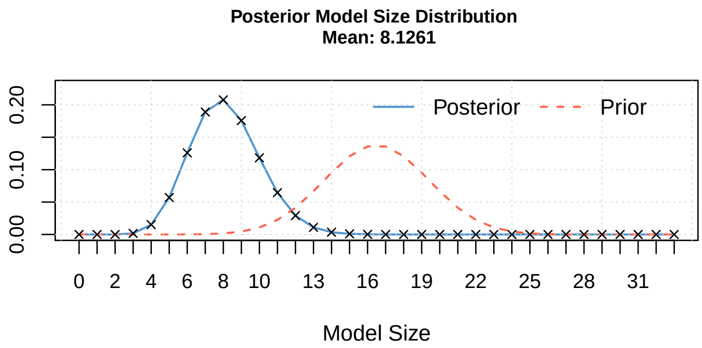
A Diagnostics of Bayesian Model Averaging

Table A1: Summary of BMA estimation (baseline model)

Mean no. regressors	*Draws*	*Burn-ins*	*Time*
8.1261	$2 \cdot 10^8$	$1 \cdot 10^8$	11.88852 hours
No. models visited	*Modelspace*	*Visited*	*Topmodels*
83,511,152	$8.6 \cdot 10^9$	0.97%	34%
Corr PMP	*No. Obs.*	*Model Prior*	*g-Prior*
0.9999	198	uniform / 16.5	UIP
Shrinkage-Stats			
Av= 0.995			

Notes: UIP = unit information prior, PMP = posterior model probability.

Figure A1: Model size and convergence (baseline model)



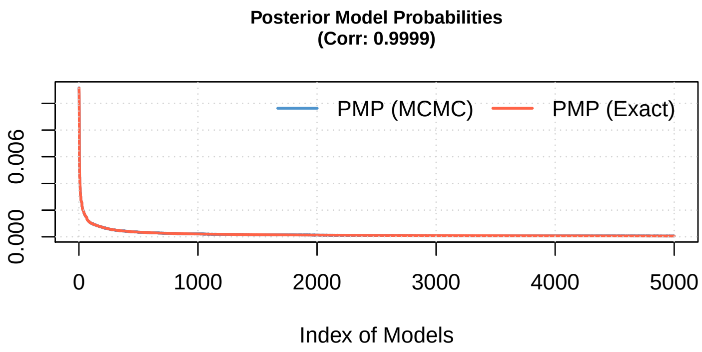
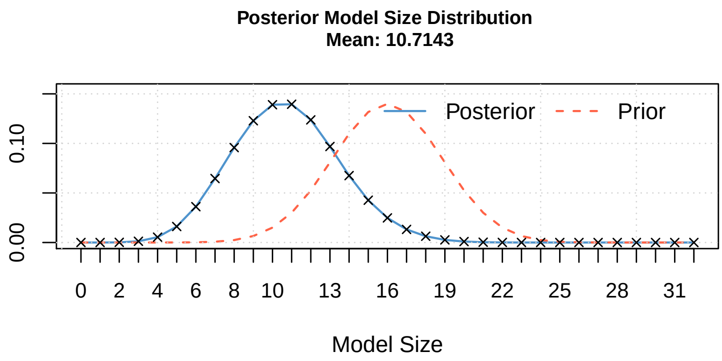


Table A2: Summary of BMA estimation (hump-shaped impulse responses)

Mean no. regressors 10.7143	*Draws* $2 \cdot 10^8$	*Burn-ins* $1 \cdot 10^8$	*Time* 12.15215 hours
No. models visited $104,093,439$	*Modelspace* $4.3 \cdot 10^9$	*Visited* 2.4%	*Topmodels* 16%
Corr PMP 0.9997	*No. Obs.* 100	*Model Prior* uniform / 16	*g-Prior* UIP
Shrinkage-Stats Av= 0.9901			

Notes: UIP = unit information prior, PMP = posterior model probability.

Figure A2: Model size and convergence (hump-shaped impulse responses)



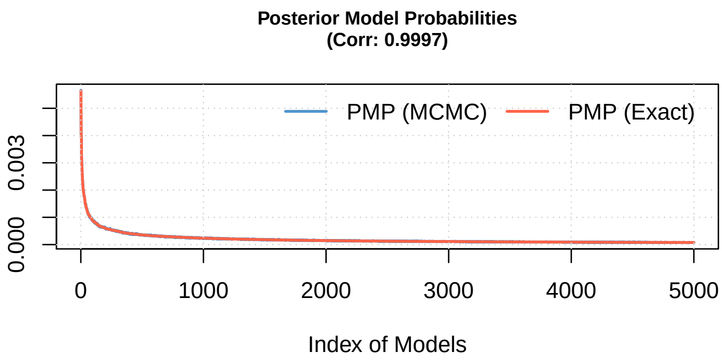
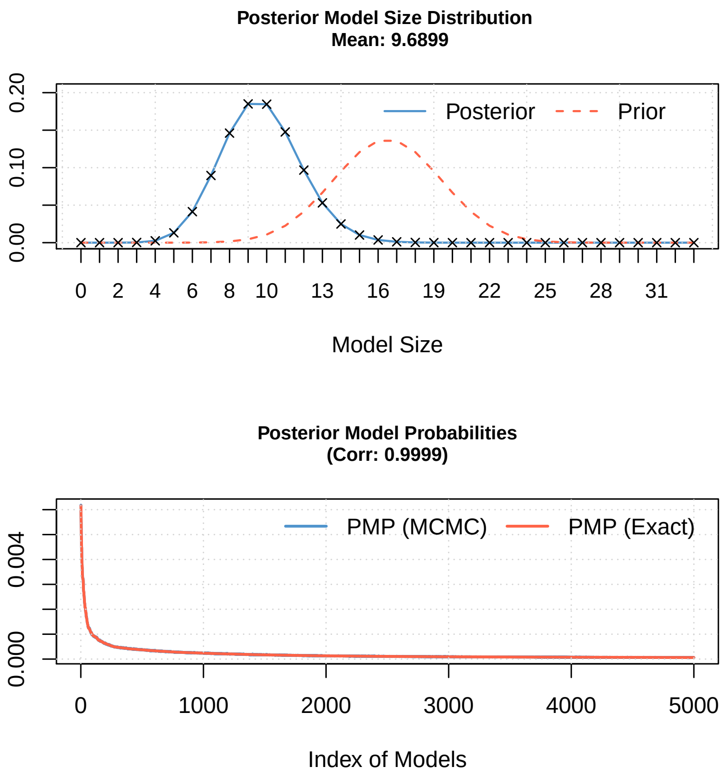


Table A3: Summary of BMA estimation (time to −0.1% decrease in prices)

Mean no. regressors 9.6899	*Draws* $2 \cdot 10^8$	*Burn-ins* $1 \cdot 10^8$	*Time* 12.0976 hours
No. models visited 87,125,827	*Modelspace* $8.6 \cdot 10^9$	*Visited* 1%	*Topmodels* 30%
Corr PMP 0.9999	*No. Obs.* 173	*Model Prior* uniform / 16.5	*g-Prior* UIP
Shrinkage-Stats Av= 0.9943			

Notes: UIP = unit information prior, PMP = posterior model probability.

Figure A3: Model size and convergence (time to −0.1% decrease in prices)



B Results of Censored Regression

Table B1: Censored regression, general model (all variables are included)

Response variable: transmission lag		
Country characteristics		
GDP per capita	-9.792*	(5.192)
GDP growth	1.512	(1.346)
Inflation	-17.41**	(8.695)
Financial dev.	22.17***	(6.084)
Openness	-11.16**	(5.595)
CB independence	30.20**	(12.27)
Data characteristics		
Monthly	-4.402	(6.920)
No. of observations	4.287	(5.186)
Average year	-0.168	(0.367)
Specification characteristics		
GDP deflator	5.102	(4.281)
Single regime	4.143	(3.497)
No. of lags	8.132*	(4.744)
Commodity prices	-1.284	(2.861)
Money	1.768	(2.949)
Foreign variables	4.102	(3.400)
Time trend	2.700	(5.791)
Seasonal	7.231*	(4.057)
No. of variables	1.352	(3.536)
Industrial prod.	-6.785*	(3.904)
Output gap	-10.41	(7.681)
Other measures	-6.246	(5.017)
Estimation characteristics		
BVAR	-1.147	(5.094)
FAVAR	14.53**	(6.525)
SVAR	-4.243	(3.008)
Sign restrictions	-3.270	(5.163)
Publication characteristics		
Price puzzle	3.651	(2.537)
Study citations	-0.717	(1.734)
Impact	-0.742	(0.699)
Central banker	5.313	(3.633)
Policymaker	9.024	(6.137)
Native	-1.996	(3.043)
Publication year	0.0475	(0.453)
Constant	62.32	(50.10)
Observations	198	

Notes: Standard errors in parentheses. Estimated by Tobit with the upper limit for transmission lags equal to 60 months. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.