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Discussion Paper No. 50

Shocks versus structure: explaining differences in exchange rate pass-through across countries and time

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Kristin Forbes,[1] Ida Hjortsoe[2] and Tsvetelina Nenova[3]

Abstract

We show that exchange rate pass-through to consumer prices varies not only across countries, but also over time. Previous literature has highlighted the role of an economy's 'structure' — such as its inflation volatility, inflation rate, use of foreign currency invoicing, and openness — in explaining these variations in pass-through. We use a sample of 26 advanced and emerging economies to show which of these structural variables are significant in explaining not only differences in pass-through across countries, but also over time. The 'shocks' leading to exchange rate movements can also explain variations in pass-through over time. For example, exchange rate movements caused by monetary policy shocks consistently correspond to significantly higher estimates of pass-through than those caused by demand shocks. The role of 'shocks' in driving pass-through over time can be as large as that of structural variables, and even larger for some countries. As a result, forecasts predicting how a given exchange rate movement will impact inflation at a specific point in time should take into account not just an economy's 'structure', but also the 'shocks'.

Key words: Pass-through, exchange rate, price level, inflation, monetary policy.

JEL classification: E31, E37, E52, F47.

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I. Introduction

Exchange rate movements are an important—and in some countries the most important—determinant of inflation.[1] Therefore, understanding how any exchange rate fluctuation will "pass-through" to import prices and headline inflation is critically important for modelling macroeconomic dynamics, economic forecasting, and setting monetary policy. Estimating pass-through to aggregate prices, however, is not straightforward. Pass-through not only varies substantially across countries, but also across time within a given country. What determines these variations in pass-through? Do they primarily reflect structural differences across economies, *i.e.*, country or industry or firm characteristics that are relatively slow to change? Or do different rates of pass-through primarily reflect changes in the economic conditions (*i.e.* the shocks) driving the exchange rate movements, influences which could change quickly? This paper attempts to answer these questions by assessing the role of "shocks" versus "structure" in explaining variations in pass-through to aggregate prices. It finds that both play a meaningful role, and it is optimal to take into account both the "shocks" and the "structure" to fully understand the determinants of pass-through across countries and across time.

This analysis attempts to bridge two branches of literature that have focused on very different determinants of pass-through, resulting in very different approaches to modelling and estimation. The largest and most well-known branch of literature focuses on explaining the substantial differences in pass-through across countries by examining their structural characteristics. This literature has documented a number of characteristics that are important, such as: openness and the composition of imported goods (Campa and Goldberg, 2005 and 2010), the extent of nominal rigidities (Devereux and Yetman, 2003, and Corsetti *et al*., 2008), the role of foreign currency pricing, especially in invoicing (Gopinath *et al.*, 2010, Gopinath, 2015, and Devereux *et al.*, 2015), the dispersion of price changes (Berger and Vavra, 2015), the frequency of price adjustments (Gopinath and Itskhoki, 2010), the inflation-fighting credibility of the central bank (Taylor, 2000, Gagnon and Ihrig, 2004, Choudri and Hakura, 2006, Caselli and Roitman, 2016 and Carriere-Swallow *et al.*, 2016), and the extent of monopoly power and competition in product markets (Devereux *et al*., 2015, and Amiti *et al.*, 2016).[2] A subset of this literature attempts to explain gradual changes in pass-through across time resulting from structural changes in specific economies. For example, several papers document a fall in pass-through in the United States from the 1980s to the 1990s and examine the role of slow-moving variables, such as changes in the composition of imports, the monetary policy framework, or the role of China (e.g., Marazzi *et al*., 2005 and Gust *et al*., 2010).[3]

A second, and much smaller, branch of the literature analysing pass-through has focused on the role of the shocks corresponding to exchange rate movements. This literature has focused primarily on explaining changes in pass-through over time within individual countries (instead of across countries). This approach builds on the theoretical literature showing that firms adjust their prices

[1] See Cecchetti, Feroli, Hooper, Kashyap, and Schoenholtz (2017) and Forbes, Kirkham, and Theodoridis (2017) for evidence that exchange rate movements are an important determinant of the persistent, trend rate of inflation in the US and UK.
[2] See Burstein and Gopinath (2014) for an overview of this extensive literature and other variables that have been analysed in this framework.
[3] Work examining changes in pass-through outside of the US resulting primarily from slow-moving structural change include: the decline in pass-through in Switzerland in the 1990s (Stulz, 2007), the decline in pass-through to import prices in the UK between 1995 and 2004 (Mumtaz *et al.*, 2006), the decline in pass-through in the euro area since 1996 (Ozyurt, 2016), and changes in pass-through since the crisis (Jasová, Moessner, and Takáts, 2016).

and mark-ups differently after different shocks, implying that the shocks leading to an exchange rate movement can be important in determining the effects on pricing and inflation.[4] This concept has been discussed in the macroeconomic literature for years, such as in Klein (1990), and the general concept has often been incorporated in this larger literature by using control variables (such as GDP) to proxy for shocks or by using firm-level data.[5] Only a few papers, however, have explicitly modelled the role of the shocks underlying exchange rate movements when estimating pass-through. Shambaugh (2008) is the first example that we know of, but its VAR approach was not widely incorporated in academic work or policy analysis. This may have reflected the limited set of shocks identified in the framework, which were difficult to reconcile with those in most theoretical open-economy models and which made it hard to apply the framework to estimate pass-through in real-time. Forbes, Hjortsoe and Nenova (2015) develop a more tractable framework using a different set of assumptions to identify shocks that are consistent with theoretical models and more directly applicable to forecasting and policy analysis. However, they only estimate their model for the UK. Most recently, Comunale and Kunovac (2017) build on the Forbes *et al.* (2015) framework for selected economies in the euro area.

This disconnect between the branches of literature estimating pass-through at the macroeconomic level is striking. The largest branch of literature focuses primarily on economies' structural characteristics to explain differences in pass-through across countries and over longer periods of time, while the much smaller branch focuses primarily on the economic conditions (the shocks) to explain differences in pass-through over time within specific countries. The theoretical literature modelling pass-through, however, clearly shows an important role for both a country's structure (both at the industry and macro level) and the shocks underlying an exchange rate movement. We examine whether the current focus of most of the empirical literature on the structural differences makes sense. We assess the role of structural characteristics and of economic conditions in explaining differences in exchange rate pass-through, both across countries and over time. Does it make sense to focus on one approach to understand variations in pass-through over time and another to understand the cross-section of pass-through? Or are there benefits to incorporating both the "shocks" and the "structure" when analysing both pass-through across time and across countries?

To answer these questions, the paper begins by estimating pass-through using a standard reduced-form model, based on the seminal work of Campa and Goldberg (2005), and recently updated by Burstein and Gopinath (2014) and Gopinath (2015). We focus on a sample of 26 small open economies with flexible exchange rates—the sample which will form the basis of the remainder of this paper. These reduced-form estimates of pass-through show substantial variation across countries. They also show substantial variation over short and long periods of time within some individual countries—with pass-through increasing over time in some countries, decreasing in others, and showing sharp movements at some points in time in others. These results suggest that

[4] This literature includes Bils (1987), Dornbusch (1987), Krugman (1987), Rotemberg and Woodford (1999), and more recently Corsetti *et al.* (2009) and Gilchrist and Zakrajsek (2015).

[5] For further discussion, see Burstein and Gopinath (2014), Campa and Goldberg (2005) and Ihrig *et al.* (2006). Ito and Sato (2008) show the importance of simultaneously controlling for monetary policy changes when estimating pass-through. Smets and Wouters (2002) discuss how pass-through is routinely modelled in DSGE frameworks used in policy institutions that attempt to capture these effects.

understanding pass-through will require a framework that explains both differences across countries as well as over time, and allows for a diversity of country experiences.

The next section of the paper moves from the reduced-form estimates of pass-through that are fairly standard in this literature to shock-dependent estimates. It builds on the framework developed in Forbes, Hjortsoe and Nenova (2015) for the UK, but modifies it to estimate pass-through for the sample of 26 developed and emerging economies conditional on the shock causing the exchange rate movement. The estimates suggest that a given exchange rate movement can be associated with very different price dynamics depending on the shock underlying the exchange rate fluctuation. For example, on average across the sample, a depreciation caused by a monetary policy shock corresponds to the largest increase in domestic prices, while a depreciation caused by a demand shock corresponds to a decline in domestic prices. Put slightly differently, monetary policy shocks imply a high positive correlation between exchange rates and prices, while domestic demand shocks imply a negative correlation. Moreover, different shocks have played different roles in driving exchange rate movements across countries, as well as across time within individual countries. For example, some countries' exchange rates are more often affected by monetary policy shocks, while others' exchange rates are more likely to be affected by demand shocks. This suggests that the nature of the shocks driving exchange rate movements could play some role in explaining differences in pass-through across countries, as well as over time within countries.

We then compare the determinants of variations in estimated pass-through in both the cross-country and time dimension. We begin by assessing how various structural variables that have been previously highlighted in the literature explain differences in pass-through across countries. Most of these variables have the expected sign and are individually significant. For example, countries with more volatile inflation, higher inflation, more volatile exchange rates, a larger share of imports invoiced in foreign currency, a higher share of imports in GDP, or defined as an emerging market, have higher pass-through on average. We also show that the preponderance of different shocks behind exchange rate movements in each country—and especially the importance of monetary policy shocks and demand shocks—may influence the estimated degree of pass-through, although these results are often statistically insignificant. The significance of many of the individual estimates fluctuates based on the specification, however, likely reflecting the high correlations between many of the variables (especially the structural variables) and the limited sample size.

The next section uses the same framework to explore the time-series dimension of pass-through. We begin by assessing the role of various structural variables and find that many of these variables continue to be important in explaining changes in pass-through across time within countries. Some structural variables, however, appear to be less important in explaining the time-series dimension than the cross-section dimension. For example, although the volatility of inflation remains highly significant in explaining pass-through in both the cross-country and time-series dimension, the foreign currency share of imports, exchange rate volatility, trade openness, and the differentiation of imports all become less important in explaining the time-series than the cross-section dimension of pass-through. On the other hand, the shocks corresponding to exchange rate movements are more often significant and appear to play a more important role in explaining changes in pass-through across time within countries than they played in explaining differences across countries.

We then tie together the various results with a few examples in order to better understand the economic magnitudes of the effects of "shocks" and "structure" in explaining the variations in pass-through in the cross-section as well as the time series. These examples indicate that a country's structural characteristics and the shocks corresponding to exchange rate movements both have meaningful effects on estimates of exchange rate pass-through. The effects of structural characteristics on the average rates of pass-through across countries tend to be substantially larger than those of the shocks, while both "shocks" and "structure" play a similar and economically important role in explaining changes in pass-through over time within individual countries. For some countries, however, changes in the characteristics of the shocks corresponding to exchange rate movements can be more important than structural characteristics when explaining the time-series dimension of pass-through.

The paper concludes that in order to understand pass-through, it is important to consider both the "structure" of the country and the "shock" underlying the exchange rate movement. Both play an important role in explaining the time-series dimension of pass-through, while the structural variables appear to be more important in explaining the differences across countries. This suggests that any institution attempting to forecast inflation, or understand how a given exchange rate movement will affect prices in the future, should consider the "shocks" underlying the exchange rate movement as well as the "rule of thumb" estimates of pass-through for the country based on structural factors. This approach combining the different branches of the literature on pass-through could improve the ability of central banks to forecast inflation and therefore set monetary policy appropriately.

The remainder of the paper is as follows. Section II reports the reduced-form estimates of pass-through across countries and over time. Section III develops the shock-based framework to evaluate the link between exchange rates and prices, reports estimates of that link for each shock, and shows how the shocks differ over time within individual countries. Section IV estimates the role of structural factors and shocks in explaining different rates of pass-through across countries, while Section V repeats the same analysis for differences in pass-through over time. Section VI assimilates the various results and provides specific examples to evaluate the economic magnitudes and relative importance of the different structural and shock-based estimates. Section VII concludes.

II. Reduced-Form Estimates of Pass-through: Across Countries and Over Time

In order to assess the role of structural characteristics and shocks in explaining aggregate pass-through, we first calculate reduced-form pass-through coefficients for each country and time period in our sample. This section estimates these coefficients using a standard, reduced-form specification at the core of the literature and central to the branch of research focusing on the structural determinants of pass-through. It begins by discussing the sample, data, and methodology. Then it estimates the average rate of pass-through for each country over the full sample. The section closes with time-varying estimates of pass-through within each country, including a brief discussion of what these estimates imply for understanding differences in pass-through across countries and time.

a. *Sample, data and methodology*

We focus on a sample of diverse countries that meet three criteria: have flexible exchange rates, are small open economies (in the sense that their economic conditions do not affect world export prices), and have data on the key variables required for the analysis.

In order to categorize the countries with flexible exchange rates, we begin with countries classified into the two *de facto* floating exchange rate regime categories – "floating" and "free floating" – according to the IMF's *67th Annual Report on Exchange Rate Arrangements and Exchange Restrictions* for 2015 (the last year of our sample). Then we collate a time series for each of these countries' exchange rate regimes from 1990. In order to have a sufficient time-series to analyse changes in pass-through across time, we only keep countries which were also classified as having a floating exchange rate throughout at least the previous ten years (i.e., from 2006 to 2015).[6] In other words, our sample duration ranges from 26 years (1990-2015) for countries with a long history of floating exchange rates (such as Australia and Japan) to 10 years for countries which adopted floating exchange rates more recently, but have had them in place since at least 2006 (such as Israel and Romania).

The second requirement for countries in our sample is that they are "small open economies", in the sense they do not affect world export prices. This requirement is necessary to satisfy the identification assumptions for our model used to assess the role of shocks in determining pass-through (and discussed in more detail in Section III). In our base case, this only involves excluding the United States from our sample, although we also examine the impact of removing Japan.[7] China and countries in the euro area were already excluded as they do not meet the criteria as having flexible exchange rates.

The final requirement is that we have quarterly data on domestic consumer prices, world export prices, exchange rates, short-term interest rates and real GDP. The resulting sample of 26 countries includes 11 advanced countries (Australia, Canada, Iceland, Israel, Japan, Korea, New Zealand, Norway, Sweden, Switzerland, and the United Kingdom) and 15 economies we will refer to as "emerging" (Brazil, Chile, Colombia, Ghana, India, Mexico, Peru, Philippines, Poland, Romania, Serbia, South Africa, Thailand, Turkey and Uruguay). The exact data sources, variable construction and definitions, and the sample periods used for each country are listed in Appendix A.

In order to obtain pass-through estimates for this sample of advanced and emerging economies, we follow the standard methodology developed in Campa and Goldberg (2005), and recently updated in Burstein and Gopinath (2014) and Gopinath (2015). More specifically, we estimate a distributed lag regression of changes in domestic consumer prices on the following explanatory variables: the trade-weighted exchange rate (contemporaneous to four quarter lags), the trade-weighted export prices

[6] In the IMF's classification methodology before 2009, the two floating categories were referred to as "managed floating with no pre-determined path for the exchange rate" and "independently floating". For countries which have alternated exchange rate regimes, we use the most recent period that the exchange rate has been in one of the floating categories. Switzerland is the one country that is not continuously classified in one of the "floating" categories over this period, due to the ceiling it imposed on the Swiss franc from 6 September 2011 to 15 January 2015. We continue to include Switzerland in the sample, however, as the exchange rate could still fluctuate to some extent based on market forces during this period, and also due to its classification in the floating categories for the majority of the sample. Moreover, excluding Switzerland from the analysis has no meaningful impact on the key results.

[7] Japan was the largest country in our sample at the end of 2015, according to the IMF *World Economic Outlook* April 2017 estimate of its GDP converted into US dollars using market exchange rates.

of trading partners (contemporaneous to four quarter lags), and GDP growth (contemporaneous). We use headline consumer prices as our dependent variable, as it is more widely available and more reliably measured than import prices in many countries in our sample. Pass-through to consumer prices is also the measure of pass-through most important for forecasts and setting monetary policy. The resulting country regressions can be expressed as:

$$\Delta p_{i,t} = \alpha_i + \sum_{n=0}^{4} \beta_{i,n} \Delta s_{i,t-n} + \sum_{n=0}^{4} \gamma_{i,n} \Delta wxp_{i,t-n} + \delta_i \Delta gdp_{i,t} + \varepsilon_{i,t}, \quad (1)$$

where $\Delta p_{i,t}$ is the quarterly log change in the domestic consumer price index (CPI) of country *i* in period *t*; $\Delta s_{i,t-n}$ is the quarterly log change in country *i*'s trade-weighted exchange rate index in period *t-n;* $\Delta wxp_{i,t-n}$ is the quarterly log change in world export prices (the trade-weighted average of country *i*'s trading partners' export prices) in period *t-n;* and $\Delta gdp_{i,t}$ is the log change in country *i*'s real GDP[8].

In this framework, exchange rate pass-through in country *i* is captured by the sum of the coefficients on all lags of the exchange rate, *i.e.* $\sum_{n=0}^{4} \beta_{i,n}$. For our base case, equation (1) is estimated with lags for four quarters using OLS with Newey-West standard errors robust to autocorrelation of lag order of up to eight quarters.

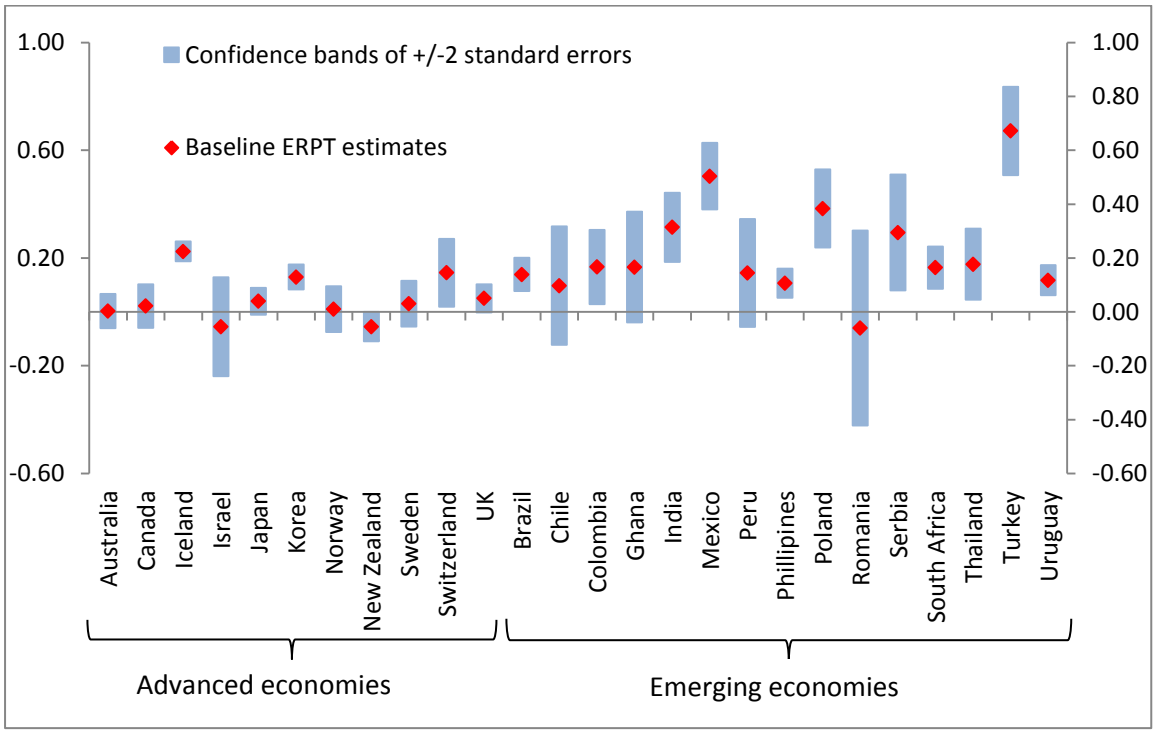
b. Reduced-form estimates of pass-through: Across countries

Figure 1 shows the resulting estimates of pass-through from equation (1) for our sample of advanced and emerging economies over the full sample period from 1990 to 2015 (or as long as possible for each country as discussed above). We will refer to these results as estimates of "long sample" pass-through, in order to differentiate them from the estimates for shorter periods discussed in the next section. The higher the coefficient, the greater is pass-through, *i.e.* the more prices rise (fall) after an exchange rate depreciation (appreciation). The interpretation of the point estimates is also straightforward; a 0.1 coefficient means that a 10% increase in the exchange rate (i.e. a 10% depreciation) corresponds to a 1% increase in the level of consumer prices.

The figure shows that pass-through varies substantially across countries. It ranges from around 0 in several countries to around 50% in Mexico and 70% in Turkey. The average rate of pass-through for advanced economies is 5% (or 0.05), while the average for the emerging economies is 23% (or 0.23). This result of higher, average estimated pass-through in emerging markets relative to in advanced economies is a standard finding in the literature, and Section IV analyses some of the drivers of this cross-country variation. The light blue bands in Figure 1 show the 95% confidence intervals for each country's pass-through estimates. In many cases these bands are small, indicating fairly precise estimates. In other countries, however, especially several emerging economies, the bands are substantially wider and indicate less precise estimates (such as for Romania).

[8] This is included to control for changes in domestic conditions which could also affect prices directly rather than just through the exchange rate. We also estimated this regression with alternative control variables such as short-term interest rates, oil prices and one to four lags of the dependent variable. The results of the 27 variations are discussed below and were generally stable and similar to the baseline ones reported here.

Figure 1. Estimates of "long sample" exchange rate pass-through (ERPT) by country



Although the specification in equation (1) used to calculate the estimates in Figure 1 is fairly standard, different papers have used a number of variants. For example, some papers use 8 lags (instead of 4) for different control variables, some papers include a control for oil prices (with different lag structures), some include a control for interest rates, some do not include a control for GDP growth, and some include one or several lags of the dependent variable. In order to assess if the long-sample estimates of pass-through in our base case change fundamentally—or in systematic ways—with these different specifications, we have also estimated 27 variations of our baseline specification. Appendix Figure B1 reports the point estimate of long-sample pass through for each country in our sample based on equation (1), and then the full range of estimates obtained from the other 27 specifications. The full list of the 28 different specifications is in Appendix Table B1.

These robustness checks indicate that changes in the specification of equation (1) can yield different point estimates of the estimated pass-through coefficient for specific countries. It is difficult to discern any consistent patterns or bias, however, in how the different specifications change the estimates across countries. For example, the baseline estimates for Australia and Canada are towards the lower end of the range of estimates obtained from these different specifications, while those for Switzerland and Turkey are towards the top of their respective ranges. In many cases, the pass-through estimates in our base case are around the middle of the ranges from these different specifications (such as for Brazil, Japan, Mexico, Norway and the UK). Therefore, the base case estimates do not appear to be systematically greater or less than estimates of pass-through obtained through other common specifications using this reduced-form approach.

c. Reduced-form estimates of pass-through: Across time

Although these notable differences in the average rates of pass-through across countries have been well-documented in the literature, there has been less attention – in particular at policy institutions

and among economic forecasters – to the fact that these averages can mask meaningful changes in the extent of pass-through across time within individual countries. Instead, these long-sample rates of pass-through are often used as "rules of thumb" for how an exchange rate movement will affect future prices in a specific country.[9] This tendency is surprising given the evidence from a number of countries that pass-through can change notably over time, and even within short periods of time, such as shown for the UK in Forbes, Hjortsoe and Nenova (2015), for Switzerland in Stulz (2007), for the euro area in Comunale and Kunovac (2017), and in the United States from the 1980s to the 1990s.[10]

Figure 2 provides initial evidence that this time-series dimension of pass-through can be important. It replicates the estimates from the baseline specification in equation (1), except now calculates the pass-through coefficients for each country over shorter windows instead of the full sample. More specifically, we estimate pass-through over four non-overlapping 6-year periods: 1992-1997, 1998-2003, 2004-2009, and 2010-2015. The top panel of Figure 2 shows the results for each of the advanced economies in the sample, and the bottom panel for the emerging economies. The point estimates and 95% confidence bands are reported in Appendix Table B2.

The estimates clearly suggest that pass-through can vary in a meaningful way by period within each country, as well as across countries. For example, pass-through in Canada has varied from 17% in 1992-1997, to 33% in 1998-2003, and back to 14% in 2010-2015. Pass-through in the UK has increased over the last three periods, from close to zero in 1998-2003, to 5% in 2004-2009, to 23% in 2010 to 2015. In contrast, pass-through in the Philippines has steadily fallen over the same three periods, from 40% in 1998-2003, to 19% in 2004-2009, to 13% in 2010 to 2015.

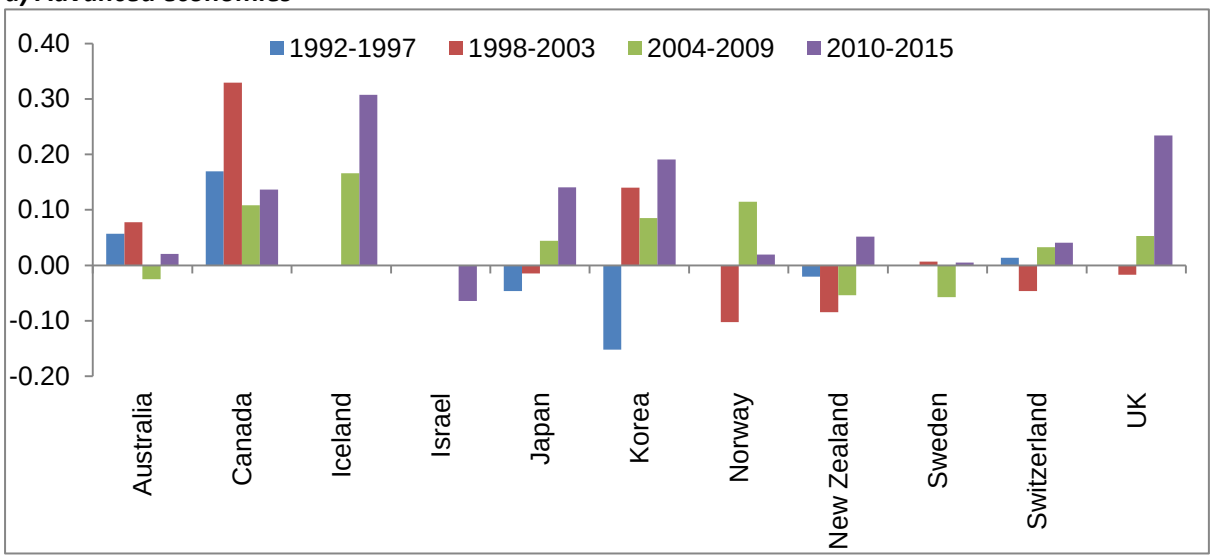
These examples highlight a broader challenge—of finding consistent trends across countries in how pass-through has changed over time. In some countries (such as Japan, Switzerland and the UK), pass-through has increased over the sample, while in other countries (such as Australia, Brazil, and Mexico), pass-through has decreased at some point. In some countries, pass-through spikes in one period and then falls back (such as in Canada, India, Norway, and Philippines). On average, pass-through in advanced economies has increased from the earlier periods (1992-1997 and 1998-2003) to the most recent period (2010-2015)—but this masks important variation amongst these economies.

Data for emerging economies over the earlier periods is more limited, and there is even greater variation in the patterns over time. Some of the sharpest increases in pass-through in emerging economies may be linked to financial or currency crises. For example, pass-through was high in Brazil, Mexico and Philippines during windows around sharp currency devaluations, and then fell sharply for each of these countries in the subsequent period.

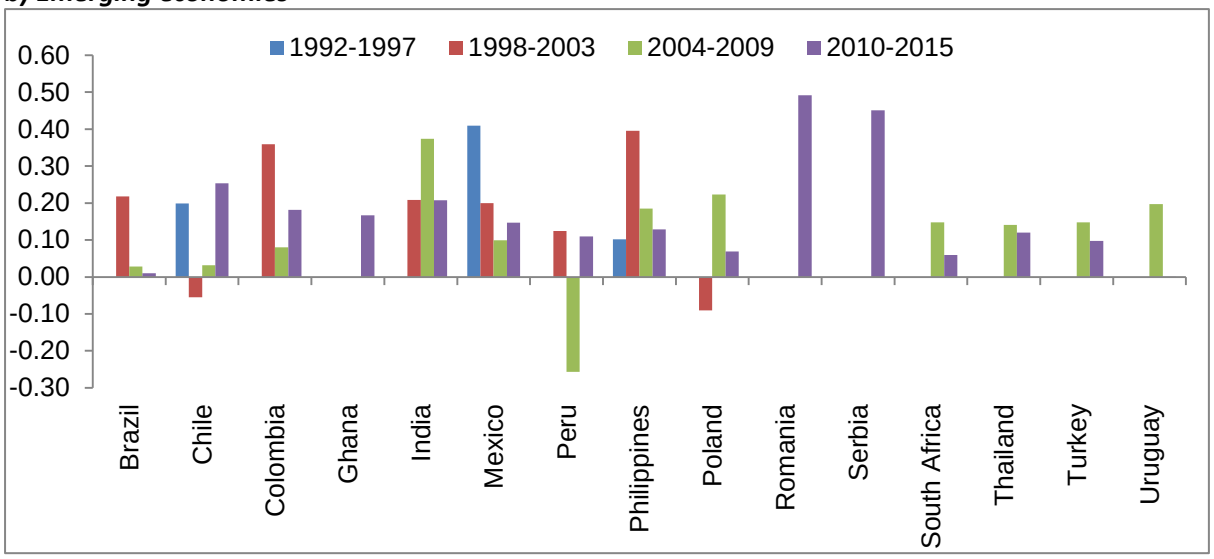
[9] See "Using rules of thumb for exchange rate pass-through could be misleading" by Forbes, Hjortsoe and Nenova, voxeu.org, 12 February 2016.
[10] See Marazzi *et al*. (2005) and Gust *et al*., (2010).

Figure 2. Pass-through estimates over four 6-year periods

a) Advanced economies



b) Emerging economies



This potential relationship between currency crises and pass-through highlights a concern with the estimates in Figure 2 (and Appendix Figure B1); focusing on these arbitrary non-overlapping periods can put undue weight on specific events that occur during that window and that might affect estimates of pass-through. Equally problematic, non-overlapping windows could overlook important variations in pass-through over time that happen within the 6-year windows or that occur in slightly different times in different countries. Therefore, in order to better capture any changes in pass-through over time, Figure 3 estimates equation (1) again, except now uses rolling 6-year periods instead of the four non-overlapping 6-year windows.

These time-varying estimates of pass-through highlight, once again, the diversity of experiences across countries. For some countries, pass-through coefficients have been relatively stable over time, while in others they have fallen (such as in Mexico, Poland and Turkey), and for others they have increased (such as in Switzerland and Chile). Some countries have similar rates of pass-through now as in the mid-1990s—but very different levels at some point between. In some cases changes in

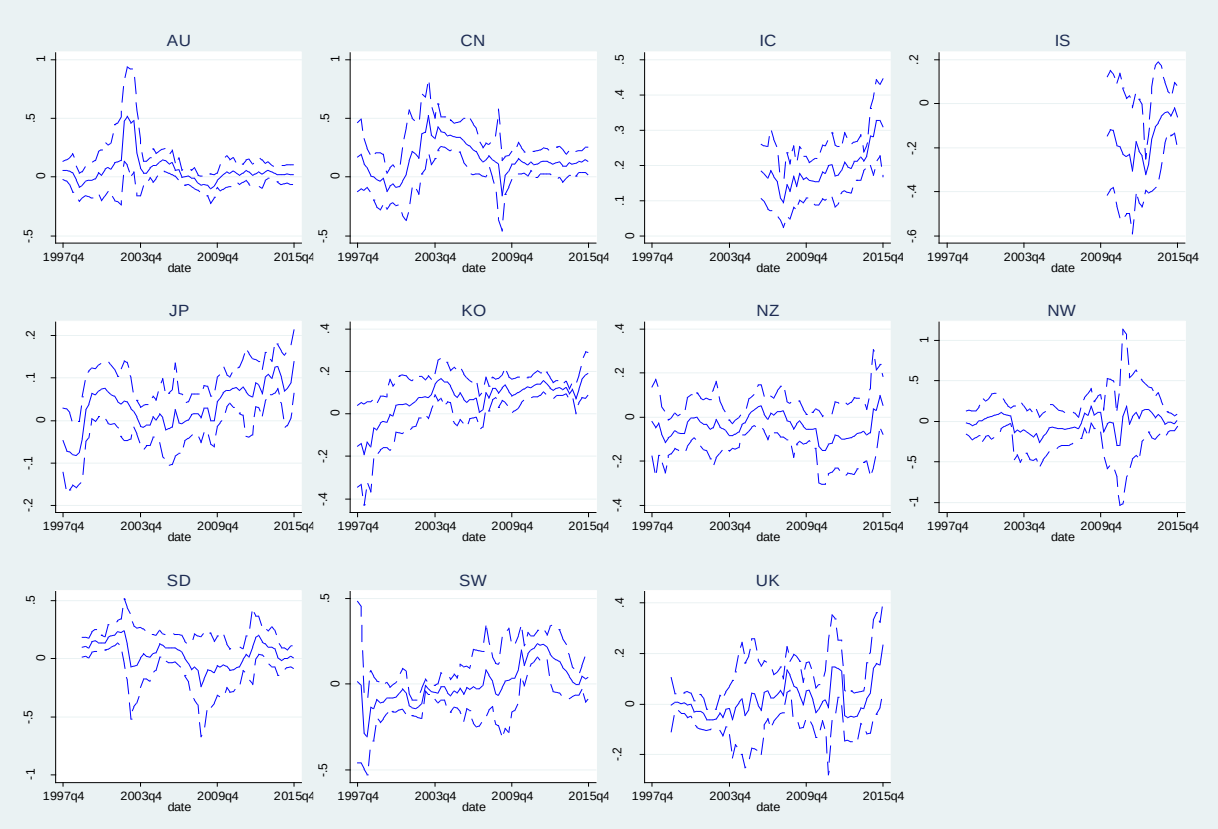
pass-through over time seem to be gradual, possibly reflecting slow-moving structural changes in the economy. In other cases the changes seem to be abrupt, possibly reflecting specific events or shocks affecting the economy.

d. Comparing reduced-form estimates of pass-through: Across countries and time

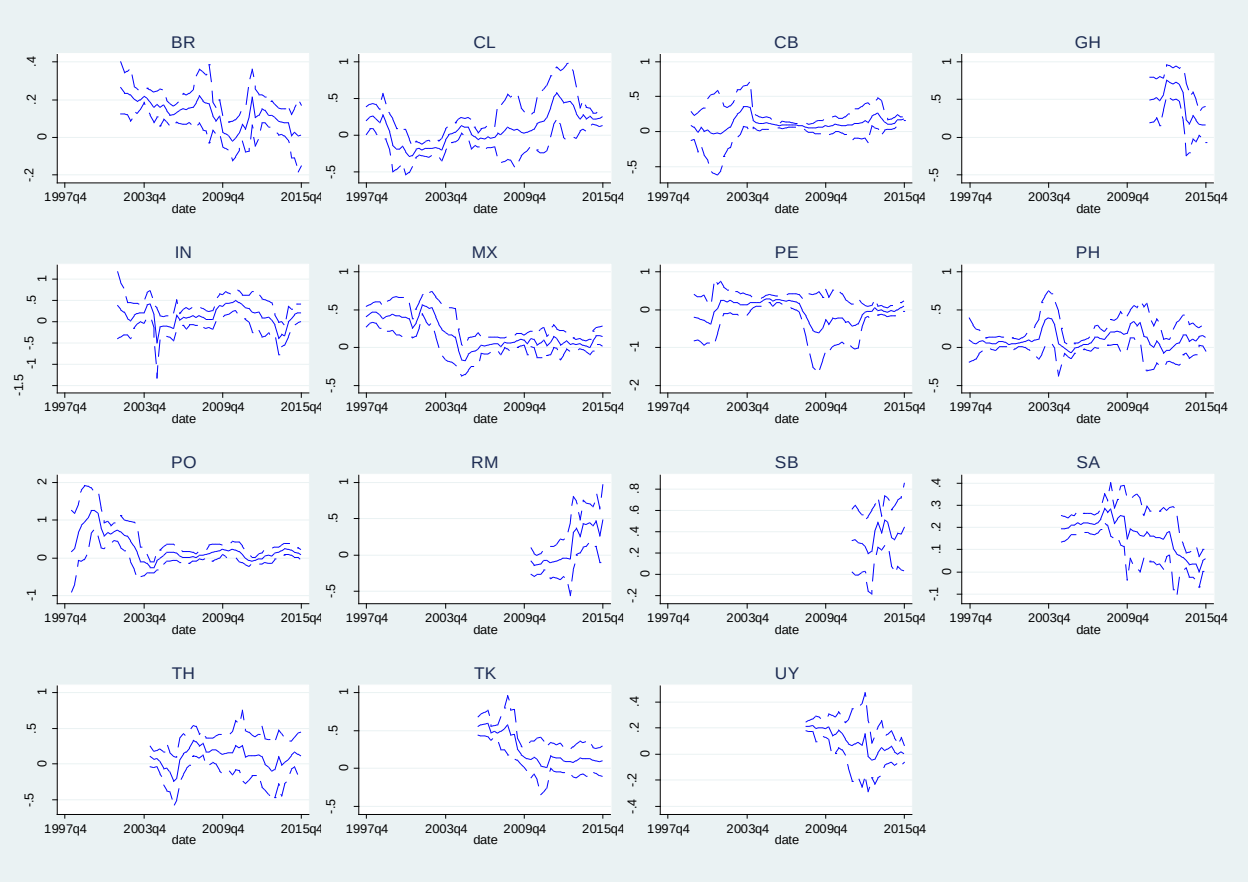
How important is the relative variation of pass-through in the cross-section relative to the time-series dimension in these reduced-form estimates? The average rate of pass-through across countries and time is 15% in our sample. Using the long-sample estimates in Figure 1, the range in the cross-section dimension of the pass-through estimates is from around 0% to 70%, with a standard deviation of 17 percentage points. Using the time-varying estimates in Figure 3, the range in the times-series dimension of the pass-through estimates for individual countries varies from fairly limited (-8% to 14% for Japan) to very large (-25% to 126% for Poland). The standard deviation for this time dimension ranges from 5 to 35 percentage points, with an average of 14 percentage points. This suggests that there is meaningful variation in estimated pass-through both across countries and across time. There may be slightly more variation, on average, in the cross-section dimension than the time-series dimension. But when moving from sample averages to individual country experiences, the variation in pass-through within individual countries across time can be even greater than the variation across countries.

Figure 3: Rolling 6-year pass-through estimates and confidence intervals

a) Advanced economies



b) Emerging economies



III. Shock-Based Estimates of Pass-through

Although estimating pass-through with the reduced-form approach used above has been fairly standard in the literature for decades, a very different approach which focuses on how the shocks underlying the exchange rate movement may affect pass-through has recently begun to gain more attention. This approach was initially introduced in Shambaugh (2008), but the shocks identified within his framework were difficult to reconcile with theoretical open-economy models and use in real time for economic forecasting. Forbes, Hjortsoe and Nenova (2015) use the same principles, but develop a very different and more tractable framework based on shocks and identification assumptions more tightly linked to theoretical models and directly applicable to forecasting. When applying that model to UK data, they show that the effect of exchange rate movements on prices differs across shocks, and that a different composition of shocks can explain some of the substantial variation in pass-through over time within the UK. Comunale and Kunovac (2017) then adapt and apply the model in Forbes *et al.* (2015) to several countries in the euro area.

This section further adapts this shock-based framework and applies it to estimate pass-through for a large set of more diverse countries—for each of the 26 advanced and emerging economies in our sample from Section II. This analysis shows that the correlation between exchange rates and prices varies across shocks. In particular, exchange rate movements caused by monetary policy shocks correspond to higher pass-through than exchange rate movements caused by demand shocks. These

results hold for all of the countries in our sample, generalising the findings for just the UK in Forbes *et al.* (2015). This suggests that pass-through may be estimated to be higher in countries and time periods where exchange rate movements were mainly (or disproportionately) caused by monetary policy shocks, and estimated to be lower in countries and time periods where demand shocks played a more important role.

a. The SVAR methodology

We use a modified version of the methodology developed in Forbes *et al.* (2015) to derive shock-dependent estimates of pass-through for each of the countries for which we computed reduced-form estimates in the last section.[11] More specifically, we estimate an SVAR with five variables for each country: changes in nominal trade-weighted exchange rates, consumer price inflation, real GDP growth, short-term interest rates, and changes in trade-weighted world export prices. Detailed definitions are available in Appendix A, and all variables are at a quarterly frequency. We allow for five shocks that can affect each country's exchange rate: three domestic shocks (supply, demand, and monetary policy) and two global shocks (with permanent and with temporary effects on output).

In order to identify these shocks, we use a set of standard and straightforward long- and short-run zero restrictions and sign restrictions, summarized in Table 1. More specifically, we assume that only domestic supply shocks and the permanent global shock affect the level of output in the long run. This is consistent with the idea that only changes in technology can affect the productive capacity of an economy in the long run, and that prices will adjust to ensure that markets clear.[12] We also assume that domestic shocks do not affect world export prices, either on impact or in the long run, which is the common "small open economy" assumption made in the literature.[13] Instead, only global shocks (either permanent or temporary) may have an impact on world export prices. Next, we impose several short-run sign restrictions on domestic shocks.[14] Supply shocks are associated with a negative correlation between GDP and the CPI on impact. Positive demand shocks are associated with a positive correlation between GDP and the CPI, a counter-cyclical monetary policy response, and an exchange rate appreciation. Monetary policy shocks are identified such that a lower interest rate is associated with a rise in GDP and the CPI, and a depreciation of the nominal exchange rate. Finally, our identification scheme does not impose any sign restrictions on the global shocks and only differentiates between the two based on the persistence of their impact on UK GDP. This combination of sign restrictions and zero restrictions constitutes the minimum number of economically sensible restrictions allowing us to identify the shocks of interest.

[11] The main difference between this framework and that in Forbes *et al.* (2015) is that we exclude import prices from the SVAR. Unfortunately there is not sufficient, reliable data on import prices for the countries in our sample over the time-series needed to estimate the model. We also do not allow for exogenous shocks to the exchange rate, as it is no longer possible to identify this shock with only four domestic variables.

[12] This identification restriction is based on work by Blanchard and Quah (1989) and Gali (1999) and is widely used in the SVAR literature, including by Shambaugh (2008) and Erceg *et al.* (2005).

[13] For example, see Liu *et al.* (2011) and Carrière-Swallow and Céspedes (2013).

[14] For additional explanation and evidence of these assumptions, see the theoretical model and discussion in Forbes *et al.* (2015). Also see Fry and Pagan (2011), Canova and de Nicolo (2003), Ellis *et al*. (2014) and Mountford (2005).

Finally, we impose this identification using an algorithm based on Rubio-Ramirez *et al.* (2010) and Binning (2013) and estimate the model using Bayesian methods with Minnesota priors.[15]

Table 1. SVAR identification

	Domestic supply shock	Domestic demand shock	Domestic monetary policy shock	Global permanent shock	Global temporary shock
			Short-run restrictions		
GDP	+	+	–		
CPI	-	+	–		
Interest rate		+	+		
Exchange rate		-	-		
World export prices	0	0	0	+	
			Long-run restrictions		
GDP		0	0		0
CPI					
Interest rate					
Exchange rate					
World export prices	0	0	0		

b. Shock-Based estimates of pass-through

We estimate this framework for each of the 26 countries in our sample from 1990 to 2015.[16] The framework allows us to analyse not only how pass-through changes depending on the underlying shocks, but also to assess the relative importance of different shocks in driving exchange rate movements across countries and time.

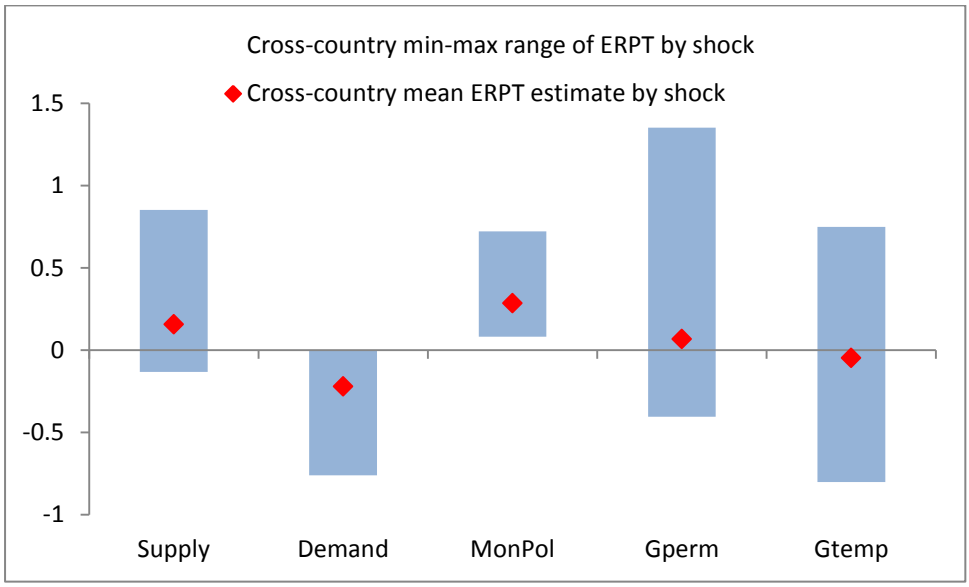
Figure 4 plots a summary of the initial results, averaged across countries. It shows the average percent change in consumer prices relative to the exchange rate (*i.e.*, pass-through), 8 quarters after a 1% depreciation in the exchange rate due to each shock. The shaded areas also show the range of these estimates across countries. The figure shows very different degrees of pass-through based on why the exchange rate has moved. A 1% depreciation corresponding to a monetary policy shock (looser monetary policy) corresponds to an increase in consumer prices of about 0.3% after about two years (on average across countries). In contrast, the same depreciation corresponding to a domestic demand shock (weaker domestic demand) corresponds to a decrease in consumer prices of about 0.3% over the same period. The other shocks causing currency depreciations have somewhat smaller effects and vary more based on the country under consideration.

The light-blue bands in Figure 4, however, show that pass-through corresponding to monetary policy shocks is different than pass-through corresponding to demand shocks for all countries in our sample. This suggests that the shock driving an exchange rate depreciation (or appreciation) – and in particular whether it's caused primarily by monetary policy or demand shocks – is important to

[15] The technical details of the estimation are identical to those in Forbes *et al.* (2015) and described in their Appendix B.
[16] Similarly to the estimates in Section II, we use data as far back as possible to 1990.

understand the magnitude and sign of the link between exchange rate movements and consumer prices. It could therefore also be important in explaining the variation in pass-through estimates across countries and time reported in Section II.

Figure 4. Cross-country averages and ranges for shock-dependent exchange rate pass-through (ERPT), eight quarters after SVAR shock



Notes: *The light blue range depicts the range of median shock-dependent pass-through estimates across the 26 countries, conditional on the shock causing the exchange rate to move. The first column shows the estimates after a domestic supply shock, the second after a domestic demand shock, the third after a domestic monetary policy shock and the fourth and fifth after permanent and temporary global shocks, respectively.*

But are certain shocks more important than others in explaining currency movements? Figure 5 reports the proportion of the forecast error variance for the exchange rate index explained by each of the five shocks, averaged across the full sample of countries. It shows that domestic demand and monetary policy shocks are the most important determinants of exchange rate movements on average across the countries and years in our sample. These shocks account for about 55-60% of the exchange rate forecast error variance after eight quarters. Domestic supply shocks and temporary global shocks appear to explain the smallest proportion of exchange rate movements.

Are there differences in the composition of shocks driving exchange rate movements across countries and/or across time, so that these differences in shock-dependent estimates of pass-through matter for overall pass-through? In order to answer this question, we examine how the contributions of the five shocks driving exchange rate movements vary across countries and over time within individual countries using several different approaches. Appendix Figure C1 shows the forecast variance decompositions for each country averaged over the full period. Appendix Figure C2 plots the historical decompositions over time for each country based on year-on-year exchange rate changes. Appendix Figure C3 reports the key statistics for a decomposition of the role of the two

most important shocks (to monetary policy and domestic demand) for the 6-year windows used in Figures 2 and 3.[17]

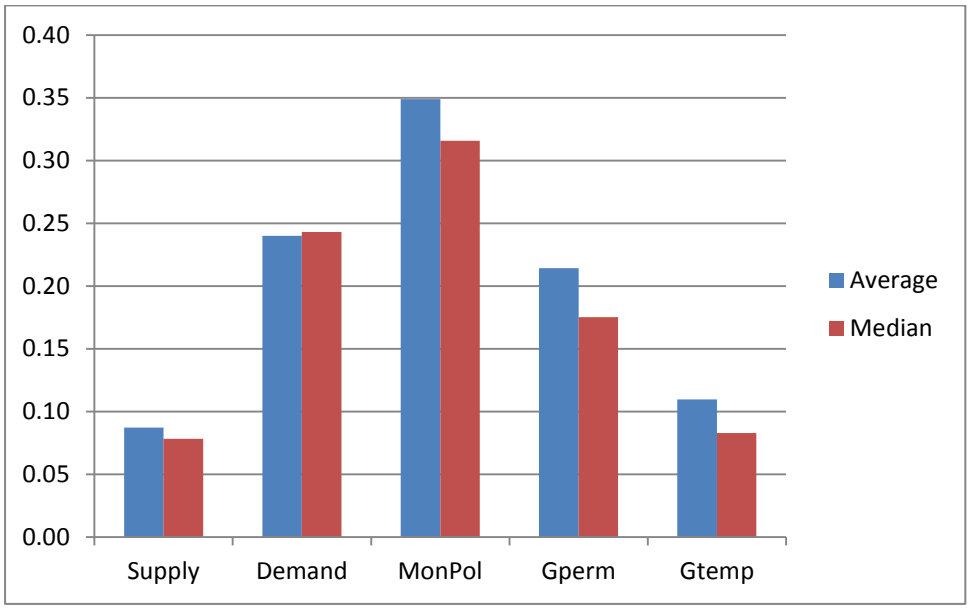
This series of decompositions of the role of the different shocks driving exchange rate movements continues to show a range of experiences in both the cross-section and time dimension. As an example of how these different weights could help explain differences in pass-through across countries, consider the full sample forecast error variance decompositions of exchange rate movements by country in Appendix Figure C1. In the advanced economies, Iceland is at one extreme—where almost 60% of the exchange rate forecast error variance is explained by monetary policy shocks. In contrast, Australia is at the other extreme, where only about 20% of the variance is explained by monetary policy shocks. Instead, demand shocks play an unusually large role in Australia (explaining over 50% of the exchange rate forecast error variance). Consistent with monetary policy shocks corresponding to greater pass-through, and demand shocks corresponding to lower pass-through, Iceland has the highest rate of pass-through in the advanced economies (at 22%), and Australia one of the lowest (at about 0%). Of course, this is a simplified example and does not control for the wide array of other variables that could explain differences in pass-through between Iceland and Australia, but it provides an example of how the types of shocks driving exchange rate movements could play a role in explaining differences in pass-through across countries.

Similarly, consider Korea and Chile as examples of how different shocks driving exchange rate movements can explain changes in pass-through over time within an individual country. As shown in Figure 3, Korea's and Chile's estimated pass-through has increased steadily since the 1990s. In both countries, this increase in estimated pass-through has corresponded to a notable rise in the contribution of monetary policy shocks to their exchange rate variances (as shown in Appendix Figure C3). Once again, this correlation is not a formal test of the determinants of pass-through, but it does highlight that the shocks corresponding to exchange rate movements change over time and therefore might drive changes in pass-through over time.

In the empirical analysis that follows, we will use these estimates of the contributions of different shocks to exchange rate movements in different countries and at different points in time. We will focus on the relative role of the two most important shocks—the domestic demand and monetary policy shocks. As shown in Figure 4, these are not only the most important shocks driving exchange rate movements, but also those which correspond to consistently different estimates of pass-through across all the countries in the sample. This allows us to assess if the relative importance of these specific shocks driving exchange rate movements can explain some of the variation in pass-through across countries and over time.

[17] More specifically, we construct a measure of the relative contribution of each shock over rolling 6-year windows by dividing the summed squares of each shock's contributions to quarterly exchange rate fluctuations over that window by the sum of squared contributions of all shocks. We report results for the demand and monetary policy shocks, which will be the key focus of the analysis below. An alternative measure could also be constructed by estimating the SVAR model over 6-year rolling windows and obtaining a formal rolling forecast error variance decomposition of the exchange rate. We prefer our measure based on the historical decomposition because of the imprecision resulting from estimating a five-variable, two-lag SVAR model using only 24 quarterly observations.

Figure 5. Average share of exchange rate forecast error variance (across countries) explained by SVAR shocks



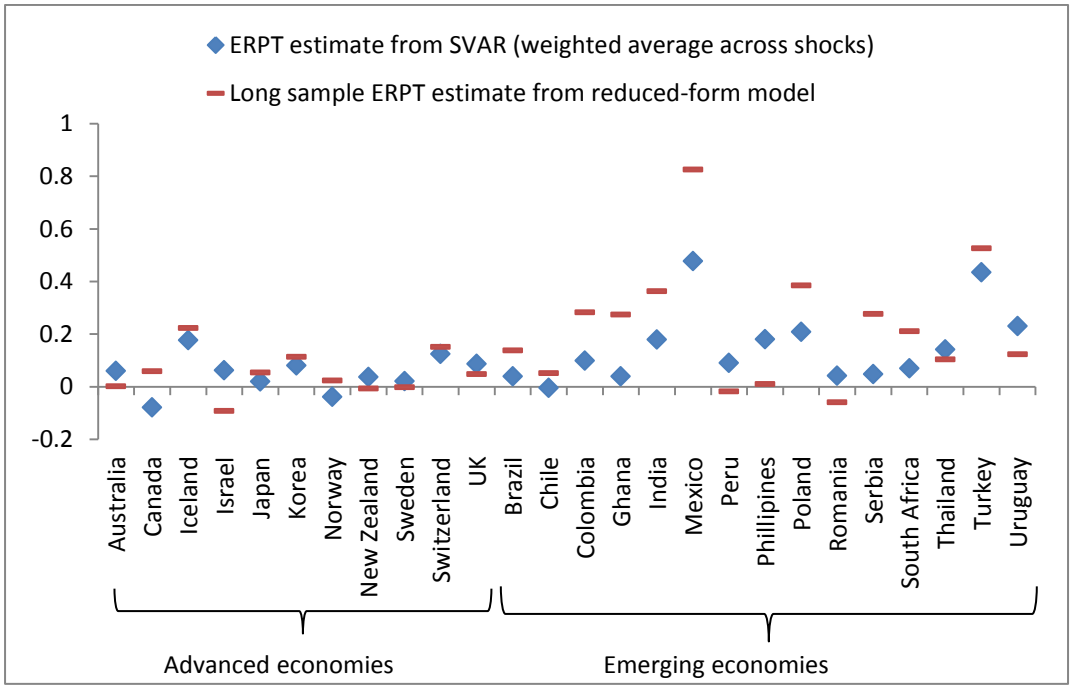
Notes: *The first pair of columns shows the estimates for a domestic supply shock, the second for a domestic demand shock, the third for a domestic monetary policy shock and the fourth and fifth for permanent and temporary global shocks, respectively.*

c. Shock-based versus reduced-form estimates of pass-through

Finally, we compare the estimates of pass-through obtained using this framework identifying the shocks behind exchange rate movements with those estimates of pass-through obtained in Section II, based on the reduced-form framework. To calculate the shock-dependent estimates, we use the forecast error variance decomposition over the whole sample period to weigh the shock-dependent exchange rate pass-through estimates and thus get full-sample estimates for each of the countries in our sample. Figure 6 reports the resulting estimates in blue diamonds, with the red lines showing the reduced-form pass-through estimates from Section II.

The pass-through estimates obtained using these two very different techniques are relatively close in most countries, and especially for advanced economies. For example, for countries such as Japan, Sweden, Switzerland, and the UK, the diamonds and lines showing the shock-based and reduced-form estimates intersect on the graph. For some emerging markets, there is a more notable difference between the two sets of estimates—although there is no clear pattern of one specification yielding higher or lower estimates. For example, for Peru and the Philippines, the shock-based estimates are greater than the reduced-form estimates, and for India and Mexico, the reduced-form estimates are larger than the shock-based. Overall, however, the estimates using these two frameworks are well correlated—with a correlation of 0.78 for the sample as a whole.

Figure 6. Comparing pass-through (ERPT) estimates from SVAR to reduced-form estimates



IV. Determinants of Cross-country Differences in Pass-Through

Now that we have estimated pass-through for our sample of 26 countries using the reduced-form approach common in the literature, as well as the shock-based approach developed more recently, it is possible to combine results to assess the relative importance of "shocks" versus "structure" in explaining pass-through. This section begins by assessing the importance of structural determinants in explaining the differences in pass-through across countries (as estimated in the reduced-form regressions in Section II). Then it incorporates the contribution of the different shocks driving exchange rate movements (as estimated in Section III), before testing for the importance of all of these factors simultaneously. This section of the paper focuses on understanding the cross-section dimension of pass-through (*i.e.*, the average rate of pass-through over the full time period available for each country) and ignores the time-series dimension. Section V applies the same framework to assess the importance of "shocks" versus "structure" in understanding the time-series dimension of pass-through for each country.

a. Structural determinants of pass-through across countries

In order to assess the role of country-specific or "structural" characteristics in explaining differences in pass-through across countries, we follow the two-stage regression approach used in Campa and Goldberg (2005). More specifically, we regress the OLS estimates of exchange rate pass-through from Section II on a range of variables that can affect pass-through and are consistent with the theoretical and empirical literature. Also following Campa and Goldberg (2005), we estimate the regressions with weighted (or generalized) least squares, using the inverse of the variance of the estimated pass-through coefficients as weights. This reduces the importance of imprecisely estimated exchange rate pass-through (ERPT) coefficients in our results.

We begin by focusing on variables that have been highlighted in the literature as significant in explaining differences in pass-through across countries. We will call these "structural" variables to simplify discussion, although some variables are only loosely "structural" and can change over short periods of time and may reflect policy choices. We begin with a measure of the share of imports invoiced in foreign currency, which tends to be positively correlated with pass-through (as shown convincingly in Gopinath, 2015).[18] The next three control variables are: the volatility of the exchange rate, the average inflation rate, and the volatility of inflation. Past work has found that these tend to be positively correlated with pass-through as firms in countries with higher or more volatile inflation or more volatile exchange rates tend to adjust prices more quickly to changes in relative international costs (see Campa and Goldberg, 2005 and Carriere-Swallow *et al.*, 2016). We also include a dummy variable equal to one for emerging markets, which tend to have less well anchored inflation expectations and a shorter history of independent central banks, both of which correspond to higher pass-through (see Jasova *et al*., 2016).

Then we include additional structural variables which focus on the economy's pattern of production. We include trade openness (as measured by each country's share of imports to GDP), as countries more exposed to imports tend to see a greater effect of exchange rate movements on prices (as noted in Choudhri and Hakura, 2006). We also control for the share of less differentiated goods in imports (as measured by the share of raw materials in imports), which tends to be positively correlated with pass-through as firms with less differentiated goods tend to more quickly pass on price changes resulting from exchange rate movements (as highlighted in Campa and Goldberg, 2005). Finally, we include a variable measuring the degree of regulation in domestic markets. More regulated markets tend to be more concentrated and have firms earning higher margins, allowing them to better absorb exchange rate movements without adjusting prices, and thus leading to less pass-through (as shown in Amiti *et al.*, 2016).[19]

Table 2 (columns 1-8) reports results when one of these structural variables at a time is used to explain different rates of pass-through across countries. In most cases, the coefficient on the structural variable has the expected sign and is statistically significant. More specifically greater exchange rate pass-through is significantly correlated with: a larger share of imports invoiced in foreign currency, more volatile exchange rates, higher inflation, more inflation, and the dummy variable for emerging market economies. These correlations agree with the existing literature. There are, however, also some variables where the bivariate regression coefficients are not significant. For example, both the measures of openness and differentiated goods in imports have the expected positive correlations with pass-through, but are not statistically significant.[20] Finally, the coefficient

[18] We use the published dataset accompanying Gopinath (2015) in our cross-country analysis. This provides the average historical invoicing currency breakdown for the imports of 18 of the 26 countries in our sample. When we examine the changes in pass-through over time within countries in Section V, we instead use a similar measure constructed by Ito and Kawai (2015). This only covers 13 countries in our sample, but provides a useful time dimension. The historical average of the Ito and Kawai (2015) measure is almost identical to the Gopinath (2015) estimates for this subset of countries.

[19] The measure of domestic regulation is developed by the OECD and captures the burden of regulations in the energy, transport and communications sectors. The OECD have recently started to publish an economy-wide measure of product market regulation (Koske *et al.*, 2015). Although the latter measure is broader and therefore would be our preferred measures, it is only available for a shorter period and for fewer countries—which further limits the already small degrees of freedom. The two measures are correlated, however, and substituting the economy-wide measure in our regression does not materially change our results (but reduces our degrees of freedom and affects the significance of some results).

[20] In other work, the composition of imports is only found to affect pass-through over time rather than cross-country (see Campa and Goldberg, 2005).

on the regulation measure is positive, instead of negative, and statistically significant. This may reflect the challenges in measuring regulation or omitted variable bias—as many of the structural variables are correlated (as shown in Appendix Table B3). For example, a positive correlation between the emerging market dummy and the regulation variable, combined with the positive relationship between the emerging market variable and the extent of pass-through, could cause the coefficient on regulation to be estimated as positive—simply reflecting the omitted effect of the emerging market dummy. This points to the need to shift to a multivariate regression framework—which is explored in part c below.

b. Shock-based determinants of pass-through across countries

In addition to a country's structural characteristics, could the different shocks causing exchange rate movements also affect the extent of pass-through across countries? For example, if some countries are more affected by monetary policy shocks, which Section III shows lead to greater pass-through, would those countries also tend to have greater estimated pass-through coefficients than other countries whose exchange rate fluctuations are more often caused by supply shocks or domestic demand shocks?

To test this, Table 2 continues its simple bivariate regressions predicting the different rates of pass-through across countries, except now includes controls (one at a time) for the contributions of the five SVAR shocks to the forecast error variance decomposition of the exchange rate. In other words, it now controls for the "shocks" instead of the "structure" in explaining differences in pass-through across countries. In addition, as Section III showed that the greatest differences in pass-through arise, on average, from exchange rate movements driven by demand shocks relative to those driven by monetary policy shocks, we also include the ratio of the contribution of the demand shocks to that of the monetary policy shocks as an additional control variable.

The resulting coefficient estimates to the right of Table 2 on the shock contributions are highlighted in grey and generally have the expected sign. For example, countries whose exchange rates are more often driven by demand shocks have lower exchange rate pass-through, and those whose exchange rates are more driven by monetary policy, supply shocks and global permanent shocks have higher pass-through. The relative contribution of the demand and monetary policy shocks—the two biggest drivers of exchange rate movements and which show the greatest differences in pass-through across countries—also has the expected negative sign. The coefficient estimates corresponding to the predominance of each shock, however, are generally not significant. This suggests that the nature of the shocks driving the exchange rate do not appear to be significant, unconditional drivers of cross-country differences in pass-through, at least over the full sample period.

Table 2. Determinants of estimated exchange rate pass-through: full sample, all control variables individually

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Foreign currency %	0.50**													
	(0.18)													
ER volatility		4.12***												
		(1.19)												
π (average)			10.91***											
			(2.40)											
π volatility				17.54***										
				(2.73)										
Emerging market dummy					0.10**									
					(0.05)									
Trade openness						0.33								
						(0.21)								
Less differentiated goods/imports							0.12							
							(0.36)							
Regulation								0.08**						
								(0.03)						
% demand shock									-0.26					
									(0.17)					
% monetary policy shock										0.06				
										(0.15)				
% demand shock to % monetary policy											-0.04			
											(0.03)			
% supply shock												0.30		
												(0.40)		
% permanent global shock													0.14	
													(0.18)	
% temporary global shock														-0.07
														(0.40)
Constant	-0.31*	-0.07	-0.00	-0.04	0.08***	0.01	0.08	-0.15	0.17***	0.09	0.15***	0.08*	0.08*	0.12**
	(0.16)	(0.06)	(0.03)	(0.03)	(0.03)	(0.07)	(0.08)	(0.11)	(0.04)	(0.06)	(0.03)	(0.04)	(0.05)	(0.04)
# observations	*18*	*26*	*26*	*26*	*26*	*26*	*26*	*19*	*26*	*26*	*26*	*26*	*26*	*26*
Degrees of freedom	*16*	*24*	*24*	*24*	*24*	*24*	*24*	*17*	*24*	*24*	*24*	*24*	*24*	*24*
Adjusted-R^2	*0.28*	*0.30*	*0.44*	*0.62*	*0.12*	*0.05*	*-0.04*	*0.23*	*0.06*	*-0.03*	*0.05*	*-0.02*	*-0.02*	*-0.04*

*Notes: Estimated using weighted least squares with the inverse of the variance of the estimated pass-through coefficients as weights. Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. The left-hand side variable is exchange rate pass-through, as estimated in Section II. Explanatory variables used in the regressions are the share of foreign currency invoicing in imports, the standard deviation of the exchange rate, the average quarterly inflation rate, the standard deviation of quarterly inflation, a dummy variable for emerging markets, trade openness (the share of imports in GDP), share of less differentiated imports (the share of raw materials in imports), the degree of market regulation, the contribution of the domestic demand shock to the forecast error variance decomposition of the exchange rate and that of the domestic monetary policy shock, the relative contribution of those two shocks, the contribution of the domestic supply shock, of the global permanent shock and of the global temporary shock.*

c. Shocks vs. Structure: Determinants of pass-through across countries

Finally, given the concerns about omitted variable bias, we simultaneously include different combinations of the "structural" variables with different combinations of the "shock" variables to explore their joint effects on exchange rate pass-through. Given the limited degrees of freedom and high correlations between many of the variables (as shown in Appendix Table B3), however, only a few variables can be included simultaneously. We therefore try several different combinations in a logical order, with the corresponding results in Tables 3a and 3b.

First, column 1 includes all five structural variables from Table 2 that have a significant coefficient with the expected sign. The coefficients on these variables change considerably when included simultaneously – most likely reflecting the high correlations between them.[21] Column 2 of Tables 3a and 3b reports a similar regression, but excludes the foreign currency share of imports in order to make use of all the observations in our dataset rather than just the 18 countries with data on invoicing currency shares. The standard deviation of inflation appears to be the strongest predictor of exchange rate pass-through in each country. It remains significant when the other four significant structural controls from Table 2 are included, and also receives the highest R^2 in the bivariate regressions in Table 2. Therefore, given its high correlation with the other variables in this set, the remainder of Table 3a focuses on inflation volatility as the control for nominal and currency-related structural characteristics as we add additional variables. Table 3b instead uses the foreign currency share of imports as the control for nominal and currency related structural characteristics.

Second, we explore whether any of the other three structural variables more closely related to the economy's pattern of production (openness, differentiated goods in imports, and regulation) add any explanatory power to the regressions predicting a country's average rate of pass-through (while controlling for the volatility of inflation) in Table 3a. Column (3) suggests that higher openness and a greater share of raw materials in imports can both contribute to higher pass-through and improve our ability to explain cross-country differences in pass-through (the adjusted R^2 increases by 0.18). The degree of regulation becomes insignificant and negative once we control for the other structural variables, as expected given our priors that the earlier positive coefficient may reflect omitted variable bias.

Finally, we add three of the shock variables – the share of the exchange rate forecast error variance explained by demand shocks, monetary policy shocks, and the ratio of the two – to the volatility of inflation (columns 4-6). The supply, global permanent and global temporary shocks are associated with more varied relationships between exchange rate movements across countries (as shown in Figure 4), so we will not focus on them as much in the remainder of the analysis. None of these shock-based control variables are significant, but they retain their expected signs (positive for monetary policy shocks, and negative for demand shocks and the ratio of the two). Columns 7-9 of Table 3a report results from simultaneously including controls for each of the shock variables and the combination of structural variables that were significant. The shocks remain insignificant and some of the coefficients on the additional structural variables become insignificant as well. The volatility of inflation, however, remains highly significant in each specification.

[21] For example, Gopinath (2015) discusses how the choice of invoicing currency is an endogenous decision that depends on exchange rate risk and monetary policy credibility.

Table 3b shows the same regression results, but conditional on using the foreign currency share of imports as our control for nominal and currency-related structural characteristics. The foreign currency share is less powerful than inflation volatility in explaining cross-country differences in estimated pass-through across our sample of 26 countries, but has received strong support in other work using a different sample of countries and time period (such as Gopinath, 2015). The share of foreign currency invoicing becomes significant (at the 5% or 10% level) when there is also a control for the proportion of exchange rate movements caused by monetary policy shocks (columns 5 and 8). Moreover, the shock-based variable in column (5) is also significant (at the 10% level), suggesting that countries with exchange rate movements more often caused by monetary policy shocks may have greater pass-through on average. This supports the theory that shocks causing exchange rate movements may have some role to play in explaining cross-country differences, although these regressions should be interpreted cautiously as they have very limited degrees of freedom and the shock-based coefficient estimates are often not significant.

Overall, structural characteristics appear to be of primary importance in explaining different rates of pass-through across countries, even after controlling for the nature of the shocks driving the exchange rate movement. Since many of these structural characteristics are highly correlated, it can be hard to isolate exactly which are most important, although the volatility of inflation appears to play a prominent role. There is also some evidence that the shocks corresponding to exchange rate movements may play some role in explaining different rates of pass-through across countries. Although these shock-based coefficients generally have the expected sign, they are often not statistically significant and do not appear to play nearly as important a role as the structural variables. These results support the approach generally followed in this literature that focuses on structural variables to understand cross-country differences in average rates of pass-through over long periods of time. In the next section we examine whether the drivers of the variation in pass-through within a country over time are the same as across countries.

Table 3. Determinants of estimated exchange rate pass-through: full sample, combinations of control variables

a) Controlling for the volatility of inflation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Foreign currency %	0.06								
	(0.17)								
ER volatility	0.18	1.25							
	(1.18)	(1.13)							
π (average)	3.82	-4.72							
	(6.82)	(5.95)							
π volatility	17.17**	24.52***	23.61***	17.09***	18.17***	16.90***	17.27***	17.50***	16.74***
	(7.70)	(6.99)	(3.21)	(2.92)	(2.66)	(2.82)	(2.82)	(2.69)	(2.77)
Emerging market dummy	-0.08	-0.05							
	(0.05)	(0.05)							
Trade openness			0.33**				0.29*	0.19	0.25
			(0.14)				(0.15)	(0.15)	(0.15)
Less differentiated goods/imports			0.38*				0.23	0.21	0.17
			(0.21)				(0.24)	(0.21)	(0.24)
Regulation			-0.02						
			(0.02)						
% demand shock				-0.06			0.06		
				(0.11)			(0.13)		
% monetary policy shock					0.15			0.11	
					(0.09)			(0.10)	
% demand shock to % monetary policy						-0.02			-0.01
						(0.02)			(0.02)
Constant	-0.10	-0.09**	-0.19**	-0.03	-0.10**	-0.02	-0.19*	-0.19**	-0.14
	(0.12)	(0.04)	(0.07)	(0.04)	(0.05)	(0.03)	(0.10)	(0.08)	(0.09)
# observations	*18*	*26*	*19*	*26*	*26*	*26*	*26*	*26*	*26*
Degrees of freedom	*12*	*21*	*14*	*23*	*23*	*23*	*21*	*21*	*21*
Adjusted-R^2	*0.70*	*0.64*	*0.82*	*0.60*	*0.64*	*0.62*	*0.63*	*0.65*	*0.63*

Notes: *Estimated using weighted least squares with the inverse of the variance of the estimated pass-through coefficients as weights. Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. For further details on variable definitions, see notes to Table 2.*

b) Controlling for foreign currency share of imports

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Foreign currency %	0.06		0.18	0.29	0.44**	0.35	0.29	0.43*	0.32
	(0.17)		(0.42)	(0.27)	(0.17)	(0.21)	(0.29)	(0.20)	(0.23)
ER volatility	0.18	1.25							
	(1.18)	(1.13)							
π (average)	3.82	-4.72							
	(6.82)	(5.95)							
π volatility	17.17**	24.52***							
	(7.70)	(6.99)							
Emerging market dummy	-0.08	-0.05							
	(0.05)	(0.05)							
Trade openness			0.23				0.16	0.06	0.17
			(0.28)				(0.26)	(0.24)	(0.23)
Less differentiated goods/imports			-0.08				-0.09	0.02	-0.11
			(0.43)				(0.38)	(0.32)	(0.35)
Regulation			0.05						
			(0.07)						
% demand shock				-0.25			-0.21		
				(0.24)			(0.30)		
% monetary policy shock					0.27*			0.24	
					(0.13)			(0.16)	
% demand shock to % monetary policy						-0.04			-0.04
						(0.03)			(0.03)
Constant	-0.10	-0.09**	-0.25	-0.06	-0.37**	-0.14	-0.10	-0.37**	-0.15
	(0.12)	(0.04)	(0.23)	(0.29)	(0.15)	(0.20)	(0.36)	(0.16)	(0.23)
# observations	*18*	*26*	*15*	*18*	*18*	*18*	*18*	*18*	*18*
Degrees of freedom	*12*	*21*	*10*	*15*	*15*	*15*	*13*	*13*	*13*
Adjusted-R^2	*0.70*	*0.64*	*0.17*	*0.28*	*0.40*	*0.31*	*0.22*	*0.31*	*0.26*

Notes: *Estimated using weighted least squares with the inverse of the variance of the estimated pass-through coefficients as weights. Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. For further details on variable definitions, see notes to Table 2.*

V. Determinants of Pass-Through over Time

The reduced-form estimates of pass-through in Section II showed that pass-through can vary substantially not only across countries, but also over time within individual countries. This section uses the same framework used to assess the cross-country differences in pass-through to analyse the time-series dimension. As in the previous section, we begin by testing for the role of structural factors, then test for the role of shocks, before testing for both simultaneously. We assess whether the structure and shocks matter both for the pass-through estimates over the 6-year periods reported in Figure 2, as well as for the rolling coefficient estimates reported in Figure 3.

a. Structural determinants of pass-through over time

A number of papers have documented how structural changes can affect the extent of pass-through over time. For example, Campa and Goldberg (2005) and Gagnon and Ihrig (2004) show that a smaller share of less differentiated goods in imports and more credible monetary policy contributed to the decline in pass-through in some advanced economies during the 1980s and 1990s. To assess the role of these types of variables in our framework, we estimate similar second-stage regressions as used in Section IV, except attempt to explain pass-through over the 6-year periods reported in Section II (using the estimates for the four non-overlapping periods shown in Figure 2 and the rolling coefficients in Figure 3) instead of over the full 25-year sample period. When examining the determinants of the pass-through estimates over the four non-overlapping 6-year periods, we simply use the average level of the estimated coefficients and the explanatory variables over the corresponding period. That approach is problematic for the corresponding analysis based on the rolling pass-through coefficients from Figure 3, however, because these are serially correlated by construction. To mitigate this problem, these second-stage regressions use quarterly first differences for the rolling exchange rate pass-through estimates, as well as for the explanatory variables.

For each of these regressions, we also include country fixed effects in order to control for any time-invariant structural characteristics that could explain differences (or persistent changes) in pass-through across countries. We also continue to control for the same set of structural variables used above, but exclude the dummy variable for emerging markets, as that is constant over time for most countries in our sample[22] and should only affect differences across countries and not over time. The results using quarterly changes in rolling exchange rate pass-through estimates also exclude the foreign currency share of imports and the domestic market regulation measure from the set of explanatory variables, as these are updated too infrequently[23] to use as determinants of differences in pass-through within a given quarter. The results when each structural variable is included individually are reported in Tables 4 and 5. The results for different combinations of the control variables are reported in Tables 6 and 7.

Starting with the bivariate regressions controlling for the structural variables (columns 1-7 of Table 4 and columns 1-5 of Table 5), we find that some of the structural variables that are significant in the cross-country regressions appear to be less important when considering the time dimension of pass-through. For example, the foreign currency share of imports becomes insignificant (Table 4), and exchange rate volatility is no longer significant at the 5% level under either timing convention. Both

[22] Israel and Korea are the only countries in our sample that changed status, having been re-classified as advanced economies by the IMF in the mid-1990s.
[23] The foreign currency share of imports is updated every few years and the OECD's regulation variable is updated annually.

the inflation rate and inflation volatility, however, remain highly significant, suggesting that higher and more volatile inflation is consistently associated with higher pass-through over time and not just across countries. Of the other structural variables, those measuring openness and the share of differentiated goods in imports are sometimes significant at the 10% level, while the measure of regulation is insignificant.

These results suggest some structural variables, and especially the volatility and average level of inflation, can help explain changes in pass-through over time in individual countries. When taken as a whole, however, the structural variables are generally less significant and robust than in the previous section, suggesting they play less of a role in explaining changes in pass-through over time than across countries.

b. Shock-based determinants of pass-through over time

Do shock-based variables have more success than the structural variables in explaining changes in pass-through over time? To test this, we continue to use the same specifications and estimate second-stage regressions of pass-through on the set of shock variables that were the focus of Section IV – the share of exchange rate forecast error variance explained by demand shocks, monetary policy shocks and the ratio of the two.

Results estimating the time-series dimension of pass-through using the shock-based variables are shown in columns 8-10 of Table 4 and columns 6-8 of Table 5 in grey. In contrast to the results for the cross-country regressions, all three shock-based variables are significant (while maintaining the expected signs) in both specifications.[24] In addition, whereas the adjusted R-squared coefficients of the cross-country bivariate regressions including structural variables were much higher than those for the shock-based controls (see Table 2), the explanatory power of the structural and shock-based variables are similar in these regressions explaining the differences in pass-through over the four non-overlapping periods (Table 4). In other words, the shock variables appear to be more important in explaining variations in exchange rate pass-through over relatively short periods of time than across countries, and about as important as structural characteristics.

[24] The other three shocks (supply, global permanent and global temporary) were not significant and are not reported for brevity.

Table 4. Determinants of estimated exchange rate pass-through: four 6-year periods, all control variables individually

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Foreign currency %	0.95									
	(0.60)									
ER volatility		1.29*								
		(0.70)								
π (average)			6.10**							
			(2.87)							
π volatility				12.40***						
				(2.85)						
Trade openness					0.63*					
					(0.32)					
Less differentiated goods/imports						0.77*				
						(0.38)				
Regulation							0.00			
							(0.02)			
% demand shock								-0.22*		
								(0.12)		
% monetary policy shock									0.32***	
									(0.12)	
% demand shock to % monetary policy										-0.03**
										(0.01)
Constant	-0.65	-0.04	-0.03	-0.04	-0.12	-0.10	0.00	0.16*	-0.03	0.20**
	(0.42)	(0.05)	(0.04)	(0.03)	(0.07)	(0.07)	(0.06)	(0.09)	(0.04)	(0.09)
# observations	*39*	*74*	*74*	*74*	*74*	*76*	*59*	*74*	*74*	*74*
Degrees of freedom	*25*	*47*	*47*	*47*	*47*	*49*	*39*	*47*	*47*	*47*
Adjusted-R^2	*0.47*	*0.52*	*0.53*	*0.63*	*0.52*	*0.52*	*0.49*	*0.52*	*0.55*	*0.53*

Notes: *Estimated using weighted least squares with the inverse of the variance of the estimated pass-through coefficients as weights. Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. For further details on variable definitions, see notes to Table 2.*
The four six-year periods considered are 1992-1997, 1998-2003, 2004-2009, and 2010-2015. All regressions include country fixed effects.

Table 5. Determinants of estimated exchange rate pass-through: changes in 6-year rolling pass-through estimates, all control variables individually

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ER volatility	-0.00							
	(0.19)							
π (average)		5.66***						
		(1.51)						
π volatility			6.03***					
			(0.94)					
Trade openness				-0.21				
				(0.41)				
Less differentiated goods/imports					0.49			
					(0.55)			
% demand shock						-0.27***		
						(0.04)		
% monetary policy shock							0.15***	
							(0.03)	
% demand shock to % monetary policy								-0.02***
								(0.00)
Constant	-0.01**	-0.01*	-0.01*	-0.01**	-0.01**	-0.01	-0.01*	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
# observations	*1474*	*1474*	*1474*	*1323*	*1474*	*1450*	*1450*	*1450*
Degrees of freedom	*1447*	*1447*	*1447*	*1297*	*1447*	*1423*	*1423*	*1423*
Adjusted-R^2	*-0.00*	*0.01*	*0.02*	*-0.00*	*-0.00*	*0.03*	*0.02*	*0.02*

Notes: *Estimated using weighted least squares with the inverse of the variance of the estimated pass-through coefficients as weights. Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. All explanatory variables are first differenced to match the timing convention of the independent variable. For further details on variable definitions, see notes to Table 2. All regressions include country fixed effects.*

c. *Shocks vs. Structure: Determinants of pass-through over time*

To complete our analysis of the determinants of pass-through over time, we simultaneously control for the structure and shock-based variables. We use the same criteria as in the last section to select the exact specifications: first include the most significant of the nominal and currency-related variables (which are highly correlated with each other), then test whether any of the remaining structural factors have explanatory power, and then introduce our shock variables. The results are reported in Tables 6 and 7 and support the preliminary conclusions from the regressions controlling for each of the variables separately.

The first set of results suggests that inflation volatility is still the most robust nominal or currency-related predictor of pass-through among the structural variables (see columns 1 and 2 of Table 6 and column 1 in Table 7). Therefore, we will continue to include this as a control in most of our specifications. Trade openness (measured as the ratio of imports to GDP) is sometimes significant (in the specification using the four time periods in column 3 of Table 6, but not for the rolling estimates in column 2 of Table 7). In contrast, the share of less differentiated goods in imports and the degree of regulation in domestic markets are not significant.

The most noteworthy change from the cross-section results, however, are the coefficients on the three shock variables; they have the expected sign and are usually significant. More specifically, the relative contribution of demand versus monetary policy shocks is significant at the 5% level after controlling for all significant structural factors in the sets of regressions using both timing approaches (columns 6 and 9 of Table 6 and columns 5 and 8 of Table 7). A higher contribution of monetary policy shocks is also significantly correlated with higher pass-through in some of the specifications using both timing conventions. This set of results suggests that the shock variables appear to be more important in explaining differences in exchange rate pass-through across time than across countries, and that of the shock variables, the most important is the prevalence of monetary policy shocks (by itself or in relation to the prevalence of demand shocks).

To check the robustness of these results and better understand the time frame over which the shocks seem to matter for exchange rate pass-through, we also estimate these regressions with pass-through coefficients estimated over 7-, 8-, and 10-year windows. The role of inflation volatility remains significant in each of these variants. The significance of the other structural variables fluctuates, however, based on the length of the windows considered. For example, the share of less differentiated goods in imports is significant when using 7-year windows, but not over the other windows; the degree of regulation is significant when using 8-year windows, but not the other two. Also, none of the three additional structural variables was significant with the 10-year windows after controlling for the volatility of inflation.

In sharp contrast, the role of the shock-based variables are more robust to these various timing conventions. All three shock-based variables remain significant in the regressions using changes in the rolling coefficients, as well as for the non-overlapping 7- and 8-year periods (at least at the 10% level). The only timing conventions in which they are no longer significant is the non-overlapping 10-year windows. This is not surprising as this longer window is closer to the “long-sample” pass-through estimates in which the nature of the shocks driving the exchange rate movement appears to be less important than for shorter periods.

Overall, these short-sample results suggest that the shocks behind an exchange rate movement are an important determinant of pass-through over time, even after controlling for structural variables. Exchange rate movements caused by monetary policy shocks correspond to significantly higher rates of pass-through, while those caused by demand shocks correspond to significantly lower degrees of pass-through. Structural variables also play some role in explaining pass-through over time, especially the volatility in inflation, although the importance of the other structural variables varies across specifications. In addition, the importance of the underlying shocks increases as the window over which one estimates pass-through decreases. This suggests that the nature of the shocks behind an exchange rate movement is probably more important for understanding short-term variations in pass-through, while the structural variables appear to be more important in explaining pass-through over longer periods.

VI. Shocks versus Structure: Assimilating the Results

The last two sections showed that variables measuring both an economy's structure as well as the shocks corresponding to an exchange rate movement can be statistically significant in estimating pass-through. But what are the magnitudes of the effects of the "structure" and "shock" variables? Even if the variables are significant, are the effects economically meaningful? How important are the two effects when explaining the cross-section relative to the time-series variation in pass-through? And how important are each of these variables in explaining overall pass-through? To answer these questions, we will focus on the role of inflation volatility as a proxy for the "structure" variables—as this was identified as the most consistently significant structural variable in explaining exchange rate pass-through in both the cross-section and time-series results. We will also focus on the share of the forecast error variance of the exchange rate explained by monetary policy shocks as a proxy for the "shock" variables—as this was identified as the most consistently significant shock variable in explaining exchange rate pass-through, especially over time.

a. Shocks vs. structure: What are the magnitudes of the effects?

To assess the magnitude of the effects of "structure" and "shocks" on exchange rate pass-through, it is useful to consider what the estimates would imply for countries that have different characteristics for the key structure and shock variables.

To begin, we evaluate the role of these structure and shock variables in explaining the cross-section variation in pass-through. Australia is an example of a country with low inflation volatility—with its standard deviation of quarterly CPI inflation ranking in the first quartile of our sample (at 0.5 percentage points on a quarterly basis). In contrast, Uruguay is an example of a country with high inflation volatility—with its standard deviation of inflation ranking in the third quartile of our sample (at 1.4 percentage points). To gauge the economic importance of inflation volatility on estimates of pass-through (holding all else equal), we multiply the difference between these two values of the structural variable (0.9 percentage points) by the estimated coefficient on inflation volatility from a specification that includes both "structure" and "shock" drivers of pass-through (such as column 5 of Table 3a). The calculated effect is meaningful; a country with Uruguay's inflation volatility is predicted to have exchange rate pass-through 17 percentage points higher than a country with Australia's lower inflation volatility.

It is also possible to do a similar comparison to assess the magnitude of the "shock" variables—such as the effect of the role of monetary policy shocks. Peru is an example of a country with a low contribution of monetary policy shocks to exchange rate movements—ranking in the first quartile on this basis (with monetary policy shocks causing 26% of unexpected exchange rate movements). In contrast, Romania is a country where monetary policy shocks play a greater role—ranking in the third quartile on this measure (with monetary policy shocks causing around 50% of exchange rate movements). Using the coefficient estimates from the same regression specification (from column 5 of Table 3a), shifting from Peru's weight on monetary policy shocks to that of Romania (*i.e.* increasing the contribution of monetary policy shocks to the unexpected exchange rate variance by 24 percentage points) would be expected to increase pass-through to consumer prices by 4 percentage points. This estimated magnitude of moving from the first to third quartile of the sample in the "shocks" variable on the average rate of pass-through for a given country is smaller than the magnitude from a similar move for the "structure" variable, suggesting that "structural" variables are more important in explaining the cross-section variation in pass-through. The effect of the shock variables, however, is still meaningful and economically important.

Next, moving from the cross-section to time-series dimension, we perform a similar comparison to assess the magnitude of the role of structure and shock variables in explaining the variation over time in pass-through within a country. To calibrate this exercise, assume an increase in inflation volatility or an increase in the contribution of monetary policy shocks by the average shift for all countries in the sample based on the non-overlapping 6-year windows. This corresponds to a 1 percentage point change in inflation volatility and an 18 percentage point change in the weight of monetary policy shocks. When combined with the estimates in column 5 of Table 6 (which controls for both structure and shock drivers of pass-through), this suggests that a country which experiences this average increase in inflation volatility over any of the short six-year periods would be predicted to have exchange rate pass-through increase by 13 percentage points. A country that experiences this average increase in the role of monetary policy shocks would be predicted to have exchange rate pass-through increase by 7 percentage points. Once again, the magnitude of the estimated effect of the structure variable is estimated to be larger than that of the shock variable, although both suggest large and economically meaningful effects.

b. Shocks versus structure: What is the explanatory power?

As an alternative way of quantifying the relative roles of "shocks" versus "structure" in the determination of exchange rate pass-through across countries as well as over time, it is also possible to compare changes in standard goodness-of-fit measures, such as the adjusted-R^2 from the cross-country and panel regressions. To make this comparison, we will continue to focus on the same measures to proxy for the role of shocks (the share of the forecast error variance of the exchange rate explained by monetary policy shocks) and structure (the standard deviation of inflation).

We begin by re-estimating a simplified set of cross-section regressions for long-sample exchange rate pass-through (in other words, we focus on the cross-section for one time period constituting the full sample). The three main regressions are reported in Table 8. The first column only includes the structure variable, the second column only includes the shock variable, and the third column includes both measures simultaneously. The simple regression only including the structural measures has a goodness-of-fit measure of 0.62, while the regression only including the shock

variable has a goodness-of fit of around zero. The column with both measures has a goodness-of-fit only slightly higher than that with only the structural variable. This suggests that the structure variable can explain a meaningful share of the variation in pass-through across countries, while the shock variable adds little.

Next, we estimate simplified regressions with the same two control variables for the shorter sample pass-through estimates (but with country fixed effects) in order to focus on the time-series dimension. Table 9 reports the results. The first three columns use the pass-through coefficients over the four non-overlapping six-year windows shown in Figure 2; the last three columns use the first differences of the six-year rolling estimates reported in Figure 3. The results for both timing conventions yield similar results. The adjusted-R^2s for the simple regressions with just the structural variable or just the shock variable are similar for the non-overlapping windows (0.63 and 0.55, respectively), and identical for the rolling estimates. The adjusted-R^2 when both variables are included simultaneously increases under both timing conventions—to 0.73 for the non-overlapping windows and more than doubling for the rolling estimates.

These results further support the earlier conclusions. Both the structure and the shock variables are important in explaining differences in exchange rate pass-through over time. Both should be incorporated in any analysis of the extent of pass-through from a given exchange rate movement in a specific country. The structural variables, however, appear to be the dominant driver of differences in average rates of pass-through across countries. Although the shocks corresponding to exchange rate movements may also play some role in explaining cross-country differences in pass-through, any such role appears to be small when evaluating average rates of pass-through over long windows of time.

VII. Conclusions

This paper investigates the determinants of exchange rate pass-through to consumer prices in 26 small open economies. In line with previous work, it finds that structural characteristics (such as the volatility and average rate of inflation, the volatility of the exchange rate and the share of imports invoiced in foreign currency) play important roles in explaining differences in pass-through across countries as well as over time. The economic conditions causing the exchange rate to move, however, also seem to play some role—a factor which has not been explicitly included in most work analysing pass-through. This role of the shocks behind exchange rate movements is particularly important when considering the determinants of pass-through over time (and less so when explaining differences in pass-through across countries). In particular, exchange rate movements caused by monetary policy shocks correspond to significantly higher rates of pass-through across a range of countries, while those caused by demand shocks correspond to lower degrees of pass-through. The estimated effects of both the structural variables and the shock compositions on exchange-rate pass-through are not only significant, but also large in magnitude.

These results have important implications for understanding and interpreting estimates of pass-through, and therefore for economic forecasting and setting monetary policy. Pass-through estimates can be very sensitive to the time period considered. Some changes in pass-through may reflect changes in the structure of the economy, which often persist and could therefore indicate a

long-lasting change in the country's rate of pass-through. Other changes in pass-through could instead reflect the configuration of shocks causing the exchange rate movement, a configuration which can quickly change. In this latter case, the change in the country's rate of pass-through would be less likely to last. In other words, the role of both the shocks and structural variables is important in order to understand if changes in pass-through will persist. For central bankers, understanding these dynamics is critically important in order to forecast how a given exchange rate movement will affect inflation in the future, and therefore how to adjust monetary policy. Both the "structure" and the "shocks" matter.

Table 6. Determinants of estimated exchange rate pass-through: four 6-year periods, combinations of control variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Foreign currency %	0.57								
	(0.57)								
ER volatility	-0.84	-1.38							
	(1.42)	(0.83)							
π (average)	-10.21	-10.18**							
	(9.14)	(4.29)							
π volatility	22.93**	26.52***	15.45***	11.64***	13.68***	12.26***	16.65***	16.25***	16.32***
	(9.64)	(5.67)	(2.72)	(2.95)	(2.49)	(2.69)	(2.69)	(2.54)	(2.44)
Trade openness			1.06***				1.21***	0.92***	1.11***
			(0.37)				(0.25)	(0.33)	(0.24)
Less differentiated goods/imports			0.51						
			(0.43)						
Regulation			0.02						
			(0.03)						
% demand shock				-0.11			-0.02		
				(0.11)			(0.09)		
% monetary policy shock					0.38***			0.15	
					(0.09)			(0.12)	
% demand shock to % monetary policy						-0.03**			-0.02**
						(0.01)			(0.01)
Constant	-0.38	0.02	-0.40***	0.04	-0.09***	0.14*	-0.29***	-0.26***	-0.16*
	(0.40)	(0.04)	(0.13)	(0.08)	(0.03)	(0.08)	(0.10)	(0.07)	(0.09)
# observations	*37*	*74*	*57*	*74*	*74*	*74*	*73*	*73*	*73*
Degrees of freedom	*20*	*45*	*34*	*46*	*46*	*46*	*44*	*44*	*44*
Adjusted-R^2	*0.57*	*0.67*	*0.75*	*0.63*	*0.73*	*0.67*	*0.75*	*0.76*	*0.77*

Notes: *Estimated using weighted least squares with the inverse of the variance of the estimated pass-through coefficients as weights. Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. For further details on variable definitions, see notes to Table 2.*
The four six-year periods considered are 1992-1997, 1998-2003, 2004-2009, and 2010-2015. All regressions include country fixed effects.

Table 7. Determinants of estimated exchange rate pass-through: changes in 6-year rolling pass-through estimates, combinations of control variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ER volatility	-0.79***							
	(0.21)							
π (average)	-3.64							
	(2.25)							
π volatility	9.73***	4.97***	4.92***	6.68***	5.27***	3.53***	5.83***	4.13***
	(1.53)	(0.96)	(0.95)	(0.94)	(0.96)	(0.97)	(0.96)	(0.98)
Trade openness		-0.29				-0.22	-0.11	-0.18
		(0.43)				(0.40)	(0.40)	(0.40)
Less differentiated goods/imports		0.70						
		(0.60)						
% demand shock			-0.23***			-0.28***		
			(0.04)			(0.04)		
% monetary policy shock				0.17***			0.19***	
				(0.03)			(0.03)	
% demand shock to % monetary policy					-0.01***			-0.01***
					(0.00)			(0.00)
Constant	-0.01	-0.01**	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
# observations	*1474*	*1323*	*1450*	*1450*	*1450*	*1304*	*1304*	*1304*
Degrees of freedom	*1445*	*1295*	*1422*	*1422*	*1422*	*1276*	*1276*	*1276*
Adjusted-R^2	*0.03*	*0.02*	*0.05*	*0.05*	*0.04*	*0.06*	*0.05*	*0.03*

Notes: *Estimated using weighted least squares with the inverse of the variance of the estimated pass-through coefficients as weights. Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. All explanatory variables are first differenced to match the timing convention of the independent variable. For further details on variable definitions, see notes to Table 2.*
All regressions include country fixed effects.

Table 8. Determinants of estimated exchange rate pass-through: comparing explanatory power of "shocks" versus "structure" across countries

	(1)	(2)	(3)
π volatility	17.54***		18.17***
	(2.73)		(2.66)
% monetary policy shock		0.06	0.15
		(0.15)	(0.09)
Constant	-0.04	0.09	-0.10**
	(0.03)	(0.06)	(0.05)
# observations	*26*	*26*	*26*
Degrees of freedom	*24*	*24*	*23*
Adjusted-R^2	*0.62*	*-0.03*	*0.64*

Notes: *Estimated using weighted least squares with the inverse of the variance of the estimated pass-through coefficients as weights. The dependent variable is the full sample reduced-form pass-through estimates shown in Figure 1.Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. For further details on variable definitions, see notes to Table 2. All regressions include country fixed effects.*

Table 9. Determinants of estimated exchange rate pass-through: comparing explanatory power of "shocks" versus "structure" over time

	(1)	(2)	(3)	(4)	(5)	(6)
	Non-overlapping 6-year windows			Rolling 6-year windows		
π volatility	12.40***		13.68***	6.03***		6.68***
	(2.85)		(2.49)	(0.94)		(0.94)
% monetary policy		0.32***	0.38***		0.15***	0.17***
		(0.12)	(0.09)		(0.03)	(0.03)
Constant	-0.04	-0.03	-0.09***	-0.01*	-0.01*	-0.00
	(0.03)	(0.04)	(0.03)	(0.00)	(0.00)	(0.00)
# observations	*74*	*74*	*74*	*1474*	*1450*	*1450*
Degrees of freedom	*47*	*47*	*46*	*1447*	*1423*	*1422*
Adjusted-R^2	*0.63*	*0.55*	*0.73*	*0.02*	*0.02*	*0.05*

Notes: *Estimated using weighted least squares with the inverse of the variance of the estimated pass-through coefficients as weights. Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. The dependent variable in regressions (1)-(3) is the level of exchange rate pass-through estimated over four non-overlapping six-year periods shown in Figure 2. The dependent variable in regressions (4)-(6) is the first difference of the rolling six-year exchange rate pass-through estimates shown in Figure 3; the explanatory variables in those regressions are also first differences in the six-year rolling standard deviation of inflation and the rolling contribution of monetary policy shocks. For further details on variable definitions, see notes to Table 2. All regressions include country fixed effects.*

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Appendix A: Data sources and sample periods

Appendix Table A1. Country-specific data sources

Country	Sample period[a]	Data sources for:					
		Consumer price index[b]	Nominal effective exchange rate index	Real GDP (national currency, seasonally adjusted)	Short-term interest rate[c]	Value of imports (national currency, seasonally adjusted)	Nominal GDP (national currency, seasonally adjusted)
ADVANCED ECONOMIES							
Australia	1990q1-2015q4	IMF International Financial Statistics	IMF International Financial Statistics	IMF International Financial Statistics	Central bank rate, IMF International Financial Statistics	OECD Quarterly National Accounts	OECD Quarterly National Accounts
Canada	1990q1-2015q4	IMF International Financial Statistics	IMF International Financial Statistics	OECD Economic Outlook	Central bank rate, OECD Main Economic Indicators	OECD Quarterly National Accounts	OECD Quarterly National Accounts
Iceland	2000q1-2015q4	IMF International Financial Statistics	IMF International Financial Statistics	IMF International Financial Statistics	Central bank rate, Central Bank of Iceland	OECD Quarterly National Accounts	OECD Quarterly National Accounts
Israel	2004q1-2015q4	IMF International Financial Statistics	IMF International Financial Statistics	IMF International Financial Statistics	3-month interbank rate, OECD Main Economic Indicators	OECD Quarterly National Accounts	OECD Quarterly National Accounts
Japan	1990q1-2015q4	IMF International Financial Statistics	IMF International Financial Statistics	IMF International Financial Statistics	Central bank rate, Oxford Economics	OECD Quarterly National Accounts	OECD Quarterly National Accounts
Korea	1990q1-2015q4	IMF International Financial Statistics	IMF International Financial Statistics	IMF International Financial Statistics	Central bank rate, IMF International Financial Statistics	OECD Quarterly National Accounts	OECD Quarterly National Accounts
Norway	1993q1-2015q4	IMF International Financial Statistics	IMF International Financial Statistics	IMF International Financial Statistics	Central bank rate, IMF International Financial Statistics	OECD Quarterly National Accounts	OECD Quarterly National Accounts
New Zealand	1990q1-2015q4	IMF International Financial Statistics	IMF International Financial Statistics	IMF International Financial Statistics	Overnight interbank rate, OECD Main Economic Indicators	OECD Quarterly National Accounts	OECD Quarterly National Accounts
Sweden	1993q1-2015q4	IMF International Financial Statistics	IMF International Financial Statistics	IMF International Financial Statistics	Official discount rate, Sveriges Riksbank	OECD Quarterly National Accounts	OECD Quarterly National Accounts
Switzerland	1990q1-2015q4	IMF International Financial Statistics	IMF International Financial Statistics	IMF International Financial Statistics	Central bank rate, IMF International Financial Statistics	OECD Quarterly National Accounts	OECD Quarterly National Accounts
UK	1993q1-2015q4	IMF International Financial Statistics	IMF International Financial Statistics	IMF International Financial Statistics	Central bank rate, IMF International Financial Statistics	OECD Quarterly National Accounts	OECD Quarterly National Accounts
EMERGING ECONOMIES							
Brazil	1995q4-2015q4	IMF International Financial Statistics	IMF International Financial Statistics	Oxford Economics	Central bank rate, Oxford Economics	OECD Quarterly National Accounts	OECD Quarterly National Accounts
Chile	1990q1-2015q4	OECD Main Economic Indicators	IMF International Financial Statistics	OECD Economic Outlook	Central bank rate, Oxford Economics	OECD Quarterly National Accounts	OECD Quarterly National Accounts
Colombia	1990q1-2015q4	IMF International Financial Statistics	IMF International Financial Statistics	IMF International Financial Statistics	90-day deposit certificate rate,	OECD Quarterly National Accounts	OECD Quarterly National Accounts

					OECD Main Economic Indicators		
Ghana	1990q1-2015q4	IMF International Financial Statistics	IMF International Financial Statistics	Ghana Statistical Services	Central bank rate, IMF International Financial Statistics	Oxford Economics	Oxford Economics
India	1990q1-2015q4	IMF International Financial Statistics	Bank for International Settlements	OECD Main Economic Indicators	Lending rate, IMF International Financial Statistics	OECD Quarterly National Accounts	OECD Quarterly National Accounts
Mexico	1990q1-2015q4	IMF International Financial Statistics	IMF International Financial Statistics	OECD Quarterly National Accounts	90-day T-bill rate, IMF International Financial Statistics	OECD Quarterly National Accounts	OECD Quarterly National Accounts
Peru	1993q3-2015q4	IMF International Financial Statistics	J.P. Morgan	Central Reserve Bank of Peru	Central bank rate, IMF International Financial Statistics	IMF International Financial Statistics	Central Reserve Bank of Peru
Philippines	1990q1-2015q4	IMF International Financial Statistics	IMF International Financial Statistics	Oxford Economics	Central bank rate, Oxford Economics	IMF International Financial Statistics	Philippine Statistics Authority
Poland	1992q1-2015q4	IMF International Financial Statistics	IMF International Financial Statistics	Oxford Economics	Central bank rate, Oxford Economics	OECD Quarterly National Accounts	OECD Quarterly National Accounts
Romania	2004q1-2015q4	IMF International Financial Statistics	IMF International Financial Statistics	Oxford Economics	Central bank rate, Oxford Economics	IMF International Financial Statistics	NIS - National Institute of Statistics, Romania
Serbia	2002q1-2015q4	IMF International Financial Statistics	National Bank of Serbia	IMF International Financial Statistics	Discount rate, National bank of Serbia	IMF International Financial Statistics	Statistical Office of the Republic of Serbia
South Africa	1990q1-2015q4	IMF International Financial Statistics	IMF International Financial Statistics	Statistics South Africa	Central bank rate, IMF International Financial Statistics	OECD Quarterly National Accounts	OECD Quarterly National Accounts
Thailand	1998q1-2015q4	IMF International Financial Statistics	Bank for International Settlements	NESDB - Office of the National Economic and Social Development Board, Thailand	Discount rate, IMF International Financial Statistics	IMF International Financial Statistics	NESDB - Office of the National Economic and Social Development Board, Thailand
Turkey	2000q1-2015q4	IMF International Financial Statistics	Bank for International Settlements	OECD Main Economic Indicators	Central bank rate, IMF International Financial Statistics	OECD Quarterly National Accounts	OECD Quarterly National Accounts
Uruguay	2002q1-2015q4	IMF International Financial Statistics	IMF International Financial Statistics	Banco Central del Uruguay	Central bank rate, IMF International Financial Statistics	Oxford Economics	Oxford Economics

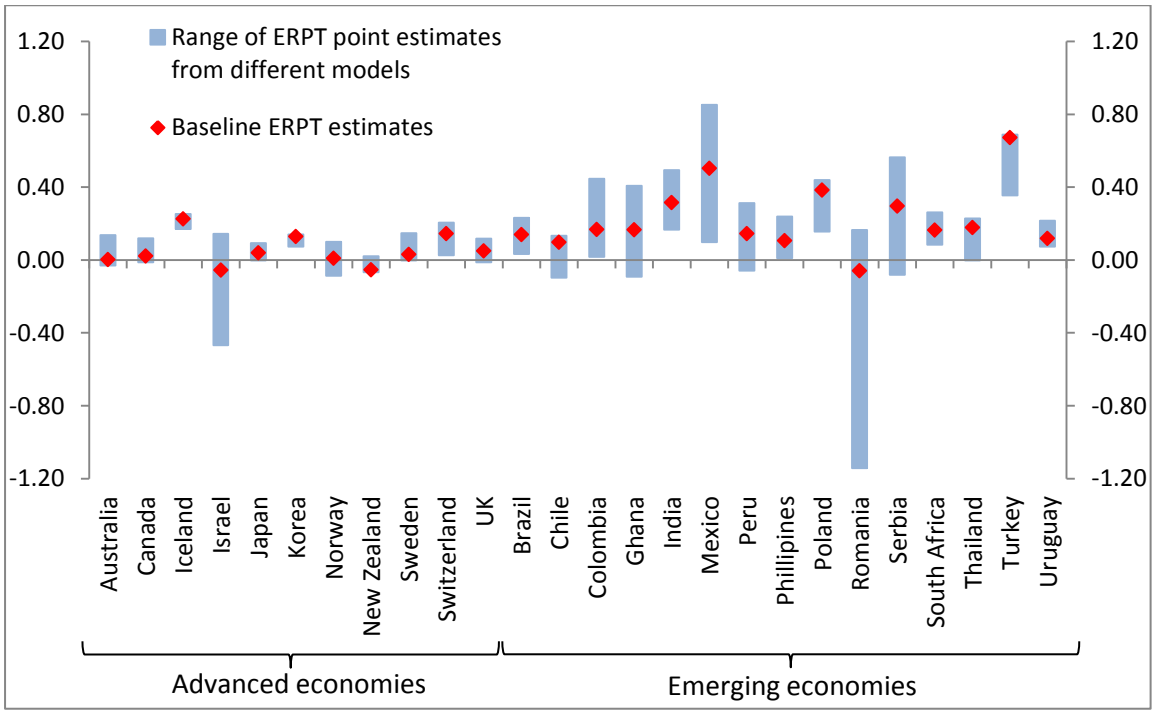
(a) As explained in the text, the sample period selection is determined by the existence of a floating exchange rate regime and data availability.
(b) We seasonally adjusted the quarterly series for all countries ourselves using the U.S. Census Bureau's X-12 method.
(c) Whenever available, we use an official policy interest rate. When that is not available or is only published for a short sample period, we resort to the shortest maturity market interest rate instead.

Appendix Table A2. Data sources common across countries

Variable	Data source	Notes
Trading partners' export prices	IMF - International Financial Statistics; Oxford Economics; National statistics offices	Export price indices, all commodities. Each country's export price index is seasonally adjusted using the U.S. Census Bureau's X-12 method.
Bilateral trade flows with trading partners	IMF - Direction of Trade Statistics	The US dollar value of imports and exports of each country in our sample with all its trading partners is used to construct the weights for trading partners' export prices.
Oil price	Thompson Reuters	Crude Oil Dated Brent U$/BBL.
Foreign currency %	Dataset developed for Gopinath (2016); available at: https://scholar.harvard.edu/gopinath/publications/international-price-system	Long-term average currency of invoicing share of imports; used in cross-sectional regressions.
	Dataset developed for Ito and Kawai (2015); provided by the authors.	Time-varying currency of invoicing share of imports; a continuous linearly interpolated version is used in panel regressions.
Less differentiated goods in imports	UNCTAD Merchandise Trade Matrix	Ratio of primary commodities (SITC 0 + 1 + 2 + 3 + 4 + 68) to the sum of total products and services.
Regulation	OECD Dataset: Regulation in energy, transport and communications 2013	The scores are linearly extrapolated from available time periods to contruct a continous time series.

Appendix B: Supplementary material on reduced-form exchange rate pass-through estimates

Appendix Figure B1. Range of estimates of "long-sample" exchange rate pass-through from 28 different model specifications. See Appendix Table B1 for a list of different specifications.



Appendix Table B1. List of 28 specifications for reduced-form estimates of pass-through

Model	Autoregressive lags?	Exchange rate lags	World export prices lags	Oil price lags?	Other controls?
1 (baseline)	No	0-4	0-4	No	Contemp. GDP growth
2	No	0-4	0-4	No	No
3	No	0-4	0-4	No	Contemp. GDP growth and short-term interest rate
4	No	0-4	0-4	0-4	Contemp. GDP growth
5	No	0-8	0-8	No	No
6	No	0-8	0-8	No	Contemp. GDP growth
7	No	0-8	0-8	No	Contemp. GDP growth and short-term interest rate
8	No	0-8	0-8	0-8	Contemp. GDP growth
9	1	0	0	No	Contemp. GDP growth
10	1	0-1	0-1	No	Contemp. GDP growth
11	1	0-2	0-2	No	Contemp. GDP growth
12	1	0-3	0-3	No	Contemp. GDP growth
13	1	0-4	0-4	No	Contemp. GDP growth
14	1	0-5	0-5	No	Contemp. GDP growth
15	1	0-6	0-6	No	Contemp. GDP growth
16	1	0-7	0-7	No	Contemp. GDP growth
17	1	0-8	0-8	No	Contemp. GDP growth
18	2	0	0	No	Contemp. GDP growth
19	2	0-1	0-1	No	Contemp. GDP growth
20	2	0-2	0-2	No	Contemp. GDP growth
21	2	0-3	0-3	No	Contemp. GDP growth
22	2	0-4	0-4	No	Contemp. GDP growth
23	2	0-5	0-5	No	Contemp. GDP growth
24	2	0-6	0-6	No	Contemp. GDP growth
25	2	0-7	0-7	No	Contemp. GDP growth
26	2	0-8	0-8	No	Contemp. GDP growth
27	3	0	0	No	Contemp. GDP growth
28	4	0	0	No	Contemp. GDP growth

Appendix Table B2. Pass-through estimates over four 6-year periods with 95% confidence bands

	1992-1997			1998-2003			2004-2009			2010-2015		
	B	**-2 s.e.**	**+2 s.e.**	***B***	**-2 s.e.**	**+2 s.e.**	***B***	**-2 s.e.**	**+2 s.e.**	***B***	**-2 s.e.**	**+2 s.e.**
ADVANCED ECONOMIES												
Australia	**0.06**	-0.02	0.14	**0.08**	-0.16	0.31	**-0.03**	-0.09	0.03	**0.02**	-0.06	0.10
Canada	**0.17**	-0.12	0.46	**0.33**	0.16	0.50	**0.11**	-0.01	0.23	**0.14**	0.02	0.26
Iceland							**0.17**	0.11	0.22	**0.31**	0.16	0.45
Israel										**-0.06**	-0.21	0.08
Japan	**-0.05**	-0.12	0.03	**-0.01**	-0.06	0.03	**0.04**	-0.01	0.10	**0.14**	0.07	0.22
Korea	**-0.15**	-0.34	0.04	**0.14**	0.09	0.19	**0.09**	0.01	0.16	**0.19**	0.09	0.29
Norway				**-0.10**	-0.40	0.19	**0.11**	-0.10	0.33	**0.02**	-0.06	0.09
New Zealand	**-0.02**	-0.18	0.14	**-0.08**	-0.15	-0.01	**-0.05**	-0.12	0.01	**0.05**	-0.08	0.18
Sweden				**0.01**	-0.26	0.27	**-0.06**	-0.31	0.20	**0.01**	-0.09	0.10
Switzerland	**0.01**	-0.46	0.49	**-0.05**	-0.09	-0.01	**0.03**	-0.16	0.23	**0.04**	-0.08	0.17
UK				**-0.02**	-0.11	0.07	**0.05**	-0.06	0.16	**0.23**	0.05	0.42
EMERGING ECONOMIES												
Brazil				**0.22**	0.19	0.25	**0.03**	-0.05	0.11	**0.01**	-0.15	0.17
Chile	**0.20**	0.01	0.39	**-0.06**	-0.20	0.09	**0.03**	-0.24	0.31	**0.25**	0.13	0.37
Colombia				**0.36**	0.06	0.66	**0.08**	-0.02	0.18	**0.18**	0.16	0.21
Ghana										**0.17**	-0.07	0.40
India				**0.21**	-0.04	0.45	**0.37**	0.11	0.64	**0.21**	0.00	0.41
Mexico	**0.41**	0.28	0.54	**0.20**	-0.16	0.56	**0.10**	0.03	0.17	**0.15**	0.01	0.28
Peru				**0.12**	-0.15	0.40	**-0.26**	-1.06	0.55	**0.11**	-0.02	0.24
Philippines	**0.10**	-0.19	0.39	**0.40**	0.04	0.75	**0.19**	-0.04	0.41	**0.13**	-0.05	0.31
Poland				**-0.09**	-0.46	0.28	**0.22**	0.09	0.35	**0.07**	-0.08	0.22
Romania										**0.49**	0.00	0.98
Serbia										**0.45**	0.04	0.86
South Africa							**0.15**	-0.04	0.33	**0.06**	0.01	0.11
Thailand							**0.14**	-0.13	0.42	**0.12**	-0.21	0.45
Turkey							**0.15**	0.01	0.28	**0.10**	-0.10	0.29
Uruguay							**0.20**	0.13	0.27	**0.00**	-0.06	0.06

Notes: *Reduced-form estimates of pass-through based on equation (1). See Appendix A for information on sample and data.*

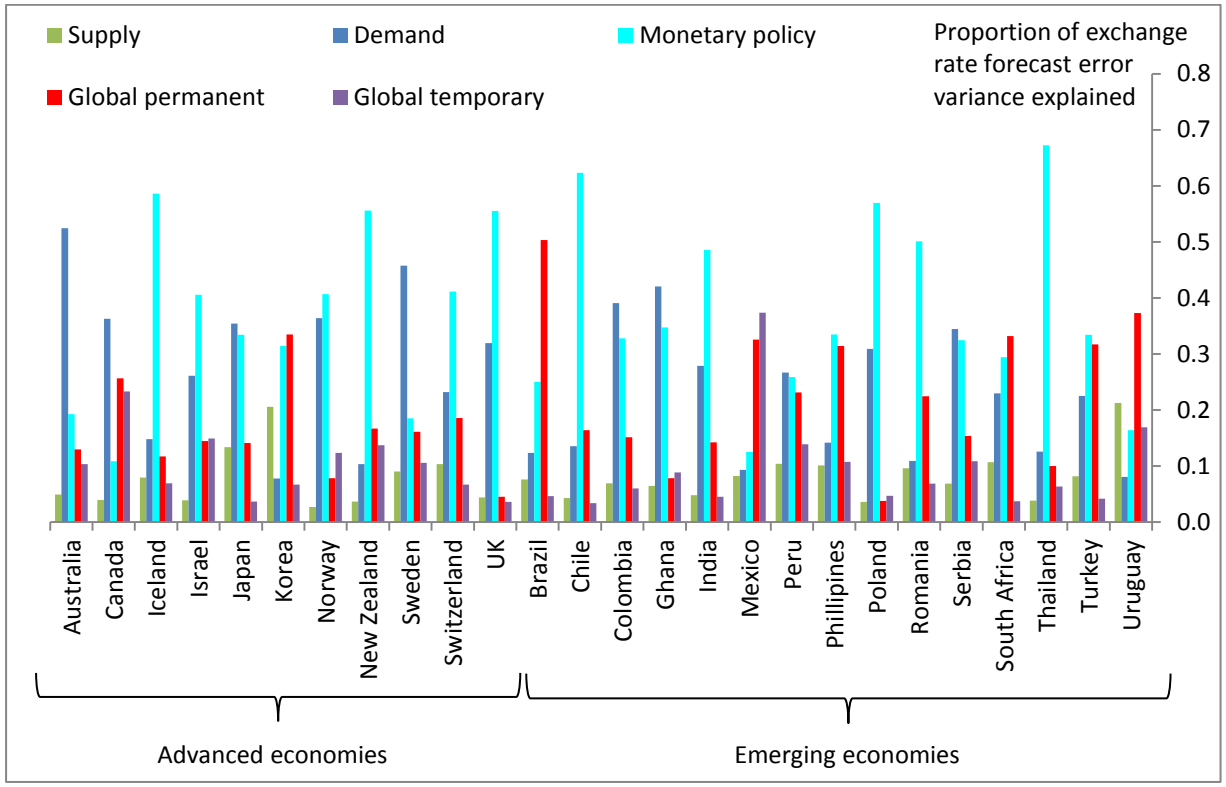
Appendix Table B3. Correlation matrix of control variables used in cross-country regressions

	Foreign currency	ER volatility	(average)	π volatility	EM dummy	Trade openness	Diff goods	Regulation	Demand	Monetary	Demand/ Monetary	Supply	Gl. Perm
Foreign currency %	1.00												
ER volatility	0.38	1.00											
π (average)	0.55	0.65	1.00										
π volatility	0.46	0.60	0.95	1.00									
EM dummy	0.57	0.41	0.81	0.73	1.00								
Trade openness	0.02	-0.33	-0.11	-0.01	-0.19	1.00							
Diff goods	0.33	0.42	0.20	0.16	0.20	-0.39	1.00						
Regulation	0.53	0.48	0.47	0.55	0.24	0.12	0.19	1.00					
Demand	-0.62	-0.47	-0.35	-0.24	-0.38	-0.22	-0.36	-0.38	1.00				
Monetary	0.29	-0.10	0.22	0.22	0.26	0.35	0.06	0.09	-0.40	1.00			
Ratio: dem. to mon	-0.54	-0.28	-0.35	-0.30	-0.38	-0.13	-0.35	-0.43	0.76	-0.78	1.00		
Supply	0.02	0.37	-0.09	-0.09	-0.14	0.05	0.67	0.16	-0.48	-0.14	-0.27	1.00	
Gl. Perm	0.32	0.65	0.31	0.18	0.34	-0.31	0.25	0.29	-0.53	-0.50	-0.05	0.43	1.00
Gl. Trans	-0.09	-0.42	-0.41	-0.38	-0.45	0.23	-0.47	-0.15	0.35	-0.54	0.69	-0.34	-0.02

Notes: *the shock variables are shaded. See notes to Table 2 for variable definitions.*

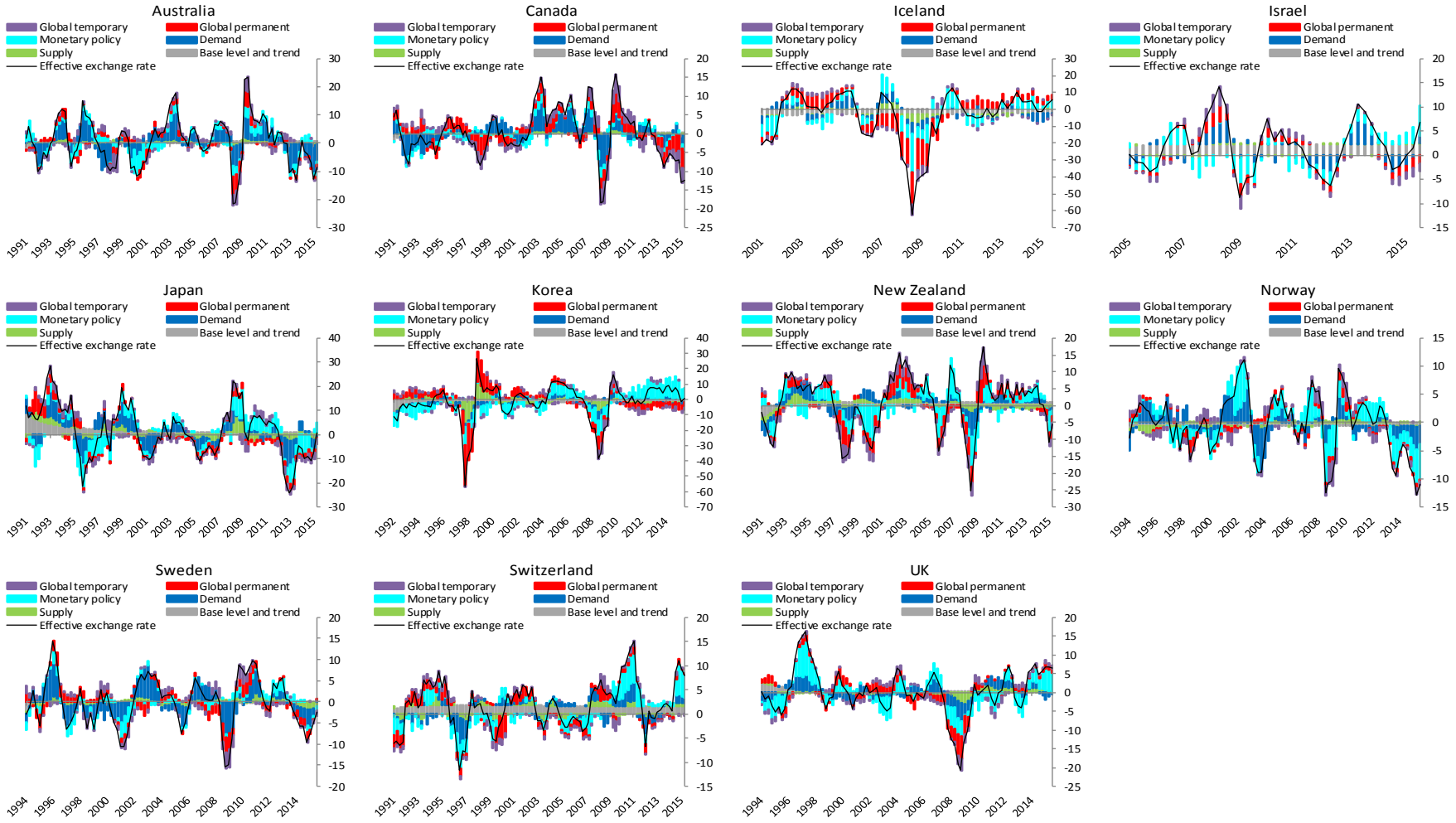
Appendix C: Contributions of shocks to exchange rate fluctuations across countries and over time

Appendix Figure C1: Forecast error variance decomposition of exchange rate changes, 1990-2015

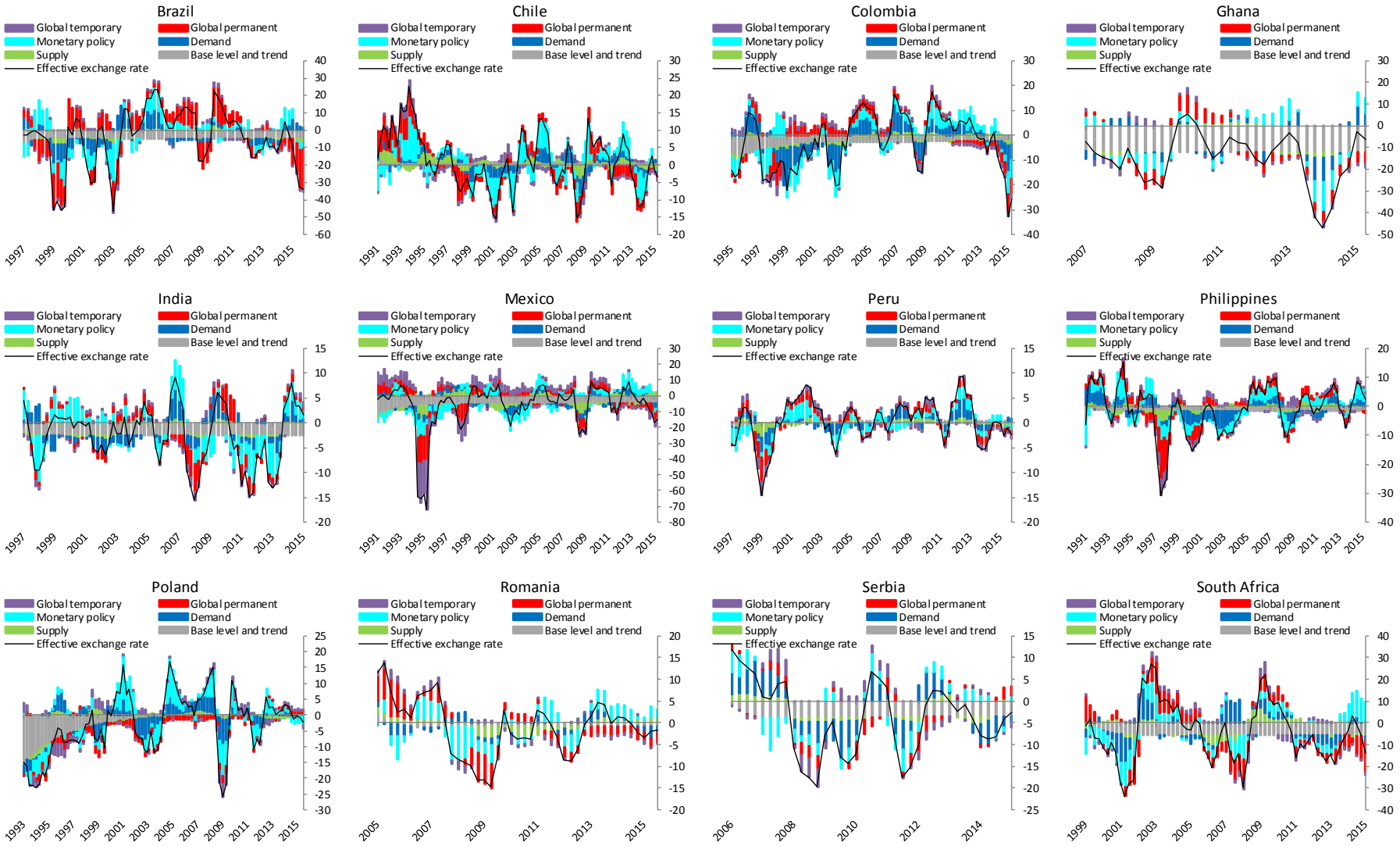


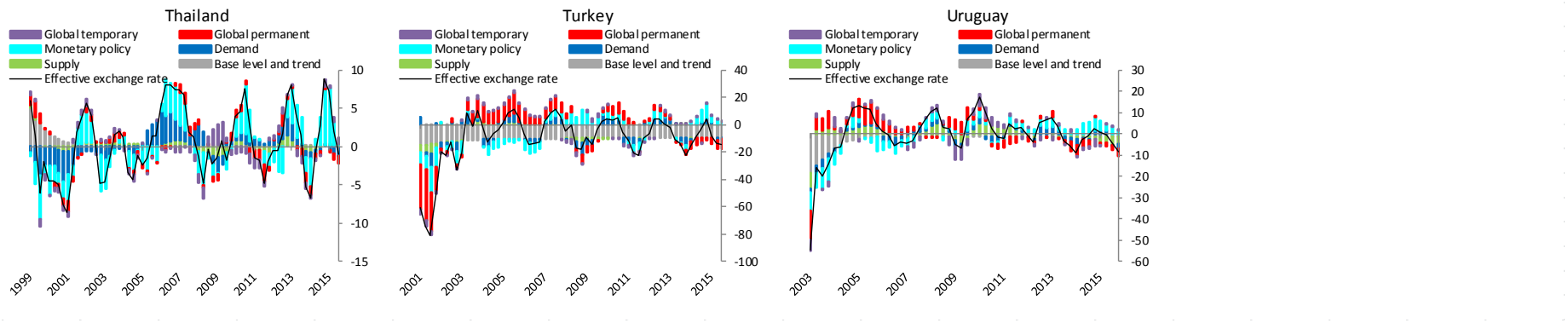
Appendix Figure C2: Historical shock decompositions of year-on-year exchange rate changes

a) Advanced economies



b) Emerging economies

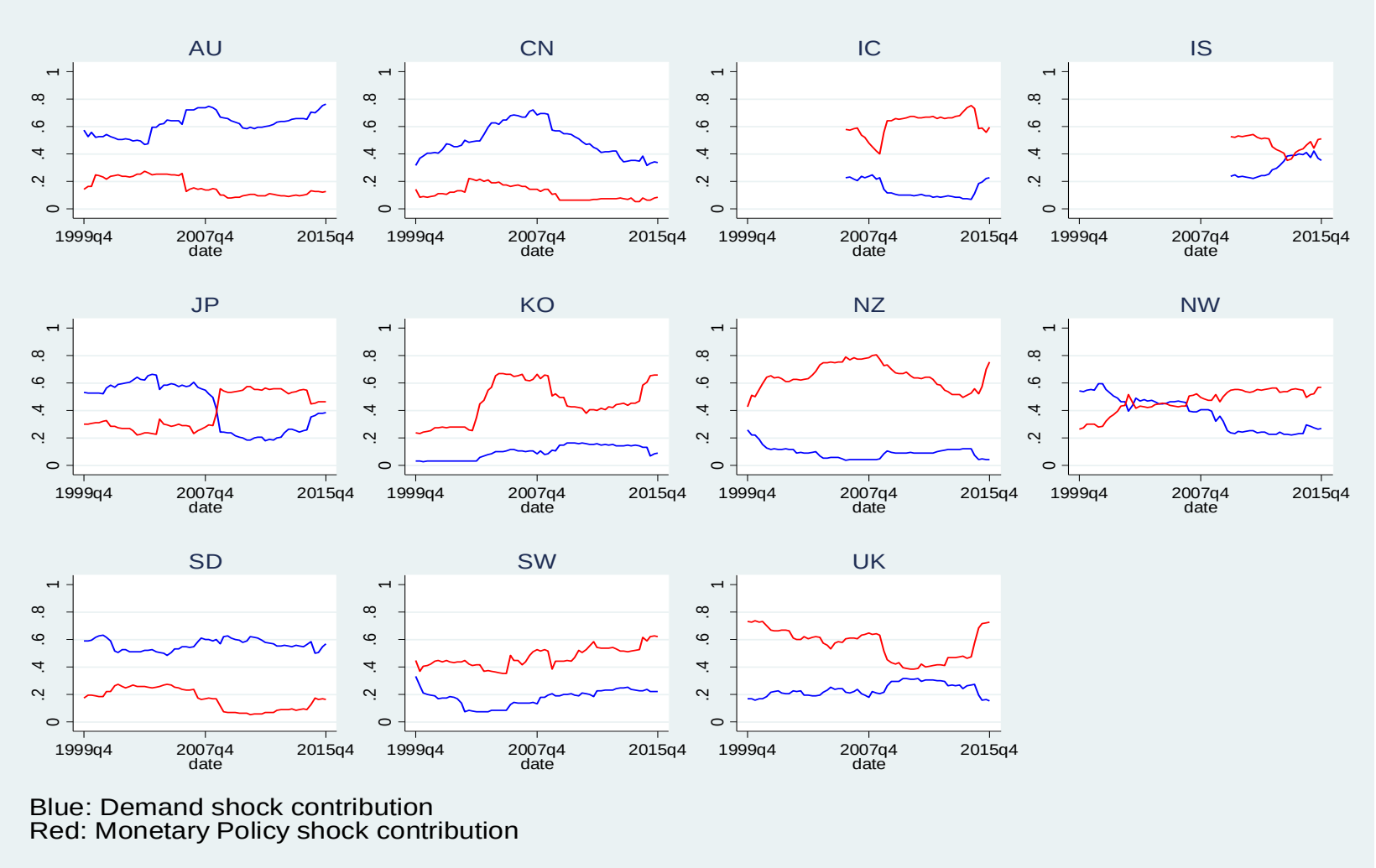




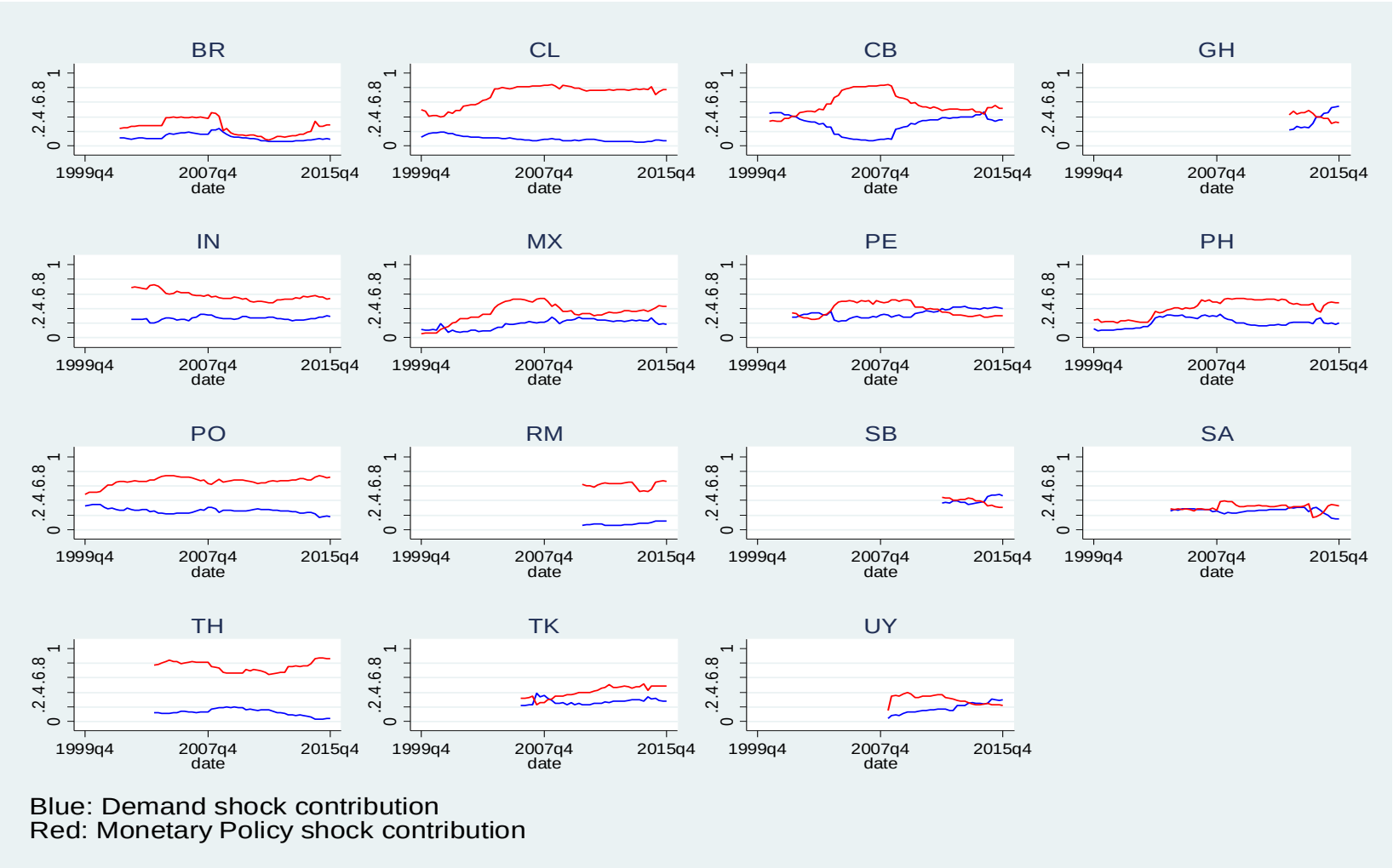
Notes: *The figures show the year-on-year changes in the quarterly trade-weighted exchange rate (effective exchange rate) of each country, decomposed into the historical contributions of the five SVAR-identified structural shocks. All data is expressed in percent. Unlike for the regression results in the rest of this paper, the exchange rate index has not been inverted for these charts, so that a positive change reflects an appreciation rather than a depreciation and vice versa.*

Appendix Figure C3: Contributions of domestic demand and monetary policy shocks to 6-year rolling exchange rate variance

a) Advanced economies



b) Emerging economies



Note: *The shock contributions are calculated as the sum of squared contributions of each shock (from Appendix Figure C1) divided by the sum of the squared contributions of all five shocks over a six-year rolling window.*