Monetary Policy Spillovers under Intermediate Exchange Rate Regimes

Ahmed, Rashad

University of Southern California

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Rashad Ahmed*

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Abstract

Testing the international Trilemma traditionally relies on discretely classified exchange rate regimes. This simplification limits the implications drawn for middle-ground policies like managed floats or basket pegs, and inhibits inference on the empirical shape of the exchange rate stability – monetary autonomy trade-off. To address these issues, this paper proposes a continuous measure of exchange rate flexibility for estimating monetary policy spillovers along the entire spectrum of peg intensities. Monetary spillovers generally increase with exchange rate stability, even within middle ground policies, and basket pegs diversify such spillovers. I then estimate the empirical shape of the trade-off using machine learning techniques, finding that the relationship between monetary autonomy and exchange rate stability is significantly non-linear in both advanced economies and emerging markets. Specifically, partially targeting the exchange rate translates to disproportionately smaller or larger monetary spillovers along middle-ground exchange rate regimes. For emerging markets in particular, active reserves management is a key mechanism associated with these non-linearities.

Keywords: International Reserves, Capital Flows, Financial Openness, International Spillovers, Exchange Rates, Trilemma, International Finance, Monetary Policy Shocks.

JEL Classifications: E4, E52, F30, F31

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1 Introduction

The international policy Trilemma Mundell [1963] states that no country can meet all three objectives: Independent monetary policy, free capital flows, and exchange rate stability. The importance of these implications has grown sharply amid the onset of rapid financial globalization, remaining an enduring topic of discussion among academics and policymakers alike. However, research on the policy Trilemma almost exclusively focuses on the effects of corner policy choices (e.g., exchange rates are either considered fixed or floating, capital accounts are either open or closed) because of the challenges associated with constructing continuous measures of Trilemma policy variables. Despite the substantial presence of intermediate exchange rate regimes around the world, we know relatively little of the implications of middle-ground policy choices on monetary autonomy. This study aims to address this gap in the literature.

A growing body of evidence suggests that the Trilemma generally holds in the short and long-run: conditional on open capital flows, international transmission of monetary policy from base countries tend to be stronger under fixed exchange rates than under floating (Frankel et al. [2004], Shambaugh [2004], Obstfeld et al. [2005], Miniane and Rogers [2007], Klein and Shambaugh [2015], Herwartz and Roestel [2017], Eichengreen [2018], Han and Wei [2018]).[1] Typical estimates of monetary pass-through suggest that transmission is incomplete (i.e. less than 1-for-1), and less complete in emerging markets, with the unanticipated component of base country monetary policy changes exhibiting greater pass-through rates (Bluedorn and Bowdler [2010]).

While the literature on international monetary spillovers under the policy Trilemma is highly active and growing, most empirical studies resort to categorizing exchange rate regimes in a binary fashion (fixed or floating) due to various challenges, including data limitations and the practical difficulties associated with classifying exchange rate regimes. Frankel et al. [2004] and Klein and Shambaugh [2015] break this trend by studying monetary autonomy while considering intermediate exchange rate regimes as a class of their own. Both studies find that intermediate regimes buy some monetary autonomy relative to fixed exchange rates. While offering several important contributions, these studies are limited in terms of allowing for heterogeneity *within* intermediate exchange rate regimes.[2] Given the wide spectrum of intermediate peg intensities, this may be an overly restrictive classification. Specifically, whether monetary policy spillovers are

[1] In contrast, a number of studies debate that the Trilemma has broken down to a 'Dilemma', rendering exchange rate policy irrelevant for monetary independence due to several reasons related to financial globalization (Calvo and Reinhart [2002], Frankel et al. [2004], Rey [2015], Miranda-Agrippino and Rey [2020], Georgiadis and Zhu [2019]). However, Klein and Shambaugh [2015] and Han and Wei [2018] specifically consider these factors and still find that monetary policy pass-through to foreign interest rates is significantly stronger (weaker) under fixed (floating) exchange rate regimes.

[2] Though importantly, Frankel et al. [2004] do differentiate between bands and managed floats, two regimes falling under the intermediate classification.

linearly, or non-linearly related to exchange rate policy remains an open question requiring greater detail on peg flexibility within the class of intermediate exchange rate regimes.

In this paper, I depart from the literature by introducing an exchange rate regime measure which is fully continuous. My particular approach brings with it three distinct advantages. First, it relaxes the constraint that all intermediate exchange rate regimes are identical. Second, It allows one to investigate the open question of whether monetary policy transmission under the Trilemma is linear in exchange rate flexibility, as typically assumed. If it is not, what are the policy implications? What mechanisms may be generating an empirical non-linearity? These are important issues that I attempt to address. Third, this approach allows for testing monetary spillovers under basket pegs, which itself remains unexplored in the empirical Trilemma literature.

Continuous exchange rate regime measures themselves are not new. A separate yet related line of research aims to study the Trilemma configuration using continuous policy measures. Aizenman et al. [2010], Aizenman et al. [2013], and Ito and Kawai [2014] investigate the Trilemma middle-ground under a continuous policy setting, but rather than focusing on monetary policy spillovers, they focus on macroeconomic outcomes and determinants of such middle-ground policy configurations (Aizenman and Ito [2014], Jordà et al. [2015], Frankel et al. [2019] and Obstfeld et al. [2019]).

Studies combining the two approaches – testing monetary policy spillovers under continuous measures of exchange rate flexibility – are few and far apart. One closely related paper, Herwartz and Roestel [2017], studies monetary pass-through in such a fashion among a sample of advanced economies, documenting a nearly linear trade-off between exchange rate stability and monetary autonomy. I build on this issue, differing from the previous study in several ways. First, I consider a larger panel of countries across both advanced economies and emerging markets. Second, I introduce a different continuous, de facto measure of exchange rate regime by drawing on the literature related to estimating currency zones.[3] I estimate non-overlapping, quarterly de facto peg intensities vis-a-vis three candidate base currencies using daily exchange rate returns. The method is flexible enough to allow for multiple exchange rate targets, allowing for spillover tests under basket peg policies. By contrast, Herwartz and Roestel [2017] rely on the exchange stability index proposed in Aizenman et al. [2008], which is a transformation of the annual standard deviation of monthly exchange rate changes. By using higher-frequency, daily exchange rate data my approach provides more consistent estimates of quarterly de facto exchange rate variability. I then go a step further in attempting to identify the underlying mechanisms which may lead to a non-linear relationship between exchange rate flexibility and monetary autonomy, namely exchange market intervention via international reserves, and international limits to arbitrage.

The main contributions of this paper are three-fold. First, under a new continuous

[3] Haldane and Hall [1991] and Frankel and Wei [1992].

exchange rate regime measure, I confirm prevailing evidence of existing monetary policy spillovers within the context of the international Trilemma. Second, I document new evidence suggesting that monetary policy spillovers can be diversified under basket pegs. Third, I test the linearity of the Trilemma through leveraging both standard econometric methods and more recent machine learning models such as Generalized Additive Models (GAMs). In both sets of tests, I identify the effects of foreign monetary policy shocks on domestic monetary policy using the instrumental variables (IV) approach of Jordà et al. [2015] and Jordà et al. [2020]. Both the standard econometric and GAM specifications point to a significant non-linear relationship between exchange rate flexibility and monetary independence along intermediate exchange rate regimes: greater exchange rate stabilization translates to disproportionately smaller or larger losses in monetary autonomy along certain parts of the peg intensity spectrum. This contrasts Herwartz and Roestel [2017], who find a near linear relationship between exchange rate stability and monetary autonomy. Moreover, net 'gains' in monetary autonomy are allocated differently across advanced economies and emerging markets. Advanced economies tend to put greater emphasis on output stabilization while emerging markets focus on inflation. Among emerging markets, active reserves management appears to be a plausible mechanism generating these empirical non-linearities. These findings are robust to a variety of sensitivity tests, including: testing for short-run and long-run monetary spillovers; accounting for the zero lower bound; alternative exchange rate regime classifications; using exogenous U.S. monetary policy shocks around FOMC events; omitting the 2008 Global Financial Crisis period; changes in the SDR basket components.

These results also bear implications for the Two-Corners Hypothesis which gained popularity after the late 90's early 2000's chain of financial crises experienced across the world. The argument is that middle ground exchange rate regimes are unstable and crisis prone, therefore exchange rate policy should converge to either fixed or floating (Frankel et al. [2000]). However, empirically this hypothesis has been continuously rejected, as middle-ground exchange rate policies are alive and well (Fischer [2001], Masson [2001], Williamson [2002], Frankel [2019], Frankel et al. [2019]). Most of the world follows an intermediate exchange rate regime. As of 2018, 46.6% of the 189 IMF member countries report administering intermediate pegs - up from 40% in 2010.[4] In addition, extensive empirical evidence suggests that many of the world's floating exchange rates are actually *managed* floats - i.e., intermediate pegs of varying flexibility. Calvo and Reinhart [2002] and Ilzetzki et al. [2019] both highlight the systematic 'Fear of Floating' exhibited by exchange rates of countries which presumably claim to float, despite pervasive contradicting evidence. My findings support this view such that across countries and over time, a substantial proportion of countries in the sample appear to partially target the

[4]Source: IMF Annual Report of Exchange Arrangements and Exchange Restrictions (AREAER) for the year 2018

exchange rate.

The rest of the paper is structured as follows: Section 2 briefly goes over the data. Section 3 discusses measurement and estimation of continuous de facto exchange rate regimes. Section 4 goes on to discuss notable trends and statistics in de facto exchange rate regimes across countries over the last two decades. Section 5 covers the baseline empirical strategy for analyzing monetary policy transmission under the policy Trilemma. Section 6 then goes over baseline results. Section 7 pays particular focus on testing for potential non-linear monetary policy spillovers under intermediate exchange rate regimes and Section 8 then explores potential underlying mechanisms which may generate these non-linearities. Section 9 covers a battery of robustness checks and Section 10 concludes.

2 Data

I consider a panel composed of 46 countries which does not include the U.S. and E.U. over the period Q1 2000 to Q4 2018 (quarterly frequency).[5] 12 are Advanced Economies and 34 are Emerging Markets. The list of countries are reported in Table A.1 in the Appendix.[6] The data was collected from multiple sources. Quarterly central bank policy interest rates are taken from the BIS and IMF IFS databases. Additional data on interest rates were collected from individual central bank websites and Global Financial Data. When official central bank policy rates could not be used, short-term treasury bills, repos, or discount rates are used. The use of short-term rates ensures that proper testing of the Trilemma, based on UIP, can be conducted such that maturities broadly match across countries.

Inflation and CPI data is primarily drawn from the BIS, IMF IFS, and the World Bank. For country-quarter observations where data was not available, annual inflation rates (divided by four) were used for imputation. Inflation is year-over-year. Nominal GDP data is from the IMF IFS database. Growth rates are computed as year-over-year. Missing observations were imputed using annual frequency growth rates from the World Bank. Daily exchange rate data is taken from the BIS and are used to estimate de-facto exchange rate peg intensity. Moreover, daily log returns are aggregated to the quarterly frequency, and combined with inflation data to recover quarterly real exchange rate returns. A positive change in the real exchange rate corresponds to local depreciation. Daily commodity price data for gold, copper, crude oil, coffee and sugar are taken from Bloomberg. Specifically, I rely on front month futures contract prices. Data on daily and quarterly CBOE VIX index values, a common gauge for global risk appetite, are from

[5]The country choice is subject to data coverage. The data is taken from all publicly available sources. After cleaning and merging data from various sources, 46 countries in total have sufficient sized samples to conduct the analysis.

[6]Select Tables and Figures are moved to the Appendix for brevity. Table an figure numbers labeled with 'A' refer to those in the Appendix.

FRED.

Annual capital controls measures are taken from the Chinn-Ito index (Chinn and Ito [2006]) derived from the IMF AREAER, and repeated over each quarter within the year. For Serbia, capital control measurements are taken from the Wang-Jahan index, which is also derived from the IMF AREAR index. Remaining missing values for Serbia are extrapolated (2000-2004, and 2014-2018). Since the index is updated through 2017, I extrapolate 2017 values to 2018. Developed and Emerging/Developing Economy classifications are taken from IMF WEO (2019). Data on foreign exchange reserves are taken from the IMF International Reserves and Foreign Currency Liquidity database. International reserves are measured as the sum of total foreign currency reserves, IMF reserve positions and SDRs. Gold holdings are excluded from calculation.

For robustness, additional tests are run using alternative definitions of exchange rate regime. Specifically, I use the Ilzetzki et al. [2019] data set on de-facto exchange rate regimes and anchor currencies, which has 14 classes of flexibility which I consolidate into a smaller set. IRR exchange rate regime only thorough Q 4 2016. I take quarterly averages of monthly exchange rate regimes. Fed Fund Futures data are taken from Bloomberg. First contract month yield changes are computed over the day of a scheduled FOMC meeting. Daily monetary policy shocks are then aggregated to the quarterly level (simple sum).

In the process of cleaning the data, I remove country-quarter observations which are deemed outliers based on: Interest rate changes greater than 5 percentage points in absolute value, interest rate levels greater than 50%, and inflation greater than 40%.[7]

3 De-Facto Peg Intensities

A key limitation across studies on the policy Trilemma is the coarse classification of exchange rate regimes. Most studies resort to a binary (or at best, discrete) splitting of observations into either 'floating' or 'fixed' exchange rate regimes. While this is an important consideration when focusing on the corner configurations of the policy Trilemma, little can be said about the monetary autonomy trade-off under more complex exchange rate targeting policies, such as an intermediate peg or basket peg. Moreover, intermediate exchange rate regimes are not all equal: policymakers choose the degree of flexibility which potentially gives way to a spectrum of exchange rate regimes (peg intensities) which vary both across countries and over time.

As a parsimonious solution for estimating a continuous measure of the de-facto exchange rate regime, I follow and extend the methodology introduced in Haldane and Hall [1991], Frankel and Wei [1992], and later on in Benassy-Quere et al. [2006]. This

[7] Comparable to Ilzetzki et al. [2019].

regression-based technique estimates continuous 'peg intensities' that are directly associated with a base currency.[8] The first-step here is to estimate non-overlapping de-facto peg intensities at the quarterly frequency. These estimates, which characterize country's exchange rate regime, can then be applied in the main analysis testing for monetary policy transmission. I extend the methodology along two dimensions. First, I rely on higher frequency (daily) data to estimate non-overlapping, lower frequency (quarterly) peg intensities. This contrasts the traditional approach of estimating peg intensities on an overlapping or rolling basis. Second, I control for global common factors and shocks which may impact exchange rate fluctuations both in the country of interest and the base country – specifically world commodity prices and global investor risk aversion.

Like Haldane and Hall [1991] I use daily exchange rate data which yields a sufficient number of observations for consistent quarterly peg intensity estimates. However at the daily frequency the issue of asynchronous trading hours across international exchange rate markets might pollute the regression analysis. One solution would be to use weekly exchange rates (Frankel and Wei [1992] and McCauley and Chan [2014]), but the number of observations to estimate quarterly peg intensities would drastically drop. To overcome the issue of potential non-overlapping trading hours while preserving the number of observations, I compute 2-day rolling average exchange rate returns following Forbes and Rigobon [2002] and Wang et al. [2017]. Then over each quarter, I estimate the following regression with daily data:

$$\Delta e^i_d(t) = \alpha_i(t) + W^{€}_{it}\Delta e^{€}_d(t) + W^{¥}_{it}\Delta e^{¥}_d(t) + W^{\$}_{it}\Delta e^{\$}_d(t) + \epsilon^i_d(t), \tag{1}$$

where $\Delta e^i_d(t)$ is the day d (of month t) change in the log exchange rate of country i vis-a-vis the IMF's Special Drawing Rights currency basket (SDR) and base currencies on the RHS denoted Δe^b_d, $b \in \{€, ¥, \$\}$, are the Euro, Japanese Yen, and U.S. Dollar vis-a-vis the SDR, respectively. I choose these three currencies as the possible set of base currencies because of their disproportionately large role in international trade and finance. The U.S. Dollar and the Euro together make up the large majority of: base currency pegs, international reserves holdings, external debt currency denomination, and trade invoicing currency globally.[9] Furthermore, following the literature, the specification implicitly assumes that these three base currencies are de facto pure floaters, making up the potential candidate target currencies for all other countries.

Note that the question of which numeraire to use is discussed extensively in the literature as it affects the interpretation of the error term when the currency does not

[8] Variants of this methodology have been recently implemented in McCauley and Chan [2014], Ito and Kawai [2016] and Ito and McCauley [2019] to study cross-country patterns in trade invoicing currencies, global imbalances and the composition of central bank foreign reserves. Frankel et al. [2019] consider continuous de facto exchange rate regimes to study their effects on economic growth.

[9] See Gopinath [2015], Maggiori et al. [2019], Goldberg and Lerman [2019] and the recent ECB note (ECB [2019]).

follow a perfect hard peg.[10] To circumvent this issue, I follow Frankel [1993] and Ma and McCauley [2011] by considering SDRs as the numeraire. Meanwhile, other solutions have been proposed: Frankel et al. [2001] use a basket of currencies – not unlike the SDR – and Frankel [1993] use consumer price indices as the numeraire.[11] Another proposed solution which does not consider a basket-type numeraire but still attempts to deal with the collinearity of exchange rates induced by triangular arbitrage is to simply use the USD as a numeraire, but have the regressions explicitly omit the USD exchange rate from the RHS. For example, Ito and McCauley [2016] and Ito and McCauley [2019] denominate exchange rate returns in USD, but on the right hand side include base country currencies but *not* the USD. Then, to estimate the weight on the USD, the authors take the difference between 1 and the sum of the estimated weights on the other base currencies. The advantage of this approach is that it simplifies the problem of choosing an appropriate numeraire. Meanwhile, a potential drawback is that the weight on the USD base is restricted such that the weights across all base currencies necessarily sum to 1. Ma and McCauley [2011] further demonstrate that the results from Frankel and Wei [1993] are robust to using either the SDR or the U.S. Dollar as the numeraire.

Equation 1 implies that the movements of each currency i are decomposed to a weighted average of the base currencies plus an idiosyncratic error term. These weights translate to peg intensities against base currencies. For example, with a currency that pegs perfectly to the U.S. Dollar (e.g. Ecuador, which has been Dollarized since 2000), $W_{it}^{\$}$ would equal 1 and the other weights would equal zero. In contrast, a purely floating exchange rate would have weights statistically indifferent from zero across all three base currencies, and an exchange rate which targets a basket (e.g. Singapore) would have non-zero weights on multiple base currencies. Therefore, the strength of the peg is given by a value between 0 and 1, where 0 is no weight (float), and a 1 is interpreted as a hard peg to the base currency. This way we arrive at a continuous measure of peg intensity for each country, for each quarter, through exploiting currency movements at the daily frequency.

An important note to emphasize is that a peg intensity estimate equal to 1 does not necessarily imply pegging, especially if the estimated regression results in a poor model fit, which would most likely coincide with statistical insignificance. To correct for such scenarios, I follow the algorithm of Ito and McCauley [2019] to clean peg intensity estimates.[12]. Additionally Figure A.1 and Table 1 report the distributional characteristics of

[10] Additionally, if the numeraire moves closely in line with one of the candidate base currencies, then that base currency will have very small variance and may be confused with the constant term (Benassy-Quere et al. [2006]).

[11] I do not consider using price indices as the numeraire because price index data is not available at the daily frequency. One could alternatively consider trade-weighted effective exchange rates as a solution to the numeraire problem (though results are likely to remain similar as the SDR and trade-weighted exchange rate returns are highly correlated).

[12] To clean and remove spurious results when estimating Equation 1: before estimating Equation 1,

R^2 across all country-quarter observations where a strong peg is estimated (i.e. there is a $\hat{W}_{it}^b = 1$).

Table 1: Summary statistics of R^2 from all country-quarter regressions where $\hat{W}_{it}^b = 1$

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(50)	Pctl(75)	Max
R^2	1,634	0.740	0.309	0.04	0.48	0.92	1	1

Immediately notice the very high median R^2 of 0.92 and that the majority of values lie between 0.48 and 1, validating that most of the identified country-quarters under strong pegs in fact bear appropriately high model fits, thereby further confirming the reliability of the first-stage results.

3.1 Controlling for common shocks

A potential issue with the standard estimation of Equation 1 is that it doesn't recognize the role of global factors or common shocks which may influence jointly country i's and base country b's exchange rate, thus generating what may appear as large or sudden shifts in exchange rate policy if not controlled for. For example, common factors may include fluctuations in global commodity prices. Through driving variation in the terms-of-trade, commodities are known to influence exchange rates of resource-dependent economies. Exchange rates exhibiting such behavior are often dubbed 'commodity currencies' (Chen and Rogoff [2003], Ahmed [2020], Beckmann et al. [2020], among several others).

In addition to commodities, global investor risk appetite appears to play an increasingly potent role in driving broad currency risk (Avdjiev et al. [2019]). Periods of high risk aversion tend to coincide with episodes of Dollar and Yen appreciation as they are viewed as global safe assets. At the same time, risk aversion drives risky asset prices lower, which may include Emerging Market or carry trade currencies. Thereby, risk aversion shocks can induce correlations in foreign exchange markets which are not necessarily be driven by the exchange rate targeting mechanism.

I first omit observations of daily log exchange rate changes exceeding 5% in absolute value to prevent crisis-related outliers from influencing peg intensity estimates (as similarly done in Ilzetzki et al. [2019] who remove inflation observations exceeding 40% in their analysis). Then, after estimating Equation 1, any statistically significant negative coefficient estimates of the peg intensities (W_{it}^b) is set to be a missing value (large negative weights are theoretically inconsistent). Statistically insignificant negative values are set to zero (because a weight of zero is not rejected in this case). Values statistically significantly greater than one are taken to be missing values (positive values exceeding one are theoretically inconsistent), and values insignificantly greater than 1 are set to 1 (becuase a weight of 1 cannot be rejected in this case).

I control for these common drivers by augmenting Equation 1 with global factors:

$$\Delta e_d^i(t) = \alpha_i(t) + \widetilde{W}_{it}^{€}\Delta e_d^{€}(t) + \widetilde{W}_{it}^{¥}\Delta e_d^{¥}(t) + \widetilde{W}_{it}^{\$}\Delta e_d^{\$}(t) + \sum_{k=1}^{K} B_{tk}\Delta c_{kd}(t) + C_t \Delta vix_d(t) + \epsilon_d^i(t). \quad (2)$$

In Equation 2, $\Delta c_{kd}(t)$ refers to daily log returns from commodity k over quarter t, and $\Delta vix_d(t)$ refers to daily log changes in the VIX index - a proxy for global risk appetite.[13] For commodities, I consider $K = 5$ heavily traded world commodities: Gold, copper, crude oil, coffee and sugar. The two estimation procedures result in two sets of de facto peg intensities: the conventional measures $\hat{W}_{it}^b$ and the estimates upon controlling for global factors $\widetilde{W}_{it}^b$ which I'll refer to as the augmented measures. For robustness, I'll typically consider both when testing for monetary spillovers.

4 Trends in Exchange Rate Policy

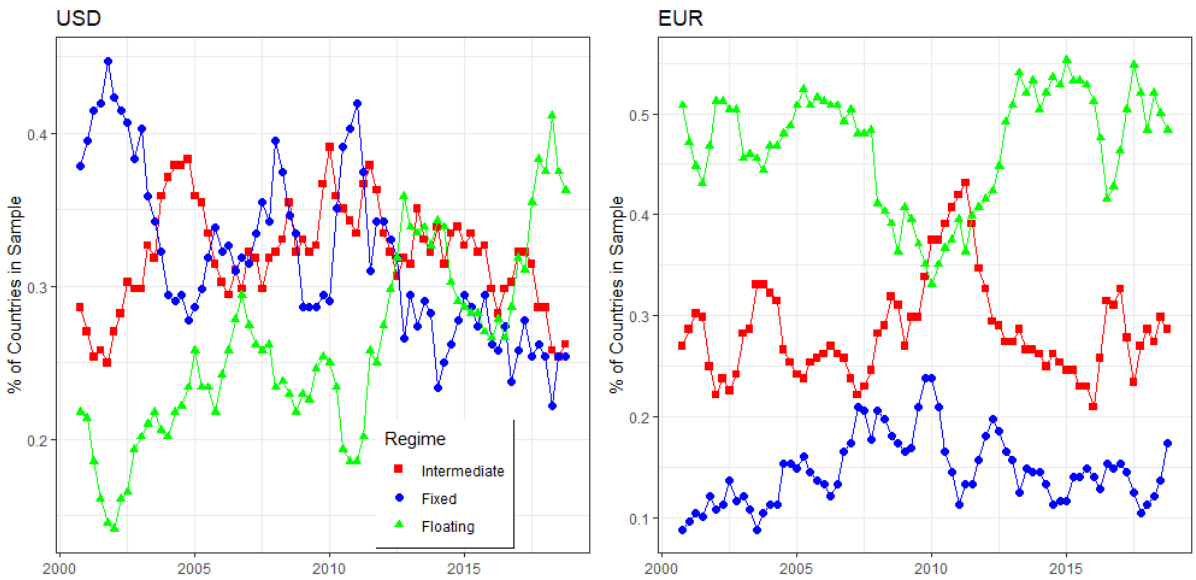
I estimate peg intensities for a sample of 52 currencies against the U.S. Dollar, Euro, and Japanese Yen (Table A.2 and continued on Table A.3).[14] Because of the broadly low peg levels against the Yen, I focus on the cross-country dynamics of USD and EUR peg intensities. Figure 1 shows percentages of countries falling into each exchange rate classification over the 2000-2018 period. Floats, intermediates and pegs are defined as peg intensity estimates $\hat{W}_{it}^b \in \{[0, .1], (.1, .9], (.9, 1]\}$, respectively. 4-quarter averages are plotted for clarity. A striking consistency is how persistent the proportion of intermediate exchange rate regimes have been over the past two decades across both base currencies, particularly the USD. Roughly a third of the sample follows an intermediate peg at any given period. Moreover, the proportion of countries floating against the USD nearly doubled from 20% in 2000 to 40% by 2018. This trend was driven by countries transitioning away from a hard USD peg, rather than intermediate pegs becoming more flexible.

A striking statistic in the data is the number and proportion of actual pure floats across the sample (Figure 2). In 2000, the only currency which had estimated peg intensities of less than or equal to 0.20 against all three base currencies was the British Pound. Including the three base currencies, that amounts to just four pure floats at the turn of the century. Proportionately, it is clear from the figure that pure floating currencies are historically scarce and continue to be so. In 2018, the number rose to ten if we include the base currencies USD, EUR and JPY under the assumption that they are floats.

[13] The CBOE VIX index is a model-free measure of 30-day expected volatility of the S&P 500 stock index derived from options prices.

[14] Exchange rate data is available for 52 countries, but due to varying data coverage, after merging all data sets together the main analysis is conducted on a panel of 46 countries as discussed in Section 2.

Figure 1: Exchange Rate Regimes Across Countries, vis-a-vis USD (left), EUR (right)



Floats, intermediates and pegs are defined as peg intensity estimates $\hat{W}^b_{it} \in \{[0, .1], (.1, .9], (.9, 1]\}$, respectively. Rolling 4-quarter averages.

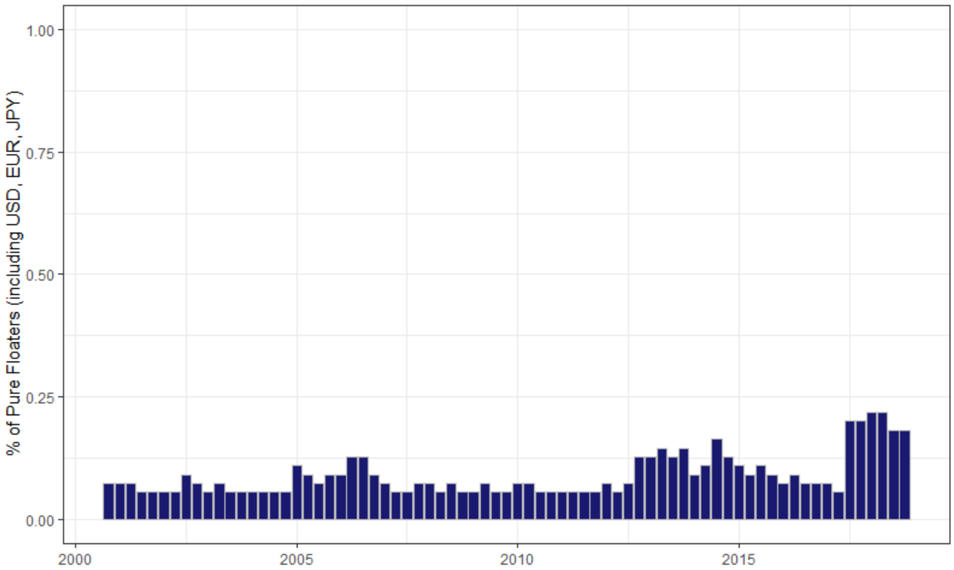
Additional identified countries are Brunei and Singapore, the Chinese Yuan, Korean Won, Thai Baht, Canadian Dollar and British Pound. The Emerging Market cases are of particular interest. The currency of Brunei is officially pegged to Singapore's, therefore its flexibility vis-a-vis the USD, EUR, or JPY rises as Singapore's flexibility rises despite *not* being a true floating currency. Throughout 2018, the Thai Baht / Singapore Dollar exchange rate was exceptionally stable, suggesting that Thailand was likely de facto targeting vis-a-vis the SGD. Singapore itself has realized steady gains in exchange rate flexibility over the past two decades. The Chinese Yuan saw its peg intensity to the USD weaken dramatically since 2016 amidst rising trade tensions between China and the United States. South Korea has been under an inflation targeting monetary regime since the early 2000's. If Brunei and Thailand are dropped from the list of true floats due to their de facto targeting of the SGD, and the case of China is considered transient, that leaves just 7 currencies under a truly pure float in 2018, with Singapore and South Korea being potentially new and notable independent floaters.

Figure 3 sorts peg intensities from lowest to highest across countries, for the year 2000 and 2018.[15] The number of hard U.S. pegs (intensity greater than 0.90) have fallen drastically over the past two decades, while the number of floaters rose. In contrast, peg intensities against the EUR have risen over the past 20 years.[16] Moreover, the

[15]The plotted intensities are 4-quarter averages.

[16]Ito and McCauley [2019] attribute this partly to commodity currencies moving away from the pure U.S. Dollar zone to a more intermediate position between the Dollar and Euro.

Figure 2: Sample Proportion of 'Pure' Floaters, 2000-2018

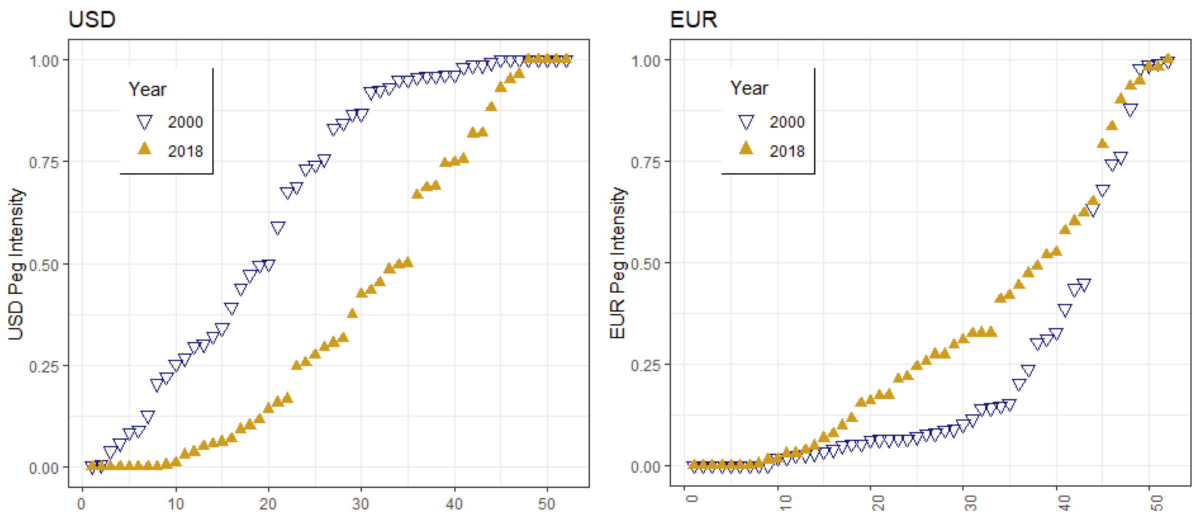


I define a currency as a pure floater in any particular quarter if all three weights, $\hat{W}_{it}^{b}$ where, $b \in$ {USD, EUR, JPY}, are estimated to be less than 0.20. Rolling 4-quarter average of $\hat{W}_{it}^{b}$ is used. Total sample contains 55 countries; number is inclusive of USD, EUR, and JPY as these assumed to float freely given their role as potential exchange rate targets by other countries.

number of countries under intermediate pegs remains substantial in 2018 (roughly 60% of the sample considering both USD and EUR), and the 'intensity curves' are relatively smooth - highlighting the importance of considering intermediate pegs across a broad spectrum. Figure A.2 in the Appendix shows 2000-2018 changes in peg intensity by currency. Against the USD, many countries which were hard pegs in 2000 have relaxed their policy by 2018, most of them following de facto intermediate policies. At the same time, most countries did increase the pegging weight attributed to the EUR. Focusing on USD pegs, Romania, South Korea, China, Brazil, Mexico, and Thailand round out the countries exhibiting the largest changes. Over this time period, Romania transitioned from a hard peg to the USD to targeting the EUR, explaining the near-maximal drop in USD peg intensity coinciding with a large rise in EUR peg intensity. In 2015, China begun transitioning from a hard de facto USD peg amidst the country's push to globalize it's currency, while the other countries are notable emerging markets that have adopted inflation targeting monetary policy over the period, thereby allowing market forces to increasingly drive their currency movements.

An important possibility to consider is whether countries which moved away from the USD are switching to EUR as a base currency to peg against. The estimated correlation between 2000-2018 changes in USD peg intensities and 2000-2018 changes in EUR peg intensities is equal to -0.23 (t=-1.64) but not highly significant in the statistical sense. The weak negative correlation implies that changes in USD peg intensity can explain

Figure 3: Peg intensities in 2000 vs 2018, vis-a-vis USD (left), EUR (right)



Annual 2000 and 2018 estimates of $\hat{W}_{it}^{b}$ are 4-quarter averages.

roughly 5% of the variation in changes in EUR peg intensity. The evidence, therefore suggests that base currency substitution was not a major factor driving transitions in exchange rate policy.

Taking a look at exchange rate intensities over time, I plot 4-quarter rolling average USD and EUR intensities for selected countries in Figure A.3 and aggregate, cross-country averages in Figure A.4. Romania's early-2000's transition from a USD peg to a EUR peg becomes clear. Singapore has steadily reduced it's peg against the USD to nearly zero, through for a large part of the 2000's the country seems to have targeted a basket with partial pegs against both the EUR and USD.

Switzerland had a strong yet imperfect peg against the EUR over most of the sample period, though the EUR peg intensity dropped considerably during the 2011 European Debt Crisis, then returning to high levels until Switzerland surprised the world with their sudden re-valuation in January 2015 when the Franc appreciated roughly 30% against the Euro. Since then, the peg intensity has continued to steadily weaken. China's hard peg to the USD is very apparent in the early 2000's (despite the government claiming to target a basket). The country continued to administer a strong (though not perfect) USD peg up until Q4 2015, and since then the USD peg intensity has dropped sharply to less than 0.10 amidst the country's push towards introducing the Yuan as a global currency. This drop is not substituted with increased EUR intensity.[17]

Overall trends in USD and EUR peg intensities across all countries in the sample are shown in Figure A.4. What is clear is that the average USD peg intensity has crept lower steadily over the past 20 years (from over 0.60 to below 0.45), with the exception of 2011

[17]It is also possible that this sharp drop in China's targeting the USD was driven by the U.S.-China trade war in an effort to insulate against the effects of tariffs.

during the European Debt Crisis where a sharp rise in USD peg intensity appears to have been driven by countries substituting away from targeting the EUR, which realized a coinciding sharp drop in intensity. Moreover the persistent rise of intermediate pegs accompanying a persistent scarcity of pure floats are not supportive of the Two Corners hypothesis, highlighting the important need to more carefully study middle-ground exchange rate policies.

The question of what might determine a country's choice of exchange rate policy is a natural (extensively-studied) follow-up. Many potential factors might drive this choice. For example, Edwards [1996] finds that political economy factors play a major role, as the choice between fixed and floating is related to the country's historical degree of political instability, the probability of abandoning a pegged rate, and the policy objectives of the domestic monetary authorities. Devereux and Engel [1998] argue that what matters is whether prices are set in the currency of the consumer or producer. Recent studies also consider the choice of operating an intermediate exchange rate regime. Ito and Kawai [2014] suggest that countries opt for more flexible exchange rate regimes when the country has: greater international reserves, more trading partners, a lower proportion of commodity exports, and greater domestic savings, while McCauley and Chan [2014] report that the composition of foreign exchange reserves strongly explains cross-country variation in (continuous measures of) exchange rate peg intensities.

Armed with continuous peg intensities against the USD and EUR, the two globally dominant base currencies, one can effectively measure monetary policy spillovers with finer granularity. That is, we can shift our attention from the corners of exchange rate policy to interior choices, i.e. intermediate regimes. The following analysis leverages these estimated peg intensities to study whether and to what degree monetary policy spillovers are consistent with the Trilemma, particularly under intermediate pegs.

5 Testing the Trilemma: Empirical Strategy

There are a number of steps that must be taken before arriving that the final econometric specification to test monetary policy spillovers. For illustrative purposes, consider a modified Uncovered Interest Rate Parity (UIP) condition which allows for both open and closed capital flow regimes:

$$R_{it} = (1 - \tau_{it})(R_{bit} + E_t[\Delta e_{ib,t+1}] + \rho_{it}) + \tau_{it} R^*_{it}, \quad \tau_{it} \in \{0, 1\}, \tag{3}$$

where whether country i administers closed (open) capital flow is given by τ_{it}: a value of 0 for open and 1 if closed. Under free capital flow ($\tau_{it} = 0$), the interest rate of country i, R_{it} should equal the interest rate of the base country, R_{bit} plus the expected percent appreciation of base country b's currency vis-a-vis country i's currency denoted

$E_t[\Delta e_{ib,t+1}]$, plus a risk premium ρ_{it}. Under a perfectly credible hard peg, $E_t[\Delta e_{ib,t+1}]$ equals zero. So under a hard peg and assuming a zero risk premium and $\tau = 0$, its easy to see that $R_{it} = R_{bit}$. That is, country i does not have any monetary autonomy as the base country interest rate fully passes through. In contrast, under a flexible exchange rate and/or time-varying risk premia, R_{it} can indeed deviate from the base country interest rate. The Trilemma implies that limiting capital flows by introducing capital controls can reduce this policy pass-through and grant greater monetary autonomy. This is shown in Equation 3 under $\tau_{it} = 1$. Under a closed capital account, UIP no longer applies and country i's interest rate is fully independent, $R_{it} = R^*_{it}$.

A major simplifying assumption of the illustration just presented is that exchange rates can be either fixed or floating, and capital controls can either be open or closed. Despite this unrealistic assumption, most studies on the policy Trilemma are restricted to such cases. By leveraging continuous measures of peg intensity, I aim to relax this assumption. Second, interest rate *levels* tend to be very persistent, thus raising the issue of potential unit roots and spurious regression results. Therefore, following the literature, we test for the monetary pass-through using interest rate *changes*. Third, as in Han and Wei [2018], it is important to condition interest rates on domestic variables which the central bank may target as we wish to capture interest rate changes exclusively driven by the Trilemma and remove bias driven by policy responses to domestic economic conditions. Additionally, it is crucial to condition base country interest rates on domestic variables (Jordà et al. [2020]) to identify base country monetary policy movements that are unrelated to domestic economic conditions.

5.1 Identification of Base Country Monetary Shocks

The base interest rates under consideration are the U.S. and E.U. (ECB) policy interest rates, $b \in \{US, EU\}$.[18] A key identifying assumption here and in the broad majority of related studies is that all other countries take changes in U.S. and E.U. monetary policy as exogenous. That is, country i's economic condition does not factor into monetary policy decisions for the U.S. and E.U., where only domestic conditions strictly determine the interest rate. Though plausible, this assumption may or may not be reasonably satisfied at all times. For example, a country's business cycle may be correlated with that of the base country. Therefore, as a robustness check I also consider a measure of unanticipated U.S. monetary policy shocks later in Section 9.4.

To remove potential endogeneity arising from policy changes driven by domestic economic conditions, instead of using interest rate changes directly, I first run the following regression resembling a Taylor-type rule where the monetary policy responds to output

[18] These two countries make up the lions share of globally held international reserves, and currency pegs.

and inflation:

$$\Delta R_{bt} = \alpha_1 + \alpha_2 \Delta y_{bt} + \alpha_3 \Delta \pi_{bt} + D_{b,ZLB}[\beta_1 + \beta_2 \Delta y_{bt} + \beta_2 \Delta \pi_{bt}] + Z_{bt}, \tag{4}$$

where ΔR_{bt} is the quarterly change in interest rate for base country b, in this case either the U.S. or E.U. Δy_{bt} and $\Delta \pi_{bt}$ are year-over-year GDP growth and inflation, respectively. Because of the drastic change in monetary policy after hitting the Zero Lower Bound (ZLB), I allow for a structural break in the regression coefficients conditional on base country interest rates hitting their effective lower bound. This is captured by an indicator variable, $D_{b,ZLB}$ which takes a value of 1 if base country b's policy rate is at the effective lower bound, and 0 otherwise. For the U.S., the interest rate is at the effective lower bound when the policy rate is 0.125% or lower, and for the E.U. when the policy rate equals 0%. For both countries, the lower bound period is persistent, occuring mostly after the 2008 Financial Crisis. The estimated residual policy rate change $\hat{Z}_{bt} \in \{\hat{Z}_{US,t}, \hat{Z}_{EU,t}\}$ – cleaned of domestic confounders – is then a measure of base country monetary policy changes that are uncorrelated with domestic economic conditions.

Naturally, most identification approaches come with drawbacks. For example, while this method allows for a structural break at the ZLB, during period of zero rates, there is nearly zero variation in the policy rate, and unconventional policies dominated the central bank toolkit. Moreover, the 'residual' approach may not always be sufficient for identifying the exogenous component of monetary policy. To validate the robustness of the results, I apply two additional approaches for estimating $\hat{Z}_{bt}$ to capture changes in the monetary policy stance despite at the ZLB. First, I replace ΔR_{bt} for the U.S. and E.U. with their respective shadow rates (Wu and Xia [2016]). Second, for the U.S. specifically, I construct a series of identified monetary policy shocks from Fed Fund futures data which yields an entirely different series of policy innovations. Results under these alternative schemes are reported in Section 9.3 and Section 9.4, respectively.

The second step required for identification is motivated by the IV strategy of Jordà et al. [2015] and Jordà et al. [2020], and more generally consistent with the broader literature on the policy Trilemma. That is, the effect of base country b's monetary policy shock on country i's interest rate depends on: country i's peg intensity with respect to the base currency of country b given by $\hat{W}^b_{it}$, and country i's capital account openness, K_{it}. Both of these variables lie within $[0, 1]$, where 0 indicates fully floating exchange rate/closed capital accounts, and 1 indicates fully pegged exchange rate and full capital openness. Taken together, the variable of interest in the baseline regression specification will be the interaction term $\hat{Z}_{bt} \times \hat{W}^b_{it} \times K_{it}$. The key difference between this measure and prevailing studies is that here, the variable measuring exchange rate regime, $\hat{W}^b_{it}$ is continuous and lies within $[0, 1]$.[19] Importantly, the identification assumption that must

[19] Jordà et al. [2015] defines exogenous monetary policy shocks in the same way – as the interaction

be satisfied is monotonicity:

$$\frac{\partial E[\Delta R_{it}|\mathbf{x}]}{\partial[\hat{Z}_{bt} \times \hat{W}^b_{it} \times K_{it}]} \geq 0. \tag{5}$$

What the assumption requires is that the change in country i's interest rate (conditional on controls, $\mathbf{x}$), is increasing in the denominator. Think of peg intensity and capital openness as measures of how exposed country i's interest rate is to the base country's, and we ideally, wish to compare two identical countries in terms of fundamentals and capital controls, but varying in exchange rate flexibility. For zero exposure, either $\hat{W}^b_{it}$ or K_{it} must equal zero. That is, the country must administer either a pure float, or a closed capital account for complete monetary autonomy – precisely what the Trilemma implies. Conversely, exposure to the base country's monetary policy is conditionally maximized (i.e. minimal monetary autonomy) when $\hat{W}^b_{it}$ and K_{it} equal 1; when country i administers a hard peg under free capital flows. The interaction term imposes the structural assumption that the Trilemma trade-offs are linear in that monetary autonomy linearly decreases as exchange rate flexibility or capital account openness rises.

5.2 Econometric Specification

The baseline regression to be tested is:

$$\begin{aligned}\Delta R_{it} = \alpha_i + \phi_1 \Delta R_{i,t-1} + \phi_2 \Delta y_{it} + \phi_3 \Delta \pi_{it} + \phi_4 \Delta RER_{it} \\ + \phi_5 \Delta VIX_t + \phi_6 \Delta \bar{R}_t \\ + \gamma_{US}[\hat{Z}_{US,t} \times \hat{W}^{\$}_{it} \times K_{it}] + \gamma_{EU}[\hat{Z}_{EU,t} \times \hat{W}^{€}_{it} \times K_{it}] + \epsilon_{it}.\end{aligned} \tag{6}$$

The baseline regression assumes that country i's interest rate responds according to an open economy Taylor-type rule (Aizenman et al. [2011], Engel [2011], Han and Wei [2014], Han and Wei [2018]) and conditions on key domestic variables which the policy rate may react to. Changes in country i's policy rate are regressed on lagged policy rates,[20] $\Delta R_{i,t-1}$, nominal GDP growth Δy_{it}, changes in inflation $\Delta \pi_{it}$, and changes in the log real exchange rate ΔRER_{it} vis-a-vis the USD. Positive changes in the real exchange rate indicate country i depreciation. Including the real exchange rate also will capture any possible evidence of Fear of Floating, one phenomena which challenges the sustainability

of the base country's monetary policy change, the exchange rate regime and degree of capital openness - but using binary measures of exchange rate regimes.

[20] The specification taking the form of a dynamic panel model is well known to suffer from Nickell [1981] bias when the time dimension is small. However, our quarterly sample provides T ranging from mid-40 to mid-70 depending on the sub-sample and country. Judson and Owen [1999] show through Monte-Carlo studies that the LSDV estimator performs well in comparison with GMM and other estimators when T=30.

of the Trilemma (Calvo and Reinhart [2002]). The choice of real exchange rates vis-a-vis the USD is intentional: it is the most relevant exchange rate, as the USD dominates among invoicing currencies in international trade, and is also the currency of choice in international finance (Gopinath [2015], Maggiori et al. [2019], ECB [2019]).[21]

Additionally the validity of the Trilemma has been actively debated in light of new evidence of a global financial cycle (Rey [2015], Miranda-Agrippino and Rey [2020]), hence the specification also controls for global factors: log changes in the VIX index given by ΔVIX_t, and $\Delta \bar{R}_t$ which denotes changes in the global average interest rate.[22] The merged panel data are unbalanced as data sources vary in their coverage (Table A.1 includes a description of countries along with the number of interest rate observations per country). Standard errors are clustered at the country level. Its worth briefly pointing out that the monetary shocks $\hat{Z}_{b,t}$ and peg intensities $\hat{W}^b_{it}$ are both estimated, and therefore subject to the classical case of measurement error (errors-in-variables problem). Because the measurement error is embedded in independent variables, under the standard assumption that the measurement error is random and uncorrelated with the independent and dependent variables in the regression, this biases the coefficients towards zero, and biases the associated t-statistic downwards. Measurement error therefore induces attenuation bias such that the resulting monetary spillover estimates are likely to be relatively conservative in the sense that they would otherwise be larger in the absence of measurement error.[23]

The final two terms preceding the residual ϵ_{it} of Equation 6 are the focus of this study. Coefficients γ_{US} and γ_{EU} capture the degree of spillover from base interest rates (U.S. monetary policy and ECB monetary policy, respectively) to country i's interest rate. Given a foreign monetary policy shock to the base country, $\hat{Z}_{bt}$, the total spillover to country i is an increasing function of peg intensity and capital account openness, $\gamma_b[\hat{W^b_{it}} \times K_{it}]$.[24]

A potential drawback of the regression specification is the imposed homogeneity of coefficients across countries. For example, weights on Taylor Rule coefficients might differ

[21] Moreover, real effective exchange rate changes are highly correlated with USD exchange rate changes such that using either do not result in meaningful changes to estimates of monetary spillovers.

[22] The global average interest rate is computed each period t as the cross-section average of ΔR_{it} across all countries i, excluding base countries. It proxies for the common factor in interest rate fluctuations and absorbs common trends across countries (Pesaran [2006]).

[23] The way to adjust standard errors when a regressor is estimated typically varies on a case-by-case basis. Often however, bootstrapping the entire estimation procedure (first stage plus second stage, etc.) is done. However, when there are many stages or many estimations in a single bootstrap round, this approach can become exceedingly intensive in terms of computation time. The approach applied in this paper is one of those scenarios: in the first stage, I estimate for each of 46 countries, and for each quarter, peg intensities, which then enter into a second stage panel regression (the first stage yielding roughly 3,450 estimates). This would then have to be bootstrapped hundreds of times.

[24] Ito and Kawai [2012] and Ito and Kawai [2014] apply a similar method to estimate a country's monetary independence, but they do not pre-condition base country interest rates on domestic variables or account for financial openness.

across countries which aim to prioritize different policy objectives: emerging markets may prioritize targeting the real exchange rate, while this may not be an objective at all among some advanced economies (Aizenman et al. [2011] and Ahmed et al. [2019]). Despite this limitation, much of the literature stands by the pooled panel regression specification as it buys considerable statistical power when dealing with cross-country panels[25]. In support of the homogeneous coefficients restriction, Han and Wei [2018] find that after estimating country-specific Taylor-type regressions, weights assigned to inflation for inflation targeting countries and non-inflation targeting countries are not statistically different. However to account for potential heterogeneity in regression coefficients, I estimate the regression on advanced and emerging market sub-samples of countries along with the full sample. Moreover in Section 7 I allow the coefficients to be estimated separately across countries binned by exchange rate peg intensity, reflecting the possibility that countries with greater monetary autonomy under a flexible exchange rate can put more weight on domestic policy objectives compared to countries administering stronger pegs (Klein and Shambaugh [2015]).

5.3 Tests and Hypotheses

The policy Trilemma assumes that $\gamma_b = 1$ from Equation 6. That is, under a perfect peg *and* open capital flows ($\hat{W}_{it}^b = 1$, $K_{it} = 1$), interest rate pass-through should be one-for-one, while under a pure float ($\hat{W}_{it}^b = 0$) *or* closed capital flows ($K_{it} = 0$), there is no interest rate pass-through (i.e. complete monetary autonomy). However, in practice it is difficult to expect this assumption to hold. First, the policy Trilemma relies on UIP being satisfied, but there is extensive empirical evidence of UIP being violated in the data. Second, as Klein and Shambaugh [2015] show, one cannot expect Trilemma-consistent pass-through if country i's interest rate changes are correlated with other factors that influence their policy rate such as expected exchange rate changes, risk premia or global shocks.

Nonetheless, there are a number of valuable tests that can be conducted. If γ_b is statistically significant and positive, that itself is evidence in favor of the Trilemma despite imperfect pass-through. A positive coefficient implies a statistically significant relationship between base country policy rates and country i's policy rates which strengthens as the exchange rate policy becomes increasingly rigid, or as capital accounts become more open. A continuous measure of exchange rate regime will let us infer whether intermediate exchange rate regimes offer intermediate degrees of monetary policy autonomy.

Given the linear form of the interaction term, it is simple to calculate spillovers under any combination of exchange rate flexibility and capital account openness. To focus on

[25] Obstfeld et al. [2005], Klein and Shambaugh [2015], Han and Wei [2018], Obstfeld et al. [2019] all employ the pooled specification in their baseline analysis.

the trade-off between monetary autonomy and exchange rate flexibility, the discussion focuses on the case where $K_{it} = 1$, or conditional on an open capital account for ease of interpretation. This way, we can make comparisons on the monetary autonomy between two hypothetical countries, both with open capital accounts, but different exchange rate policies. A similar design, though with discrete exchange rate regimes, is taken in Han and Wei [2018]. In fact, this is not a binding constraint – we can fix the capital account openness to any value of K_{it} and still infer the monetary autonomy - exchange flexibility trade-off between countries given the same capital account openness. This point is particularly important to note because the scenario of $K_{it} = 1$ may not be borne out in the data particularly among emerging markets. Fortunately, under the assumptions of the Trilemma (i.e. monetary spillovers are linearly increasing in K_{it}), the case of $K_{it} = 1$ is easily inferred from the model even for emerging markets.

Different coefficient estimates of γ_{US} and γ_{EU} suggest that monetary policy spillovers are heterogenous, and may be different depending on the base currency. Finally, a significant coefficient on both γ_{US} and γ_{EU} in a regression including both suggest (but do not conclude) that basket pegs, where the same total weight W^b_{it} is allocated across base currencies, can offer diversification benefits compared to a hard peg (where the equivalent total weight is allocated to a single currency) against a single base currency so long as the base country monetary policies are not perfectly correlated with one another. For example, a country targeting a basket of two exchange rates with weights of 50% on each, would be imperfectly exposed to both monetary policies, versus committing 100% weight towards single currency. Despite equal total foreign exposure (weights sum to 1 in both cases), the country targeting a basket is subject to less monetary pass-through, on average, from base countries in each period so long as the two base countries do not conduct synchronized monetary policy. If the two base country monetary policies are imperfectly correlated, pass-through is is reduced under a basket peg for any given quarter. If the two base country monetary policies were perfectly correlated, then there would be no difference between the two weighting schemes (and in fact, one of the RHS regressors, either the US or EU monetary policy shock, would drop out of the regression). The latter two tests would bring novel insights to the literature.

A key assumption of the regression specified in Equation 6 is the implicit linearity imposed on monetary pass-through. The effect of monetary pass-through implied by $\gamma_b[\hat{W^b_{it}} \times K_{it}]$ is linear in peg intensity and capital account openness, and it follows that under open capital accounts, the trade-off between monetary autonomy and exchange rate stability is also linear. The Trilemma trade-offs however are not necessarily required to be linear, though have been assumed to be so in some studies (Ito and Kawai [2014]). There is no consensus on the linearity of Trilemma trade-offs. Aizenman et al. [2010] and Herwartz and Roestel [2017] test the linearity assumption and find supportive evidence. In contrast, Obstfeld et al. [2019] find non-linear effects of (non-monetary) spillovers under varying degrees of exchange rate flexibility. Because of the important policy implications of (non) linearity, I explore this issue in more detail in Section 7 by exploiting the continuous nature of peg intensity measures.

6 Baseline Results

Table 2: Baseline Regression Results: All Countries

	(1)	(2)	(3)	(4)	(5)	(6)
	$\hat{W}^b_{it}$	$\hat{W}^b_{it}$ (RA, 2)	$\hat{W}^b_{it}$ (RA, 4)	$\hat{W}^b_{it}$ (RA,2)	$\hat{W}^b_{it}$ (RA, 2) $\in (0, 1)$	$\widetilde{W}^b_{it}$
$\hat{\gamma}_{US}$	0.351***	0.370***	0.402***	0.486***	0.412**	0.390***
	(0.108)	(0.124)	(0.136)	(0.177)	(0.147)	(0.098)
$\hat{\gamma}_{EU}$	0.511***	0.486***	0.581***	0.328*	0.703***	0.392***
	(0.124)	(0.133)	(0.178)	(0.178)	(0.116)	(0.120)
Adj. R^2	0.15	0.14	0.14	0.06	0.15	0.16
F-Statistic	69.51	58.77	47.31	47.80	44.91	75.25
N×T	2,882	2,532	1,937	2,532	1,727	2,909
Country FE	Y	Y	Y	Y	Y	Y
Time FE	N	N	N	Y	N	N

***,**,* refer to significance at the 1%, 5% and 10% level, respectively. Robust standard errors clustered at the Country level. Regression specification of Equation 6. Estimation period: Q2 2000 - Q4 2018. Column 5 estimates on the sub-sample of intermediate pegs (peg intensities between 0 and 1, for both U.S. and E.U.). Column 6 uses $\widetilde{W}^b_{it}$, the estimated peg intensities (Equation 2) after controlling for common shocks. Within R-squared reported.

The results for the full sample of countries are reported in Table 2. The first three columns represent different variants of the peg intensity estimate $\hat{W}^b_{it}$. The second and third columns use a 2-quarter and 4-quarter rolling average of $\hat{W}^b_{it}$, respectively denoted with (RA, 2) and (RA, 4), to replace the unsmoothed measure (column 1). Smoothing out the peg intensity estimate with past observations helps makes a more conservative choice to ensure that pegs, which tend to be persistent, are well-established (Jordà et al. [2015], Jordà et al. [2020]). Moreover, smoothing even over 2 quarters helps ensure that results are not driven by outliers and helps eliminate episodes of opportunistic pegging and sudden short-lived devaluations. Regardless, estimates are consistent and significance is broadly robust across columns. Column 4 reports results after substituting a time fixed effect for global controls. Column 5 reports results the sub-sample of country-quarter observations under intermediate pegs, and Column 6 reports results under the augmented peg intensity measure, $\widetilde{W}^b_{it}$ for additional robustness.

6.1 All Countries

Significant non-zero estimates on both $\hat{\gamma}_{US}$ and $\hat{\gamma}_{EU}$ indicate Trilemma-consistent monetary spillovers from both base countries to others (Table 2). Under free capital flows ($K_{it} = 1$), as peg intensity rises (falls), the pass-through of base country interest rates strengthens (weakens). Note that the effects are statistically different from both 0 and 1, implying imperfect Trilemma pass-through. That is, under a perfect peg and free capital flows, a 1 percentage point change in the base country (US, EU) interest rate is associated with interest rates roughly (+0.37, +0.49) percentage points higher (Column 2). Column 4 introduces time fixed effects as a robustness check - the effects of monetary pass-through broadly hold under this specification as well, and the results are robust to using the augmented measure $\widetilde{W}_{it}^{b}$.

6.2 Advanced economies

Table 3 reports estimates for the sub-sample of advanced economies. Both base country Trilemma coefficients are highly significant across the varying specifications of peg intensity and remain robust to both country and time fixed effects. Both U.S. and E.U. base country pass-through is roughly 0.70 for advanced economies, much higher than it is for the full sample. In fact, in many instances the confidence interval includes 1 – indicative of near-perfect monetary policy pass-through when targeting either base currency. Moreover, a hypothetical advanced economy with free capital flow targeting a 50-50 USD-EUR basket would import about half of each country's monetary policy change. So long as these policy rate changes in the U.S. and E.U. do not occur simultaneously, targeting a basket would appear to offer potential diversification benefits.

6.3 Emerging markets

Table 4 reports pass-through estimates for the sub-sample of emerging markets. Across all four specifications (columns 1 to 4), coefficient estimates suggest positive yet imperfect pass-through, but there is little evidence of *significant* monetary policy spillovers from the E.U., despite a number of emerging market economies pegging, at some point, to the Euro.[26] In contrast, the effect of U.S. monetary policy is statistically significant in most specifications, ranging from 0.26 to 0.44, indicating that under a perfect peg and free capital flows, monetary spillovers from the U.S. are imperfect, with emerging market interest rates rising on average +0.35 percentage points for every +1 percentage point rise in U.S. interest rates.

[26] These countries include but are not limited to: Albania, Bulgaria, Croatia, Czech Republic, Hungary.

Table 3: Baseline Regression Results: Advanced Economies

	(1)	(2)	(3)	(4)	(5)	(6)
	$\hat{W}^b_{it}$	$\hat{W}^b_{it}$ (RA, 2)	$\hat{W}^b_{it}$ (RA, 4)	$\hat{W}^b_{it}$ (RA, 2)	$\hat{W}^b_{it}$ (RA, 2) $\in (0, 1)$	$\widetilde{W}^b_{it}$
$\hat{\gamma}_{US}$	0.656***	0.742***	0.797***	0.701***	0.737***	0.529***
	(0.213)	(0.209)	(0.220)	(0.198)	(0.178)	(0.159)
$\hat{\gamma}_{EU}$	0.799***	0.759***	0.700***	0.422***	0.663***	0.701***
	(0.071)	(0.117)	(0.131)	(0.121)	(0.088)	(0.076)
Adj. R^2	0.42	0.43	0.42	0.186	0.40	0.41
F-Statistic	70.40	62.91	46.60	39.59	40.04	68.5
N×T	746	644	486	644	444	777
Country FE	Y	Y	Y	Y	Y	Y
Time FE	N	N	N	Y	N	N

***,**,* refer to significance at the 1%, 5% and 10% level, respectively. Robust standard errors clustered at the Country level. Regression specification of Equation 6. Estimation period Q2 2000 - Q4 2018. Advanced Economies sub-sample only. Column 5 estimates on the sub-sample of intermediate pegs (peg intensities between 0 and 1, for both U.S. and E.U.). Column 6 uses $\widetilde{W}^b_{it}$, the estimated peg intensities (Equation 2) after controlling for common shocks. Within R-squared reported.

6.4 Intermediate pegs

Column 5 of Tables 2, 3 and 4 consider the sub-sample of country-quarter observations which do not include pure floats or hard pegs (i.e. excluding values of 0 or 1 for $\hat{W}^b_{it}$). This is done to verify whether corner policies are driving the results of the regression tests, or whether the range of intermediate pegs actually offer a spectrum of monetary autonomy. Across the full sample, the effects of both U.S. and E.U. peg intensity remain highly significant upon omitting corner policy observations, suggesting that the intensive margin of peg intensity also matters for monetary policy. The advanced economy subgroup signals the same message: the effects of monetary policy pass-through hold for both the intensive and extensive margin of exchange rate regimes.

For the emerging market sub-group, the significance of the coefficient estimate on $\hat{\gamma}_{US}$ disappears (though remains positive) when removing observations containing corner policies (Column 5, Table 4). This may have several interpretations. One is that across emerging markets, intermediate pegs may not offer intermediate monetary autonomy, but rather *disproportionately greater* monetary autonomy than a hard peg, indicating a non-linear relationship between exchange rate flexibility and monetary autonomy: a country which introduces a little bit of exchange rate flexibility can potentially buy a lot of monetary independence. There are other possible interpretations as well: for these countries, increasing flexibility of the exchange rate might disproportionately increase the sensitivity of monetary policy to non-Trilemma factors (domestic objectives, Fear of Floating, financial cycles or commodity cycles, risk premia, etc.). So, while the base

Table 4: Baseline Regression Results: Emerging Markets

	(1)	(2)	(3)	(4)	(5)	(6)
	$\hat{W}_{it}^{b}$	$\hat{W}_{it}^{b}$ (RA, 2)	$\hat{W}_{it}^{b}$ (RA, 4)	$\hat{W}_{it}^{b}$ (RA, 2)	$\hat{W}_{it}^{b}$ (RA, 2) $\in (0, 1)$	$\widetilde{W}_{it}^{b}$
$\hat{\gamma}_{US}$	0.266**	0.265**	0.263*	0.444**	0.165	0.356***
	(0.108)	(0.121)	(0.135)	(0.198)	(0.143)	(0.116)
$\hat{\gamma}_{EU}$	0.199	0.181	0.458	0.066	0.868***	0.064
	(0.167)	(0.179)	(0.322)	(0.218)	(0.261)	(0.177)
Adj. R^2	0.13	0.13	0.12	0.04	0.13	0.14
F-Statistic	46.09	39.18	31.00	32.57	29.94	49.98
N×T	2,135	1,887	1,451	1,887	1,282	2,131
Country FE	Y	Y	Y	Y	Y	Y
Time FE	N	N	N	Y	N	N

***,**,* refer to significance at the 1%, 5% and 10% level, respectively. Robust standard errors clustered at the Country level. Regression specification of Equation 6. Estimation period Q2 2000 - Q4 2018. Emerging Markets sub-sample only. Column 5 estimates on the sub-sample of intermediate pegs (peg intensities between 0 and 1, for both U.S. and E.U.). Column 6 uses $\widetilde{W}_{it}^{b}$, the estimated peg intensities (Equation 2) after controlling for common shocks. Within R-squared reported.

country's monetary policy spillovers are less influential, the costly rising importance across other external factors may offset any benefits from monetary autonomy. In the next section, we will investigate these non-linearities further, and allow regression coefficients to vary across peg intensities to possibly reflect changing weights on policy objectives as countries move from pegs to floats.

Finally, in an interesting twist when considering only intermediate peg observations, monetary spillovers under the Trilemma with regards to E.U. monetary policy becomes statistically significant ($\hat{\gamma}_{EU}$), implying that under intermediate peg intensities, E.U. monetary policy passes through to countries which partially target the Euro and the pass-through increases as the country approaches a peg. However surprisingly, hard pegs to the Euro do not exhibit Trilemma-consistent monetary spillovers in emerging markets.

6.5 Discussion

To summarize, significant evidence of monetary policy spillovers is present in both advanced Economies and emerging Markets, but estimated monetary policy pass-through is considerably stronger among advanced economies. For the full sample and advanced economies in particular, there is robust evidence consistent with Klein and Shambaugh [2015] that the Trilemma holds under interior policy choices (i.e. peg intensities between 0 and 1), potentially allowing for partial monetary autonomy under a managed float. These results validate the prevailing literature testing the Trilemma. Both monetary policy spillovers and overall regression fit (R^2) are lower for the emerging markets sub-sample compared to advanced economies. This could be due to the presence of important factors which are correlated with country i's interest rate. For example, monetary pass-through estimates may be low in emerging markets because risk premia tend to be highly volatile (Kalemli-Ozcan [2019]). Fear of Floating and Global Financial Cycles, operating through the real exchange rate and financial conditions respectively, may also impact country i's policy choices (Calvo and Reinhart [2002] and Rey [2015]). Some emerging markets are heavily reliant on commodity trade, hence exposing themselves to commodity cycles which in turn can influence policy objectives (Aizenman et al. [2011]). Finally, recent evidence suggests that the burgeoning debt positions of emerging markets (and advanced economies) brought in by unprecedented monetary easing after the 2008 Financial Crisis may be interacting with monetary policy objectives (Ahmed et al. [2019]).

A new insight is the significance of joint pass-through from both U.S. and E.U. monetary policy – bearing a key policy implication: basket pegs can potentially mitigate monetary policy spillovers from a single country occurring under a unitary peg by taking on monetary spillovers from an additional country, effectively diversifying spillover risk. Interestingly, Emerging Markets do not seem to exhibit Trilemma-consistent monetary policy spillovers under intermediate pegs. However, this may imply that among these countries, moving from a hard peg to an intermediate peg buys a disproportionate amount of monetary independence – either unconditionally or relatively by assigning greater weight on other policy objectives. Potential non-linearities in the exchange rate regime – monetary spillover function are explored in the next section.

7 Non-linear Trilemma Trade-offs

Thus far, I've provided evidence confirming that monetary spillovers subject to the Trilemma are present in both advanced economies and emerging markets. However, as I mentioned, the regression design implicitly imposes that the spillover country i faces is linear in exchange rate flexibility: $\gamma_b \times \hat{W}_{it}^b$, given free capital flows ($K_{it} = 1$) and a unitary monetary shock ($\hat{Z}_{bt} = 1$, though the size of the shock can be arbitrary). We saw, however, that the Trilemma seems to hold for intermediate pegs among advanced economies and corner policies appear to drive the significant results among emerging markets. This brings the implication of linear monetary spillovers into question – a research area which has received limited attention.

In this section we further explore monetary policy pass-through under intermediate peg intensities, asking specifically whether the relationship with exchange rate flexibility is non-linear. Testing for non-linearities in U.S. and E.U. spillovers jointly is not feasible under the baseline regression design due to the size of the sample.[27] Therefore, I focus

[27] It would require interacting all covariates twice, and sub-samples already are limited in the number

first on non-linearities in U.S. monetary policy. Then, I modify the regression analysis to a setting which can jointly analyze the linearity of monetary spillovers under intermediate exchange rate regimes for both U.S. and E.U. Finally to further test whether the observed non-linearities are statistically significant, I extend the baseline regression to a Generalized Additive Model (GAM) specification adopted from the machine learning literature.

7.1 Peg intensity bins

I start simple with a baseline analysis which allows the researcher to investigate how well the imposed linearity assumption of the original specification is satisfied without adding complexity. To do this, I relax the linear-implied specification of the baseline regression (Equation 6) and estimate separate sub-samples, sorting by peg intensity. Again, using the 2-quarter rolling average peg intensities, $\hat{W}^b_{it}$ (RA, 2). Country-quarter observations are sorted into the following 6 bins:

	Pure Float					Hard Peg
	1	**2**	**3**	**4**	**5**	**6**
W^b_{it}	[0,0.1]	(0.1,.30]	(0.30,.50]	(0.50,0.70]	(0.70,0.90]	(0.90,1]

The regression specification must be modified due to the more limited number of observations per sub-sample after dividing the data into 6 separate groups. Moreover, I only consider peg intensities to one base country at a time, starting with the U.S (Results for E.U. shocks can be found in Table A.4). Constructing bins which condition both on U.S. and E.U. peg intensity would lead to too few observations per group.[28] The regression takes the following form:

$$\Delta R_{it} = \alpha_i + \theta_1 \Delta y_{it} + \theta_2 \Delta \pi_{it} + \theta_3 \Delta RER_{it} + \theta_4 \Delta VIX_t + \theta_5 \Delta \bar{R}_t + \gamma_{US}[\hat{Z}_{US,t} \times K_{it}] + \epsilon_{it}. \tag{7}$$

there are two key differences between Equation 7 and the previous specification, Equation 6. The first is that the lagged dependent variable is removed from the RHS. This is due to data limitations – by constructing sub-groups using more refined exchange rate

of observations they include.

[28]One could take Equation 6 and interact $\hat{Z}_b$ with binned peg intensities, which would potentially allow for both U.S. and E.U. to be jointly tested for non-linear pass-through. However, this comes at the cost of constraining all other regression coefficients to be pooled together across the entire sample. Because policy weights can vary across countries which peg or don't peg, It's crucial to allow for coefficient flexibility, something that can be achieved by estimating on sub-samples. Results from this approach are reported in Table A.4 and are broadly consistent with other specifications.

regime categories, each group will not have sufficient data along the time dimension to reduce the bias that a fixed effects dynamic panel specification generates. Moreover, each observation is now increasingly valuable for statistical power, and therefore lost observations from including a lagged dependent variable becomes costly for inference. On a positive note, since the regression specification is in interest rate *changes* the data is not persistent, thereby excluding a lagged dependent variable will not influence the results in a meaningful way.[29]

The second change is related to peg intensity. First, I only consider U.S. monetary policy spillovers, so the variable capturing shocks from the E.U. is removed. Second, peg intensity, $\hat{W}_{it}^{US}$ is removed from the trio of interactions. This is simply because now we condition the entire sample on $\hat{W}_{it}^{US}$ by estimating separate regressions per intensity bin. An advantage of this specification aside from its simplicity is that, by running separate bin-specific regressions, we allow all of the coefficients to be heterogeneous across peg intensity bins, lending to more realistic and flexible inference, and addressing some of the limitations mentioned previously over the original pooled specification.

7.2 All countries

Table 5 reports spillover estimates from U.S. monetary policy across bins ($\hat{\gamma}_{US}$), but also reports coefficients on the other covariates. This way we can infer whether monetary spillovers are non-linear in peg intensity, but also if greater monetary autonomy indeed translates to greater weights on domestic variables, namely inflation or output. The sixth row reports the spillover coefficients given by $\hat{\gamma}_{US}$, and as the Trilemma implies, the coefficients roughly increase with peg intensity, with hard pegs having the largest spillover coefficients (0.48). However, there is evidence of potential non-linearity in spillovers based on peg intensities. Under weak to moderate peg intensities ranging of 0 to 0.50 (bins 1 to 3), evidence of monetary spillovers is statistically indifferent from zero – the same as if under a fully floating policy. Evidence of monetary spillovers begin to manifest under more rigid exchange rate policy (bins 4 to 6, peg intensities from 0.5 to 1). Moreover, moderately strong pegs (bin 4 and 5) exhibit weaker monetary pass-through from the U.S.compared to hard pegs (bin 6), 0.27 and 0.20 versus 0.48, respectively. This evidence has policy implications, as it suggests that a little bit of exchange rate flexibility can potentially buy a considerable degree of monetary autonomy, and that some exchange rate stability can be bought *without* sacrificing monetary autonomy. Hence, the policy Trilemma trade-off appears to be non-linear in the data, which differs from findings of

[29] If the regression was estimated in *levels*, removing the lagged dependent variable would very likely have a major impact on coefficient estimates. To demonstrate the robustness of omitting the lagged dependent variable in Equation 3, the coefficients on $\hat{\gamma}_{US}$ and $\hat{\gamma}_{EU}$ from Table 2 column 1 would change from 0.351 to 0.364 and 0.511 to 0.500, respectively. The results remain statistically significant at the 1% level.

Aizenman et al. [2010], Ito and Kawai [2014], and Herwartz and Roestel [2017].

Table 5: Spillover Effects across Peg Intensity Bins: All Countries

Bin	1	2	3	4	5	6
$\hat{W}_{it}^{US}$ (RA, 2)	[0,0.1]	(0.1,.30]	(0.30,.50]	(0.50,0.70]	(0.70,0.90]	(0.90,1]
$\Delta\pi_{it}$	0.094***	0.115***	0.093***	0.056	0.170***	0.014*
	(0.022)	(0.043)	(0.015)	(0.044)	(0.025)	(0.007)
ΔRER_{it}	0.015	-0.009	0.003	0.017**	-0.009	0.037**
	(0.011)	(0.007)	(0.007)	(0.008)	(0.007)	(0.018)
Δy_{it}	0.029**	0.014	0.018	0.023	0.004	0.005
	(0.012)	(0.012)	(0.015)	(0.017)	(0.006)	(0.006)
ΔVIX_t	0.165**	0.302**	0.027	0.143	0.173*	-0.138**
	(0.070)	(0.118)	(0.074)	(0.130)	(0.088)	(0.060)
$\Delta\bar{R}_t$	-0.048	0.186	0.045	0.157*	0.023	0.020
	(0.082)	(0.121)	(0.072)	(0.088)	(0.034)	(0.045)
$\hat{\gamma}_{US}$	0.001	-0.010	0.142	0.276**	0.207***	0.482***
	(0.008)	(0.092)	(0.150)	(0.139)	(0.067)	(0.132)
Adj. R^2	0.01	-0.01	0.05	0.03	0.24	0.03
F-Statistic	7.16	6.15	10.39	8.91	26.68	9.84
N×T	385	356	409	356	389	684

***,**,* refer to significance at the 1%, 5% and 10% level, respectively. Robust standard errors clustered at the Country level. Regression specification of Equation 7. Estimation period Q2 2000 - Q4 2018. Country Fixed Effects included. Within adjusted R-squared reported.

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Moreover, coefficients on inflation tend to remain highly significant even under weak to moderate peg intensity (bins 2 and 3) and are approximately 7 times larger than under a hard peg (bin 6), suggesting that the gains from monetary autonomy are associated with greater emphasis on targeting domestic policy objectives, particularly inflation, The evidence suggests that pure floating is not necessary to achieve these gains. There is also some evidence that under a both floating and fixed exchange rates, and a particular intermediate pegs (bins 1, 2 and 5, 6), monetary policy is increasingly influenced by global financial conditions proxied by changes in the VIX index. Under a flexible (fixed) exchange rate, interest rate changes tend to respond positively (negatively) to changes in the VIX. Because U.S. monetary policy tends to ease in the presence of heightened risk, pegged monetary policy also falling when the VIX rises is consistent with the Trilemma.

Under floating exchange rates, interest rates tend to rise – this is shown to be driven by the emerging markets sub-sample, who tend to tighten monetary polciy, instead of ease, during periods of heightened risk aversion in hopes of mitigating sudden capital outflows.

7.3 Advanced economies

Table 6 reports results across advanced economies. Again, monetary policy pass-through estimates are nearly monotonically increasing in peg intensity. Hard pegs (bin 6) suggest full pass-through with a coefficient of approximately 1. A weakly non-linear trade-off between exchange rate regime and monetary autonomy is present among the advanced economy sub-sample. A moderate to strong peg (bins 4 and 5) have spillover estimates of 0.43 and 0.62, respectively, suggesting that giving up a little exchange rate stability can cut monetary spillovers by 50%. Weaker pegs (bins 2 and 3) suggest even greater gains in monetary autonomy which are not statistically different than monetary autonomy under a floating exchange rate. The evidence suggests that a country which floats it's exchange rate can administer stabilization with little cost in monetary independence, while a country running a hard peg can give up a little stability to buy a considerable degree of monetary autonomy.

Across advanced economies, there is consistent evidence that intermediate exchange rate regimes offer countries greater weight allocation to domestic objectives, particularly output growth, but not inflation. Under floating and most intermediate exchange rate regimes, output growth has a significant coefficient (bins 1, 2, 4 and 5) which is not present under a hard peg. Evidence that global financial conditions have strong influence over advanced economy interest rates is weak (mostly insignificant coefficient estimates on ΔVIX_{it}). Taking this point together with the results on domestic policy objectives, it appears that for advanced economies, flexibility allows countries to focus on domestic objectives without surrendering autonomy to global financial forces.

7.4 Emerging markets

Table 7 reports results for emerging markets. Across the emerging market sample under hard pegs there is significant evidence of U.S. monetary pass-through, though imperfect (coefficient of 0.367). Consistent with hard pegs to the U.S. Dollar, changes in the VIX index are associated with interest rate cuts among hard pegging emerging markets. In addition, these countries exhibit the strongest evidence of responding to real exchange rate depreciation by hiking interest rates (Fear of Floating, Calvo and Reinhart [2002]).

Like their advanced economy counterparts, across bins monetary policy pass-through appears non-linear in exchange rate peg intensity. Moving from a hard peg (bin 6) to a moderately strong peg (bin 5) can reduce on average, interest rate pass-through by two-thirds (from 0.37 to 0.13). Even more striking, is that bins 2 through 4 show no

Table 6: Spillover Effects across Peg Intensity Bins: Advanced Economies

Bin	1	2	3	4	5	6
$\hat{W}_{it}^{US}$ (RA, 2)	[0,0.1]	(0.1,.30]	(0.30,.50]	(0.50,0.70]	(0.70,0.90]	(0.90,1]
$\Delta\pi_{it}$	0.009	0.115**	0.101**	0.003	-0.099	0.092***
	(0.024)	(0.047)	(0.049)	(0.031)	(0.068)	(0.012)
Δy_{it}	0.050***	0.049***	0.009	0.016***	0.039***	0.010
	(0.017)	(0.017)	(0.013)	(0.006)	(0.009)	(0.022)
ΔRER_{it}	-0.001	-0.013	0.002	-0.015***	0.024	0.011
	(0.003)	(0.009)	(0.007)	(0.005)	(0.015)	(0.025)
ΔVIX_t	-0.093	0.062	-0.042	0.132*	0.043	-0.121
	(0.069)	(0.091)	(0.054)	(0.066)	(0.119)	(0.107)
$\Delta\bar{R}_t$	0.056**	0.129***	0.043	0.003	-0.037**	-0.031
	(0.025)	(0.042)	(0.045)	(0.033)	(0.017)	(0.039)
$\hat{\gamma}_{US}$	0.060*	0.012	0.137**	0.433***	0.616***	1.021***
	(0.035)	(0.065)	(0.057)	(0.030)	(0.106)	(0.115)
Adj. R^2	0.17	0.28	0.01	0.09	0.30	0.56
F-Statistic	8.71	10.73	2.51	3.05	4.54	19.03
N×T	167	130	100	50	37	84

***,**,* refer to significance at the 1%, 5% and 10% level, respectively. Robust standard errors clustered at the Country level. Regression specification of Equation 7. Estimation period Q2 2000 - Q4 2018. Country Fixed Effects included. Advanced Economy sub-sample only. Within adjusted R-squared reported.

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evidence of significant monetary pass-through. That is, light pegs (bin 2) and even moderate pegs (bins 3 and 4), on average, afford as much monetary autonomy as a free floating exchange rate (bin 1). Emerging market monetary pass-through, in comparison to advanced economies, appears much more non-linear in exchange rate flexibility.

Moderate pegs (bins 2 and 3) appear to put as much weight on targeting inflation as free floating emerging markets (bin 1) and about 7 times as much weight compared under a hard peg (bin 6). However, contrasting with advanced economies, there is evidence of global financial conditions significantly impacting the monetary policy of emerging markets under free floats or moderate floats (bins 1 and 2). Therefore, flexible exchange rates in emerging markets may be double-edged: while it buys monetary autonomy and greater allocation to domestic objectives, policy choices will also be influenced by global factors (Miranda-Agrippino and Rey [2020]). The sweet spot seemingly lies in the intermediate

Table 7: Spillover Effects across Peg Intensity Bins:
Emerging Markets

Bin	1	2	3	4	5	6
$\hat{W}_{it}^{US}$ (RA, 2)	[0,0.1]	(0.1,.30]	(0.30,.50]	(0.50,0.70]	(0.70,0.90]	(0.90,1]
$\Delta\pi_{it}$	0.101***	0.109**	0.093***	0.058	0.172***	0.014**
	(0.022)	(0.051)	(0.015)	(0.045)	(0.026)	(0.007)
Δy_{it}	0.026*	0.005	0.020	0.023	0.003	0.005
	(0.015)	(0.015)	(0.018)	(0.018)	(0.007)	(0.006)
ΔRER_{it}	0.026	-0.011	0.004	0.020**	-0.010	0.040**
	(0.018)	(0.008)	(0.010)	(0.008)	(0.007)	(0.018)
ΔVIX_t	0.296***	0.438***	0.060	0.151	0.175*	-0.133**
	(0.082)	(0.155)	(0.095)	(0.154)	(0.098)	(0.067)
$\Delta\bar{R}_t$	-0.122	0.223	0.047	0.232**	0.039	0.025
	(0.146)	(0.234)	(0.105)	(0.110)	(0.041)	(0.050)
$\hat{\gamma}_{US}$	-0.140	0.051	0.1490	0.210	0.134**	0.367***
	(0.214)	(0.439)	(0.333)	(0.187)	(0.060)	(0.113)
Adj. R^2	0.00	-0.07	0.04	0.06	0.26	0.01
F-Statistic	4.99	3.04	7.91	8.67	25.65	6.42
N×T	218	226	309	306	352	600

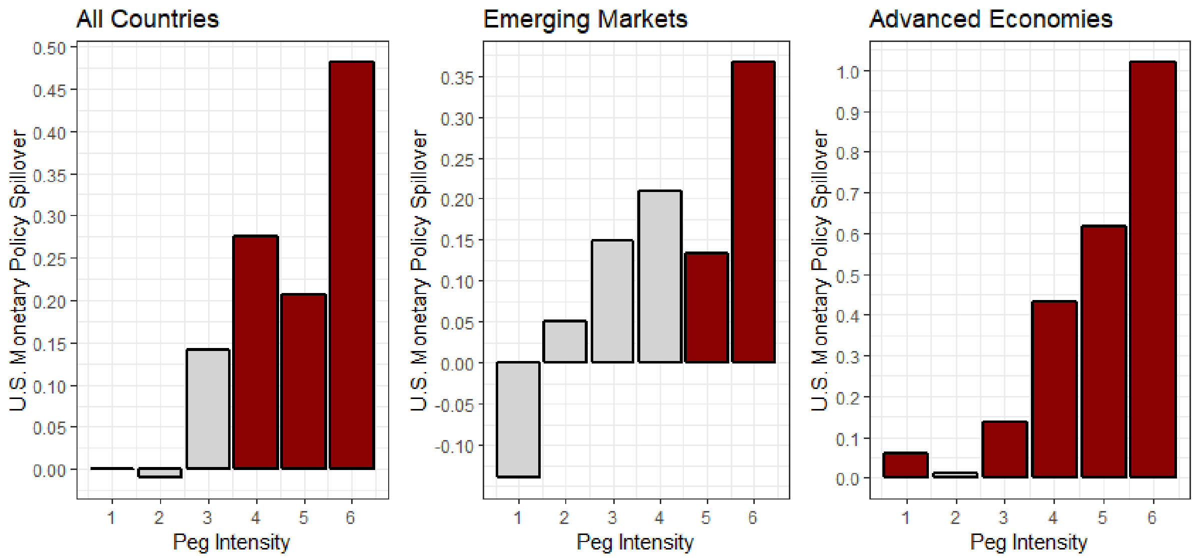
***,**,* refer to significance at the 1%, 5% and 10% level, respectively. Robust standard errors clustered at the Country level. Regression specification of Equation 7. Estimation period Q2 2000 - Q4 2018. Country Fixed Effects included. Emerging Market sub-sample only. Within adjusted R-squared reported.

range – U.S. peg intensities between 0.30 and 0.5 – where policy rates are able to adjust to domestic inflation, while buying a significant degree of monetary policy autonomy and insulation from global financial shocks.

7.5 A Generalized Additive Model Approach

The baseline non-linear regression analysis sheds light on new evidence of a varying trade-off between exchange rate flexibility and monetary independence, especially under intermediate exchange rate regimes. However, without a formal test, we cannot conclude whether the evidence points to an actual non-linear trade off, or whether the results are caused by measurement noise. For example, it is possible that for emerging markets, the relationship is indeed linear, but just so weak that under more flexible exchange

Figure 4: U.S. spillover estimates $\hat{\gamma}_{US}$ by Peg Intensity Bins



Peg intensity of 1 corresponds to pure float. Peg intensity of 6 corresponds to hard peg vis-a-vis the USD. Estimates of $\hat{\gamma}_{US}$ from Equation 7. Dark-shaded bars are statistically significant at the 10% level.

rates it is too difficult to differentiate from a null effect. To test more rigorously for non-linearities, I adopt a flexible non-paratmetric regression framework by estimating a generalized additive model (GAM), an approach first introduced in the machine learning and statistical learning literature by Hastie and Tibshirani [1990].

The concept is quite simple. Unlike linear regression which assumes that the dependent variable and the independent variable are linearly related, under a GAM, the relationship is allowed to be linear *or* a non-linear smooth function. Typically, this is denoted as:

$$Y_{it} = \beta X_{1it} + \mathbf{s}(X_{2it}) + e_{it}, \tag{8}$$

where X_{1it} takes on a traditional linear relationship with Y_{it}, but X_{2it} does not have to. The function $\mathbf{s}()$ is an unspecified smooth (non-parametric) function, often constructed from a number of basis functions (e.g. splines). While the method was introduced decades ago, GAMs have only recently gained popularity in application due to advances in computing power, as estimation can become computationally intensive under high dimensional settings. I recast the baseline regression model (Equation 6) in a GAM setting specifically tailored to address the question at hand:

$$\Delta R_{it} = \alpha_i + \phi_1 \Delta R_{i,t-1} + \phi_2 \Delta y_{it} + \phi_3 \Delta \pi_{it} + \phi_4 \Delta RER_{it}$$
$$+ \phi_5 \Delta VIX_t + \phi_6 \Delta \bar{R}_t$$
$$+ \gamma_{US}[\hat{Z}_{US,t} \times \mathbf{s}(\hat{W}_{it}^{\$}) \times K_{it}] + \gamma_{EU}[\hat{Z}_{EU,t} \times \mathbf{s}(\hat{W}_{it}^{€}) \times K_{it}] + \epsilon_{it}. \quad (9)$$

Notice in Equation 9, I leave everything as is, but now allow the the functional relationship with peg intensity, $\hat{W}_{it}^b$ to be non-linear. Moreover, this specification allows us to jointly investigate spillovers from the U.S. and E.U. because the model is able to incorporate information from the full panel, hence no sub-sampling is required. The smooth function $s(\hat{W}_{it}^b)$ is estimated via penalized cubic splines.[30] Two main estimation approaches are typically used for fitting GAMs, cross validation or generalized cross validation (GCV) or (restricted) maximum likelihood (REML). GCV is shown to be unbiased asymptotically, but in application with small samples, typically suffers from under-smoothing. For these reasons, I estimate the GAM via REML, which is typically robust to under-smoothing but more computationally intensive (Wood [2017]).

There are alternative modeling approaches to GAMs which also allow for smooth non-linear relationships in regression analysis. For instance, smooth transition models have been used prominently for modeling exchange rate dynamics (Franses et al. [2000], Taylor et al. [2001]). GAMs, however, are substantially different from smooth transition models. First, GAMs are not restricted to discrete regimes, while smooth transition models a priori assume discrete, usually two, regimes, while the transition between the regimes is smooth.[31] Moreover, the smooth transition between regimes typically has a pre-specified functional form (e.g. logistic or exponential), which itself imposes symmetry in the transition probabilities. Other potential issues with smooth transition models are that identifying the transition function may be difficult in cases where the underlying data does not provide sufficient information, and that findings can also depend on the starting values. GAMs are not restricted by any of these parametric assumptions. Finally, and crucially, GAMs are sufficiently flexible to allow for a single non-linearity in the model *within* an interaction term. By only allowing spillovers to vary non-linearly with exchange rate regime while keeping everything else similar to the standard econometric specification (Equation 3), we can call out the marginal effects of introducing non-linearity along the single, focal dimension tailored to our specific research question.

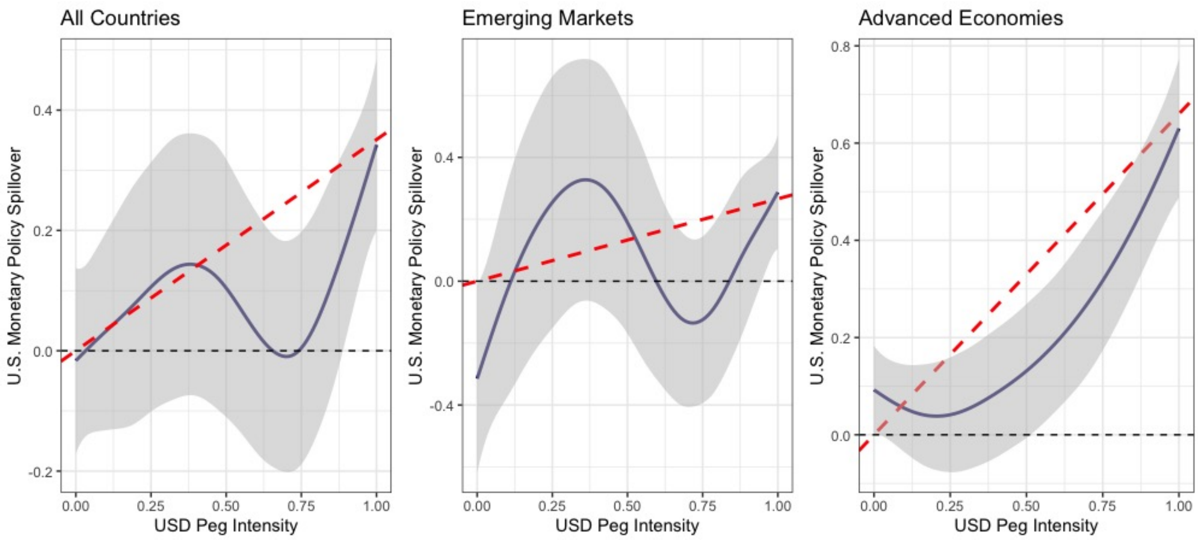
I estimate the model for all countries, and the two sub-samples (advanced economies and emerging markets). For each model, the estimation procedure selected 10 knots. Figure 5 shows U.S. spillover estimates under the GAM specification, with 95% credible

[30]Penalized cubic splines are cubic splines, but changes at knots are penalized, shrunk towards zero. This helps prevent over fitting even in the presence of many knots.

[31]More than two regimes quickly increases the number of parameters that need to be estimated.

intervals. Red dashed lines are the spillover estimates implied by the linear baseline specification, Equation 6. It's clear that for some regions of peg intensity, the non-linearity is statistically significant at the 5% level or lower across both the full sample and sub-samples.

Figure 5: GAM Estimates: U.S. spillover estimates by Peg Intensity



Spillover estimate is under free capital controls ($K_{it} = 1$). Estimates are from Equation 9. Shaded areas are 95% credible intervals. Number of knots selected: 10 via REML. Red dashed line is the implied linear spillover under Equation 6.

Across the full sample, the Trilemma effects don't appear to kick in until peg intensity reaches north of 0.50, suggesting that reasonably managed exchange rates can potentially enjoy a high degree of monetary independence. However, the Trilemma conditions appear to take effect sharply beyond a peg intensity of 0.75, accelerating rapidly. The monetary transmission function is estimated to be highly non-linear for emerging markets, making a wave-like pattern, only turning statistically significant for pegs and near-pegs. For peg intensities ranging from 0 to 0.75, monetary policy spillover estimates are statistically indifferent from zero for emerging markets. The advanced economy sub-sample also indicates non-linear monetary spillovers, with statistically insignificant estimates from a peg intensity of 0 to 0.5, but then spillover estimates accelerate sharply as peg intensity rises further.

Binned analysis results for E.U. spillovers are reported in Table A.4, with GAM estimates for E.U. spillovers are reported in Figure A.5. Unlike U.S. spillovers, E.U. spillovers do not increase monotonically across bins (but do roughly increase in peg intensity), exhibiting some non-linearity. However, under the GAM specification, these non-linearities related to E.U. spillovers are statistically insignificant. Finally, for robustness, I also present a set of results from the GAM estimation under a more conservative selection of 5 knots rather than the 10 knots selected by the estimation algorithm (Figure A.6), which increases the smoothness of the spillover function. The results and non-linear shapes presented here broadly hold, suggesting that the estimates are robust under varying tuning parameters.

7.6 Discussion

The evidence from this section points to a non-linear trade-off between exchange rate flexibility and monetary autonomy across the full sample and advanced economy and emerging market sub samples, bringing into question the traditional assumption of a linear Trilemma. Initially, under the simple binned analysis, evidence pointed to non-linear Trilemma trade-offs between monetary autonomy and exchange rate stability in both advanced and emerging countries. Weak and moderate pegs come with more stability than floating exchange rates while providing just as much monetary independence. Even moving from a hard peg to one that is strongly managed appears to reduce disproportionately the degree of monetary policy pass-through a country is exposed to. These non-linear patterns are further confirmed under the more sophisticated GAM model, and the non-linearities test as statistically significant among both advanced economies and emerging markets.

It's also apparent that under varying degrees of peg intensity, countries allocate to domestic targets differently, and this may be enabled by gains from a non-linear trade-off, or weak adherence to the Trilemma. Among advanced economies, greater monetary autonomy bought with exchange rate flexibility is associated with stronger weights on domestic policy objectives (output growth), with no evidence of a global financial cycle effect on monetary policy. For emerging markets, exchange rate flexibility and greater monetary autonomy translates to heavier emphasis on inflation as a domestic policy target. Global financial cycle effects on monetary policy are present under both floating/near-floating and near-hard/hard peg regimes in emerging markets, therefore mid-intensity pegs appear to offer the best trade-off for this group of economies in terms of monetary independence and exchange rate stability.

8 What Induces Non-Linear Monetary Spillovers?

8.1 Active reserves management

Is this empirical non-linearity between exchange rate flexibility and monetary autonomy a free lunch, or generated through some economic friction? To address this, I explore two possible mechanisms which could result in a non-linear trade off between exchange rate stability and monetary independence. The first of these is the role of reserves accumulation as an additional policy tool. The potential for foreign exchange interventions to allow a country to violate the Trilemma constraint has been discussed in the literature. Obstfeld et al. [2010] argue that the demand for reserves is crucially motivated by the objective of financial stability amid increased financial integration. Empirically, they find that countries under soft pegs tend to hold significantly greater levels of reserves.[32] These countries may wish to actively intervene in exchange markets to prevent external financial shocks from causing large exchange rate devaluations. Aizenman et al. [2010] document the trend of several emerging markets choosing to target intermediate levels of exchange rate stability and financial openness while maintaining high levels of monetary autonomy, thereby violating the Trilemma. These countries also tend to hold sizable levels of international reserves. Steiner [2017] and Angrick [2018] also report evidence suggesting that the policy Trilemma constraint can be relaxed with active reserves management.

Using international reserves to relax the policy Trilemma constraints applies whether UIP holds or is violated. If UIP holds, a country may choose to intervene in foreign exchange markets as an alternative way to stabilize the exchange rate rather than altering the interest rate directly. Specifically, sterilized interventions would, in theory, achieve exchange rate stability without changing the money supply. On the other hand, unsterilized interventions would alter the money supply, but with a lag, and therefore unsterilized interventions can also grant exchange rate stability with monetary independence – in the short-run. If UIP fails to hold (as it seems to empirically) then that itself causes the Trilemma constraints to break down. In this situation, matching the monetary policy of the base country may simply not be sufficient to maintain the desired level of exchange rate stability, with direct intervention being more effective.

To investigate the role of active reserves management, I test whether the accumulating and expending of country i's foreign exchange reserves are associated with base country monetary policy changes. To do this, I simply replace the dependent variable of the baseline equation (Equation 6) with a measure of changes in international reserves:

$$\begin{aligned}\Delta IR_{it} = \alpha_i + \phi_1 \Delta IR_{i,t-1} + \phi_2 \Delta y_{it} + \phi_3 \Delta \pi_{it} + \phi_4 \Delta RER_{it} \\ + \phi_5 \Delta VIX_t + \phi_6 \Delta \bar{R}_t \\ + \gamma_{US}[\hat{Z}_{US,t} \times \hat{W}^{\$}_{it} \times K_{it}] + \gamma_{EU}[\hat{Z}_{EU,t} \times \hat{W}^{€}_{it} \times K_{it}] + \epsilon_{it}, \quad (10)\end{aligned}$$

where ΔIR_{it} is the quarterly change in logged international reserves (excluding gold) of country i in quarter t. Reserves are measured in terms of USD. Considering the growth of reserves accounts for differences in levels of international reserves across countries, and the RHS of the equation controls for different GDP growth rates across countries – hence this specification nests the case where reserves are measured per GDP, logged IR/GDP.

[32] The effect of a hard peg was found not to be statistically significant, but economically significant and quantitatively similar to that under a soft peg.

Data on international reserves is taken from the IMF International Reserves and Foreign Currency Liquidity database.

A negative coefficient on $\hat{\gamma}_b$ suggests that a reduction in reserves is associated with a positive shock to the foreign interest rate, and this reduction strengthens in the degree of exchange rate rigidity. Under a rigid exchange rate regime, a higher foreign interest rate, without a reciprocated change in the local country interest rate, would cause capital outflows and currency depreciation. However, this could be mitigated without an interest rate change (i.e. preserving monetary independence) if the central bank steps in by selling reserves to maintain exchange rate stability.

Table 8: International Reserves and Monetary Spillovers

Dep. Variable ΔIR_{it}	All Countries	Advanced Economies	Emerging Markets
$\hat{\gamma}_{US}$	-2.00**	-0.787	-3.296***
	(0.815)	(1.445)	(1.033)
$\hat{\gamma}_{EU}$	1.400	0.456	1.923
	(3.630)	(6.723)	(2.102)
Excluding Corner Exchange Rate Policies			
$\hat{\gamma}_{US}$, $\hat{W}_{it}^{US} \in (0,1)$	-2.079**	-1.434	-4.117***
	(0.958)	(1.344)	(1.303)
$\hat{\gamma}_{EU}$, $\hat{W}_{it}^{EU} \in (0,1)$	-1.344	-3.001	0.949
	(5.065)	(7.268)	(4.162)

***,**,* refer to significance at the 1%, 5% and 10% level, respectively. Robust standard errors clustered at the Country level. Estimation period: Q2 2000 - Q4 2018. Peg intensity used: $\hat{W}_{it}^{b}$ (RA, 2).

Table 8 reports coefficient estimates. The first two rows consider the full spectrum of exchange rate flexibility including pure float and pure pegs (1,926 full sample observations) while the second two rows are considering only intermediate exchange rate regimes ($\hat{W}_{it}^{b} \in (0,1)$) (1,330 full sample observations) to assure that the results aren't driven by corner policies. Reserves seem to be more sensitive to U.S. shocks than E.U. shocks, with the latter not statistically significant across sub-samples. This is consistent, and may be associated with the role of the U.S. Dollar making up a majority of reserve assets and exchange rate pegs. The significant negative coefficients on U.S. monetary shocks suggest that countries tend to reduce international reserves in response to a U.S. tightening, possibly to stabilize the exchange rate and prevent excessive depreciation. This effect strengthens in peg intensity, and is particularly significant among emerging markets, consistent with previous studies. The effects become more pronounced when considering the sub-sample of intermediate exchange rate regimes, with E.U. shocks turning negative and economically significant (but not statistically significant) for advanced economies. For emerging markets under intermediate pegs to the U.S. Dollar, a coefficient of -4.12 implies that under a strongly managed peg (peg intensity of 0.80), a 1 percentage point U.S. interest rate shock is associated with a reduction of international reserves equal to [+1% x -4.12 x 0.80] = -3.2%.

The significant response of international reserves to monetary shocks in emerging markets, which is particularly strong under intermediate exchange rate regimes, provides some evidence supporting their role in relaxing the policy Trilemma, thereby enabling a non-linear trade off between exchange rate stability and monetary autonomy.

8.2 Limits to international arbitrage

A second mechanism that may produce a non-linear trade off between monetary autonomy and exchange rate stability is if there exists costly frictions which inhibit the free flow of capital (e.g. transaction costs, intermediation fees, illiquidity), thereby violating the UIP condition (Fama [1984], Engel [1996], Bansal and Dahlquist [2000]). In the presence of such frictions, interest rate differentials between two pegged countries can persist, only to be arbitraged when the differential widens enough to compensate the investor for the associated costs. This suggests that monetary policy spillovers should not just be an increasing function in a) financial openness and b) exchange rate rigidity, but also the c) interest rate differential between the base country and country i. In other words, when the interest rate differential is small, country i has more monetary autonomy, therefore the pass-through of a U.S. monetary policy shock should be smaller, than when the interest rate differential is large (all else fixed).

I test for evidence consistent with this hypothesis with a simple extension to the baseline regression (Equation 6):

$$\begin{aligned}\Delta r_{it} = \alpha_i + \phi_1 \Delta r_{i,t-1} + \phi_2 \Delta y_{it} + \phi_3 \Delta \pi_{it} + \phi_4 \Delta RER_{it} \\ + \phi_5 \Delta VIX_t + \phi_6 \Delta \bar{R}_t \\ + \gamma_{US}[\hat{Z}_{US,t} \times \hat{W}^{\$}_{it} \times K_{it} \times |r_{i,t-1} - r_{US,t-1}|] + \gamma_{EU}[\hat{Z}_{EU,t} \times \hat{W}^{€}_{it} \times K_{it} \times |r_{i,t-1} - r_{EU,t-1}|] + \epsilon_{it},\end{aligned} \tag{11}$$

where the monetary policy shock instrument $[\hat{Z}_{US,t} \times \hat{W}^{b}_{it} \times K_{it}]$ is further interacted with the absolute lagged interest rate differential, $|r_{i,t-1} - r_{b,t-1}|$. Under this specification, a positive estimate on $\hat{\gamma}_b$ implies that for a given degree of exchange rate flexibility and financial openness, monetary policy spillovers will be larger when interest rate differentials are wider.

Table 9: International Arbitrage and Monetary Spillovers

Dep. Variable Δr_{it}	All Countries	Advanced Economies	Emerging Markets
$\hat{\gamma}_{US}$	0.042***	0.182	0.0419***
	(0.006)	(0.161)	(0.007)
$\hat{\gamma}_{EU}$	0.004	0.317**	-0.047
	(0.054)	(0.131)	(0.060)
Excluding Corner Exchange Rate Policies			
$\hat{\gamma}_{US}$, $\hat{W}_{it}^{US} \in (0,1)$	0.013	0.208	-0.007
	(0.029)	(0.164)	(0.026)
$\hat{\gamma}_{EU}$, $\hat{W}_{it}^{EU} \in (0,1)$	0.150**	0.291**	0.108
	(0.070)	(0.130)	(0.084)

***,**,* refer to significance at the 1%, 5% and 10% level, respectively. Robust standard errors clustered at the Country level. Estimation period: Q2 2000 - Q4 2018. Peg intensity used: $\hat{W}_{it}^{b}$ (RA, 2).

Table 9 reports estimates of $\hat{\gamma}_b$, testing whether the interest rate differential influences monetary policy transmission. While broadly, coefficient estimates are positive (consistent with limits to arbitrage), statistical significance varies. The strongest evidence supporting limits to arbitrage is present in advanced economies targeting the Euro (estimate of 0.317), and this effect is robust for the sub-sample of intermediate pegs (estimate of 0.291). A significant effect of interest rate differentials on monetary pass through is also seen in emerging markets targeting the USD, however, this effect is driven by corner policies (namely emerging markets under fixed or floating exchange rate regimes).

For advanced economies targeting the Euro, the limits to arbitrage mechanism shows the strongest evidence of driving a non-linear exchange rate regime-monetary autonomy trade-off. Overall however, evidence of a limits to arbitrage friction is weaker than the evidence supporting the role of active reserves management. The use of international reserves, specifically among emerging markets, may be an important factor allowing countries to 'lean against' the Trilemma constraint, corroborating Aizenman et al. [2010]. Thus, active use of international reserves results in what appears to be exchange rate stability, without necessarily losing monetary autonomy.

9 Robustness

9.1 Long-Run Monetary Policy Adjustment

The main analysis focuses on short-run associations between country i and the base country's monetary policy, while Shambaugh [2004] highlight the possibility of long-run adjustment in the policy rate which might also depend on the Trilemma configuration. That is, even if policy rates across countries respond immediately to one another, it's also possible for country i's interest rate to be increasingly cointegrated with the base country's interest rate as peg intensity rises, so interest rate adjustment occurs over both the short-run and over a longer period of time.[33] To test for this, I extend Equation 6 to include two error-correcting terms: a cointegrating vector between country i's interest rate and the base country (U.S. and E.U. interest rates, respectively), interacted with peg intensity and capital openness:

$$(r_{i,t-1} - C_b r_{b,t-1}) \times \hat{W}^b_{i,t-1} \times K_{i,t-1}. \tag{12}$$

Typically one estimates C_b in a first-stage, but I pre-set $C_b = 1$, effectively defining the cointegrating vector as the interest rate differential between country i and base country b.[34] A negative coefficient on this term implies that when country i's interest rate exceeds the base country's, it will induce adjustment in the policy rate to catch down to the base country's. The interaction with peg intensity allows the rate of reversion to strengthen with peg intensity as expected under the policy Trilemma. The interaction with capital openness allows for comparison across countries with identical openness yet differing peg intensities.

Table 10 reports long-run spillover effects.[35] Short run estimates are included to verify that they are not sensitive to the inclusion of error-correction terms. Across the sample, there is evidence of longer-run adjustment in country i's interest rate to both base countries E.U. and U.S. which increases in country i's peg intensity to either base country. The negative coefficient sign is theoretically consistent: when the interest rate differential is positive (negative), country i's policy rate adjusts in the direction of the base country interest rate. When stratifying the sample into advanced and emerging market sub-samples, it's the emerging markets which exhibit evidence of statistically significant error-correction in their policy rates under both U.S. and E.U. pegs, while advanced economies generally only exhibit evidence of strong short-run monetary spillovers. If the

[33] This could be due to various financial market imperfections or practical limits to arbitrage.

[34] Constraining the cointegrating vector to the interest rate differential by setting $C_b = 1$ is theoretically consistent with UIP.

[35] Robust standard errors clustered at the Country level. Regression specification of Equation 6 plus error correction terms (Equation 12). Estimation period: Q2 2000 - Q4 2018. Peg intensity used: $\hat{W}^b_{it}$ (RA, 2).

Table 10: Short vs. Long-run Monetary Spillovers

Dep. Variable Δr_{it}	All Countries	Advanced Economies	Emerging Markets
$\hat{\gamma}_{US}$	0.398***	0.783***	0.283**
	(0.116)	(0.199)	(0.112)
$\hat{\gamma}_{EU}$	0.419***	0.684***	0.206
	(0.142)	(0.120)	(0.239)
$(r_{i,t-1} - r_{US,t-1}) \times \hat{W}^{US}_{i,t-1} \times K_{i,t-1}$	-0.022**	-0.035	-0.023**
	(0.011)	(0.025)	(0.011)
$(r_{i,t-1} - r_{EU,t-1}) \times \hat{W}^{EU}_{i,t-1} \times K_{i,t-1}$	-0.075***	0.001	-0.084***
	(0.022)	(0.031)	(0.024)

***,**,* refer to significance at the 1%, 5% and 10% level, respectively. Robust standard errors clustered at the Country level. Estimation period: Q2 2000 - Q4 2018. Peg intensity used: $\hat{W}^b_{it}$ (RA, 2).

sample is limited to only intermediate pegs ($\hat{W}^b_{it} \in (0,1)$), the long-run effect against E.U. peg intensity turns significant at the 1% level while the long-run effect vis-a-vis the U.S. turns insignificant,[36] precisely matching patterns in short-run effects for emerging markets under intermediate pegs, thereby supportive of potentially non-linear policy trade-offs between exchange rate stability and monetary autonomy.

Given the high rate of short-run pass-through among advanced economies, it is plausible that base country monetary policy spillovers occur rather quickly and to their full extent among these countries. The significant long-run adjustment among emerging markets at least in part, may explain their relatively weak and imperfect short run pass-through, suggesting that across emerging markets the monetary spillover from base countries may take longer. These results are consistent with the fact that emerging markets are considerably less finanially developed and host to generally weaker institutions – both factors potentially inducing greater financial market frictions compared to their advanced economy counterparts.

9.2 Alternative Measures of Exchange Rate Flexibility

As a robustness check, I also consider the fine exchange rate regime classifications of Ilzetzki et al. [2019] (IRR). For this exercise, I only consider U.S. shocks rather than both U.S. and E.U. shocks since the construction of the IRR data doesn't consider de facto basket anchors. The IRR exchange rate regime data, which are monthly, are aggregated to quarterly averages. There are five levels: Floating, Weak Managed Float, Moderate Managed Float, Strong Managed Float, and Fixed (U.S. is the anchor currency). Denote

[36] This result is not reported in Table 10.

them: 1, 2, 3 and 4 and 5, respectively. The original IRR fine classification contains 15 different regimes. I consolidate levels 2 through 13 into the respective bins described in Table 11. Using this alternative exchange rate regime classification, I test for evidence of non-linear monetary policy transmission (with respect to the exchange rate regime).

Table 11: Consolidating Ilzetzki et al. [2019] (IRR) Fine Classifications

IRR (2019)	**To**
13	1 (Float)
11, 12	2 (Weak Managed)
9, 10	3 (Moderate Managed)
6, 7, 8	4 (Strong Managed)
2, 3, 4, 5	5 (Peg)

IRR level 1, 14 and 15 are omitted. They correspond to, respectively: 1: no legal tender, 14: collapsing currency, 15: dual market with missing data.

The regression specification used is the same as Equation 6, but with only U.S. shocks, and now the discrete IRR exchange rate regimes:

$$\begin{aligned}\Delta R_{it} = \alpha_i + \phi_1 \Delta R_{i,t-1} + \phi_2 \Delta y_{it} + \phi_3 \Delta \pi_{it} + \phi_4 \Delta RER_{it} \\ + \phi_5 \Delta VIX_t + \phi_6 \Delta \bar{R}_t \\ + \gamma_{US}(IRR)[\hat{Z}_{US,t} \times D(IRR)^{\$}_{it} \times K_{it}] + \epsilon_{it}. \quad (13)\end{aligned}$$

The coefficient $\hat{\gamma}_{US}(IRR)$ represents the spillover coefficients across the five different IRR exchange rate regime classifications. If the estimates are not significantly and/or monotonically increasing in exchange rate rigidity, the story of non-linear monetary spillovers remains consistent with the primary analysis.

Table A.5 reports estimates of $\hat{\gamma}_{US}(IRR)$ across all countries, advanced economies, and emerging markets. The general pattern persists: under more rigid exchange rates (3, 4 and 5), there is disproportionately less monetary independence. The hard peg (bin 5) estimates, interestingly, are statistically insignificant for emerging markets, but highly rigid floats (bin 4) are indeed significant and subject to high monetary pass-through (estimate of 0.862). Across all three groups of countries, pass-through under free floating regimes less than 0.20 (but statistically significant among advanced economies), suggesting considerable monetary independence from the U.S. under a floating exchange rate.

To summarize, under a different measure of exchange rate regime, the results of monetary pass-through tend to be consistent with the baseline analysis. In addition, the robustness check confirms suggestive non-linearities in most cases, where different degrees of flexibility *within* intermediate exchange rate regimes indicate disproportionate gains/losses in monetary autonomy.

9.3 Accounting for the Zero Lower Bound

As mentioned in Section 5, both the U.S. and the E.U. saw prolonged episodes where the policy rate was pinned to the effective lower bound. The baseline specification treats these episodes as having little to no variation in monetary policy. Despite this, the use of unconventional policy tools were widespread in both countries, and therefore, it's important to allow for variation in monetary conditions which may not be directly observable through the policy rate. To do this, I take U.S. and E.U. shadow policy rates (Wu and Xia [2016]), which replace actual policy rates pinned to the ZLB with model-implied shadow rates. After the global financial crisis, while observed policy rates were at near-zero, unprecedented levels of monetary easing drove shadow rates into negative territory.

The approach is simple, I replace actual policy rates R_{bt} with the shadow rate value, if R_{bt} is at the effective lower bound.[37] Then, I recompute the residual monetary shock $\hat{Z}_{bt}$ from the series of ΔR_{bt} spliced with shadow rates. The results after augmenting policy shocks with shadow rates are reported in Table A.6, and are largely consistent with the baseline analysis. In the full sample, significant evidence of the spillovers under the Trilemma continues to be present, and monetary policy pass-through strengthens among the advanced economy sub-sample. For emerging markets, there is no evidence of spillovers under a EUR target, but there is significant, albeit weaker evidence of spillovers under a USD target. These results mirror those found under the baseline analysis.

9.4 Unanticipated U.S. Monetary Policy Shocks

It's very possible that residual changes in interest rates $\hat{Z}_{US,t}$ and $\hat{Z}_{EU,t}$, used as interest rate 'shocks' are still containing endogenous movements related to omitted or unobserved expectations and macroeconomic forces. As an additional robustness check, I replace $\hat{Z}_{US,t}$ with identified U.S. monetary policy shocks, exploiting the movement in Fed Fund futures contracts around FOMC announcements (Kuttner [2001]).[38] The slight alteration to the baseline regression then yields the following specification:

[37] This is precisely how the shadow rate is defined.

[38] Bluedorn and Bowdler [2010] replace changes to U.S. interest rates with these 'Fed Funds shocks' to test the Trilemma, reporting highly significant results and near complete monetary pass-through to pegged countries.

$$\Delta R_{it} = \alpha_i + \phi_1 \Delta R_{i,t-1} + \phi_2 \Delta y_{it} + \phi_3 \Delta \pi_{it} + \phi_4 \Delta RER_{it} + \phi_5 \Delta VIX_t + \phi_6 \Delta \bar{R}_t + \gamma_{US}[\mathbf{FFS}_{US,t} \times \hat{W}^{\$}_{it} \times K_{it}] + \gamma_{EU}[\hat{Z}_{EU,t} \times \hat{W}^{€}_{it} \times K_{it}] + \epsilon_{it}. \quad (14)$$

Notice that the only alteration is that U.S. interest rate residuals $\hat{Z}_{US,t}$ are replaced with Fed Fund shocks $\mathbf{FFS}_{US,t}$. These shocks are computed by taking the change in the front-month Fed Funds futures contract over the day of a scheduled FOMC meeting. Then, these daily changes are aggregated to the quarterly frequency.[39]

Table A.7 reports the baseline spillover estimates, but now with Fed Funds shocks replacing the U.S. interest rate residual. Consistent with Bluedorn and Bowdler [2010], estimates across the full sample, advanced economies, and emerging markets all suggest $\hat{\gamma}_{US} = 1$ within 95% confidence bands, suggesting approximate 1-for-1 U.S. interest rate pass-through under open capital flows and a fixed exchange rate. The full country sample and advanced economy sub-sample estimates are statistically significant at the 1% level (estimates of 0.944 and 1.049, respectively), while the emerging market estimate of $\hat{\gamma}_{US}$ using $FFS_{US,t}$ is statistically significant at the 11% level (estimate of 0.867). Overall estimates of monetary pass-through under continuous exchange rate regime measures are robust to using either actual or unanticipated changes in U.S. monetary policy.

9.5 Omitting 2008-2010 Global Financial Crisis

I omit Q1 2008 - Q4 2010 and re-estimate the baseline regression (Equation 6) to infer to what degree the 2008 Global Financial Crisis may be driving estimates of monetary pass-through. It's the conventional view that over this period, global factors were driving synchronized fluctuations in real activity and financial volatility across countries. Therefore it may be possible that correlations between monetary policy of different countries were actually responding to domestic conditions which happened to be synchronized.

Table A.8 reports the results of the baseline tests (Equation 6) after omitting the crisis period, Q1 2008 - Q4 2010. Across all countries, advanced economies, and emerging markets, the pass-through effects remain robust to omitting the crisis period. In fact, the pass-through effects on both U.S. and E.U. coefficients rise in the 'all country' sample after omitting the crisis period (to 0.522 and 0.398, respectively). Across advanced countries, spillover estimates remain stable and highly significant. The pass-through coefficient for emerging markets rises considerably (to 0.474) after omitting the crisis period. The evidence of intermediate exchange rate regimes affecting the pass-through of monetary

[39] There is no severe serial correlation generated through aggregation. Unit root tests on the quarterly FF shock series reject the null of a unit root.

policy remains a highly robust feature of the data, insensitive to the Global Financial Crisis.

9.6 Time-varying SDR Basket Weights

Effective October 2016, the IMF added the Chinese Yuan as an additional currency in the SDR basket. As of that date, the currencies and corresponding weights were U.S. dollar 41.73%, euro 30.93%, renminbi (Chinese yuan) 10.92%, Japanese yen 8.33%, British pound 8.09%. Due to the time-varying nature of SDR component weights, it's possible that our peg intensity measures, and spillover estimates are sensitive to abrupt changes in SDR composition. As a simple check to assess whether the overall results are sensitive to SDR rebalancing, I estimate the baseline regressions over the pre-2016 sample period, before the Yuan was introduced as an SDR component. Results are reported in Table A.9. Overall, the results from the pre-Yuan estimation very closely match the baseline results estimated over the entire sample period.

9.7 Including lower-dimension interaction terms

Our baseline equations for testing monetary policy spillovers include the interaction $\hat{Z}_{b,t} \times \hat{W}^b_{it} \times K_{it}$ but no lower-dimension interactions of these covariates nor do they enter individually. It may be of interest to see if any additional insight may be provided under the specification which includes all lower-dimension terms:

$$\begin{aligned} \Delta R_{it} = \alpha_i + \phi_1 \Delta R_{i,t-1} + \phi_2 \Delta y_{it} + \phi_3 \Delta \pi_{it} + \phi_4 \Delta RER_{it} \\ + \phi_5 \Delta VIX_t + \phi_6 \Delta \bar{R}_t \\ + \sum_{b \in US,EU} (\gamma_{1b} \hat{Z}_{b,t} + \gamma_{2b} \hat{W}^b_{it}) + \gamma_3 K_{it} \\ + \sum_{b \in US,EU} (\gamma_{4b} [\hat{Z}_{b,t} \times \hat{W}^b_{it}] + \gamma_{5b} [\hat{Z}_{b,t} \times K_{it}] + \gamma_{6b} [\hat{W}^b_{it} \times K_{it}]) \\ + \sum_{b \in US,EU} \gamma_{7b} [\hat{Z}_{b,t} \times \hat{W}^b_{it} \times K_{it}] + \epsilon_{it}. \end{aligned} \quad (15)$$

Under this expanded specification, the impact of a 100 basis point country b monetary policy shock ($\hat{Z}_{b,t}$) on country i's policy rate would be equal to

$$\gamma_{1b} + \gamma_{4b} \hat{W}^b_{it} + \gamma_{5b} K_{it} + \gamma_{7b} [\hat{W}^b_{it} \times K_{it}]. \quad (16)$$

For instance, a country with a fixed exchange rate and open capital account would have a spillover coefficient of $\gamma_{1b} + \gamma_{4b} + \gamma_{5b} + \gamma_{7b}$. While there is a structural interpretation of the instrument $\hat{Z}_{b,t} \times \hat{W}^b_{it} \times K_{it}$, it does not necessarily follow that including the lower-dimension terms is theoretically appropriate. Therefore this exercise is mainly exploratory.

Table A.10 reports the estimates for all coefficients linked to U.S. and E.U. monetary policy shocks ($\hat{\gamma}_{1b}$, $\hat{\gamma}_{4b}$, $\hat{\gamma}_{5b}$, $\hat{\gamma}_{7b}$). Interestingly, the flat marginal effect of a U.S. monetary policy shock given by $\hat{\gamma}_{1,US}$ is negative for all three sub-samples (all countries, advanced economies, emerging markets). Consistent with the Trilemma conditions, U.S. monetary spillovers are increasing in peg intensity ($\hat{\gamma}_{4,US}$) and capital account openness ($\hat{\gamma}_{5,US}$) while the estimate on the three-way interaction, $\hat{Z}_{b,t} \times \hat{W}_{it}^{b} \times K_{it}$, given by $\hat{\gamma}_{7,US}$ is statistically insignificant across all three sub-samples, with a positive estimate for the advanced economy sub-sample and a negative estimate on the emerging market sub-sample. As with the baseline results, the effects of E.U. monetary spillovers are not statistically significant in this extended specification.

10 Concluding Remarks

In this study, I investigate monetary policy spillovers under the Trilemma with a particular focus on intermediate exchange rates. Specifically, I test empirically the shape of the Trilemma, which often assumes a linear trade-off between exchange rate stability and monetary autonomy. To address this issue, I propose a continuous de facto measure of exchange rate regime which considers the entire spectrum of exchange rate flexibility. I test and find significant evidence of a non-linear Trilemma, such that gains in exchange rate stability may not come with a proportionate loss in monetary autonomy along some parts of the peg intensity spectrum. Moreover, I show some evidence suggesting that for emerging markets, active reserves management may be generating these empirical non-linearities. Gains in monetary autonomy from this non-linear trade off are allocated differently across advanced economies and emerging markets. Advanced economies tend to put greater emphasis on output stabilization while emerging markets focus on inflation. However, emerging market monetary policy also becomes increasingly vulnerable global financial shocks as they move towards more flexible exchange rates. I also draw implications for monetary policy spillovers under basket pegs, showing that targeting multiple exchange rates may help diversify against foreign interest rate shocks.

The fact that the Two-Corners hypothesis has been continuously rejected, combined with the scarcity of pure floats, suggests that the de facto dominance of intermediate exchange rate regimes is here to stay. This paper's findings, specifically those suggesting a non-linear Trilemma trade-off concerning monetary independence, may provide one possible explanation as to why the majority of countries consistently choose middle-ground exchange rate policies. To bolster this argument, future research includes developing a simple model which investigates under what conditions some exchange rate stabilization may be optimal in minimizing a central bank's loss function based on domestic targets.

The solution will depend on both the sensitivity of domestic economic activity to real exchange rate fluctuations and to domestic policy rate changes, both of which depend on the pass-through of foreign monetary policy.

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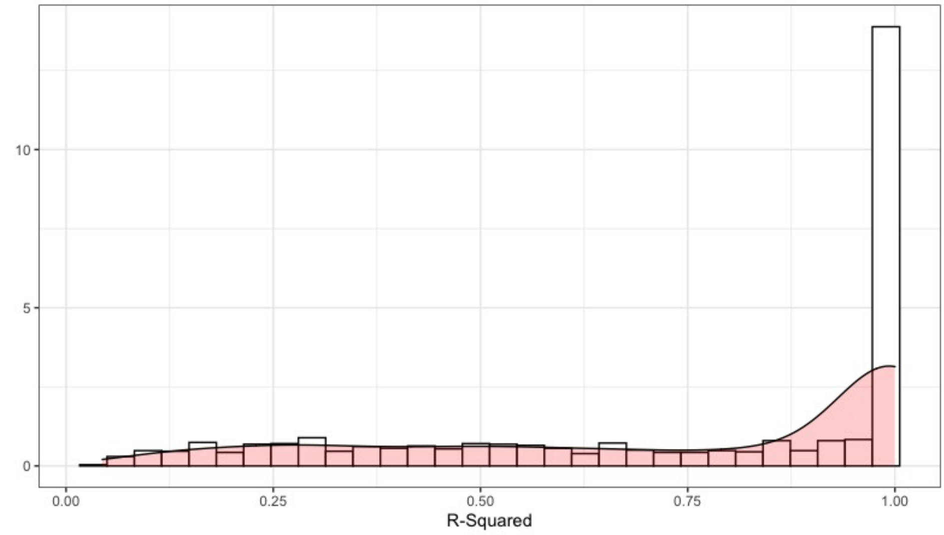
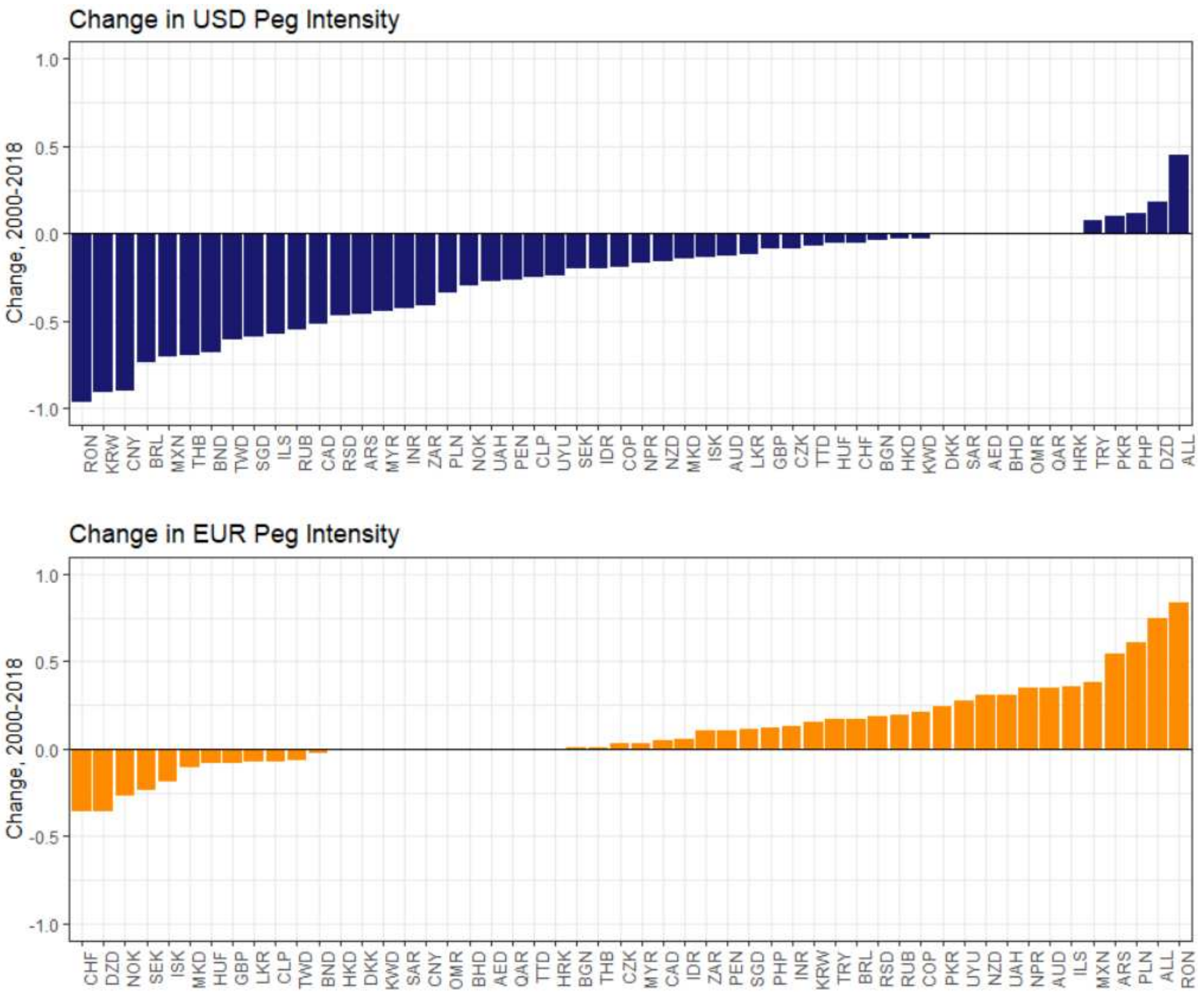
Figure A.1: Distribution of R^2 for Quarterly regressions where peg intensity estimates equal 1



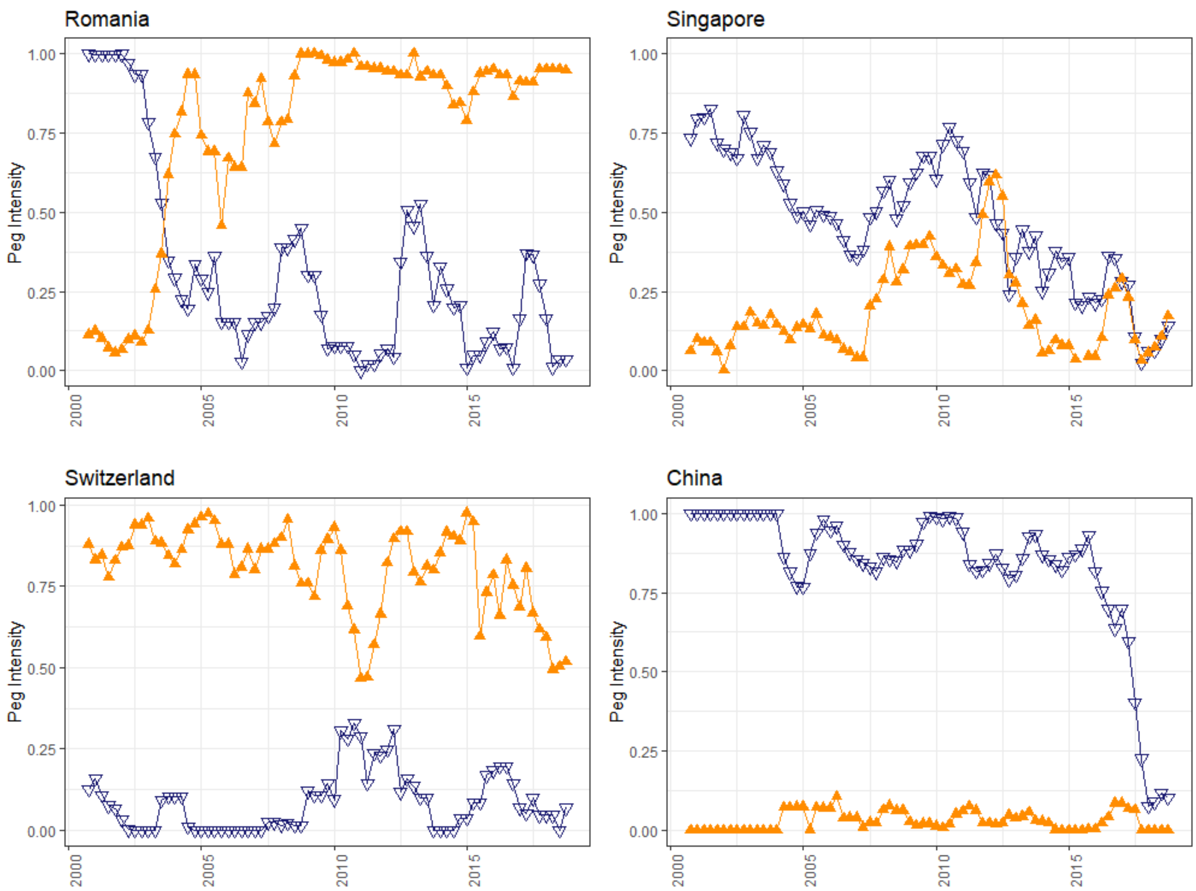
Density plot for R^2 statistics across all country-quarters which have $\hat{\tilde{W}}_{it}^b = 1$ for one b (fixed exchange rate regimes). Estimated from Equation 1.

Figure A.2: Change in Peg Intensity from 2000 to 2018 by currency



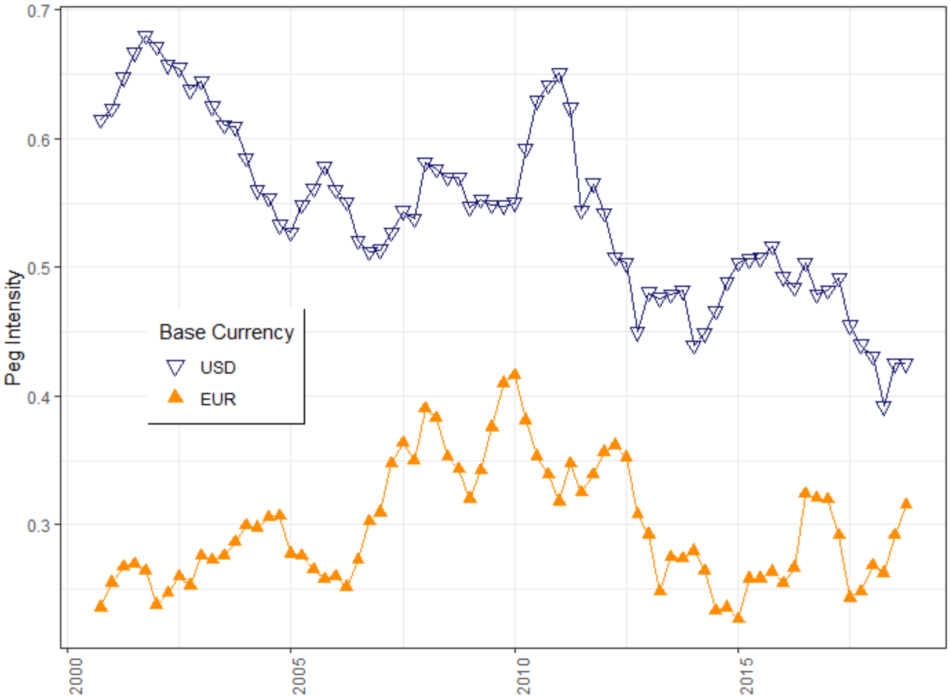
Peg intensities estimated from Equation 1, top panel reports change in intensity from 2000 to 2018 with respect to USD peg intensity. Bottom panel reports change in intensity from 2000 to 2018 with respect to EUR intensity.

Figure A.3: Peg intensities over time, selected countries



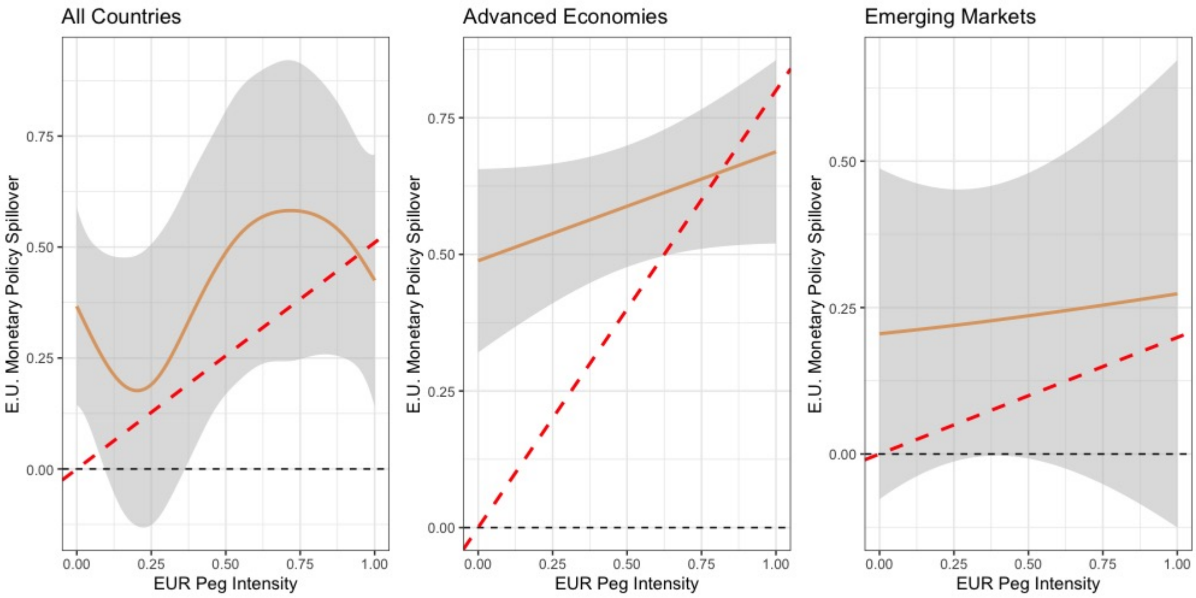
Peg intensities estimated from Equation 1, with triangle (solid) points denoting peg intensity with respect to the EUR and upside-down triangle (clear) points denoting peg intensity with respect to the USD.

Figure A.4: Peg intensities over time, cross-country average



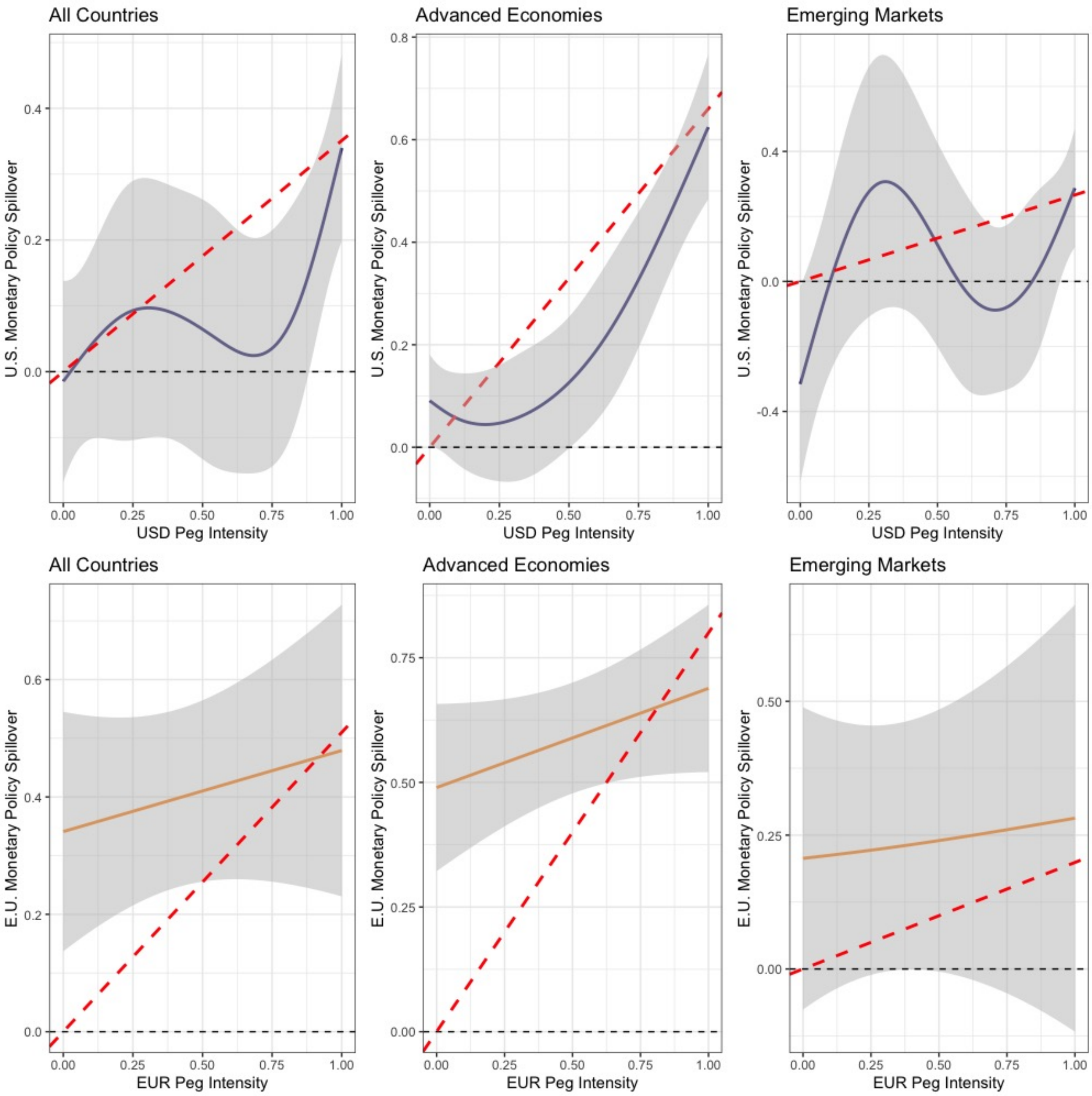
Each period point refers to the cross-country average of peg intensities. Peg intensities estimated from Equation 1, with triangle (solid) points denoting peg intensity with respect to the EUR and upside-down triangle (clear) points denoting peg intensity with respect to the USD.

Figure A.5: GAM Estimates: E.U. spillover estimates by Peg Intensity



Spillover estimate is under free capital controls ($K_{it} = 1$). Estimates are from Equation 9. Shaded areas are 95% credible intervals. Number of knots selected: 10 via REML. Red dashed line is the implied linear spillover under Equation 6.

Figure A.6: GAM Estimates: E.U. spillover estimates by Peg Intensity, with knot number set to 5



Spillover estimate is under free capital controls ($K_{it} = 1$). Estimates are from Equation 9. Shaded areas are 95% credible intervals. Number of knots selected: 5. Red dashed line is the implied linear spillover under Equation 6.

Table A.1: Country Summary

	Country	T	Type
1	Albania	75	EME
2	Argentina	62	EME
3	Australia	75	AE
4	Bahrain	75	EME
5	Brazil	73	EME
6	Bulgaria	75	EME
7	Canada	75	AE
8	Chile	74	EME
9	China	75	EME
10	Colombia	75	EME
11	Croatia	70	EME
12	Czech.Republic	75	EME
13	Denmark	75	AE
14	Hong Kong	75	AE
15	Hungary	75	EME
16	Iceland	74	AE
17	India	75	EME
18	Indonesia	75	EME
19	Israel	75	EME
20	Japan	75	AE
21	Kazakhstan	75	EME
22	Macedonia	72	EME
23	Malaysia	75	EME
24	Mauritius	75	EME
25	Mexico	74	EME
26	Nepal	75	EME
27	New Zealand	75	AE
28	Norway	75	AE
29	Peru	74	EME
30	Philippines	75	EME
31	Poland	75	EME
32	Qatar	75	EME
33	Romania	71	EME
34	Russia	74	EME
35	Saudi Arabia	75	EME
36	Serbia	72	EME
37	Singapore	75	AE
38	South Africa	75	EME
39	South Korea	75	EME
40	Sweden	75	AE
41	Switzerland	75	AE
42	Thailand	75	EME
43	Trinidad and Tobago	74	EME
44	Turkey	66	EME
45	United Kingdom	75	AE
46	Uruguay	65	EME

Summary of countries in the main panel. Type denotes Advanced (AE) or Emerging Market Economy (EME), respectively. Column T refers to country sample size of interest rate change observatoins, ΔR_{it}.

Table A.2: Peg Intensities to Base Currencies

#	Country/FX	USD (2000)	USD (2018)	EUR (2000)	EUR (2018)	JPY (2000)	JPY (2018)
1	AED	1.00	1.00	0.00	0.00	0.00	0.00
2	ALL	0.30	0.75	0.09	0.84	0.00	0.08
3	ARS	0.96	0.50	0.03	0.58	0.02	0.16
4	AUD	0.22	0.09	0.30	0.65	0.22	0.05
5	BGN	0.04	0.00	1.00	1.00	0.01	0.00
6	BHD	1.00	1.00	0.00	0.00	0.00	0.00
7	BND	0.74	0.06	0.03	0.00	0.03	0.07
8	BRL	0.99	0.25	0.05	0.22	0.02	0.51
9	CAD	0.69	0.17	0.06	0.11	0.12	0.00
10	CHF	0.13	0.07	0.88	0.52	0.03	0.24
11	CLP	0.68	0.42	0.08	0.00	0.02	0.12
12	CNY	1.00	0.10	0.00	0.00	0.00	0.00
13	COP	0.50	0.30	0.00	0.21	0.09	0.18
14	CZK	0.08	0.00	0.76	0.79	0.04	0.00
15	DKK	0.01	0.00	0.99	0.98	0.00	0.00
16	DZD	0.27	0.45	0.63	0.27	0.06	0.00
17	GBP	0.09	0.00	0.15	0.07	0.00	0.01
18	HKD	0.96	0.93	0.03	0.02	0.03	0.00
19	HRK	0.00	0.01	0.98	0.98	0.02	0.00
20	HUF	0.06	0.00	0.99	0.90	0.00	0.01
21	IDR	0.50	0.29	0.24	0.30	0.32	0.00
22	ILS	0.95	0.37	0.06	0.42	0.04	0.08
23	INR	0.92	0.49	0.02	0.15	0.03	0.01
24	ISK	0.25	0.11	0.45	0.26	0.00	0.18
25	KRW	0.96	0.05	0.02	0.17	0.19	0.05

Estimates of W_{it}^{b} from Equation 1 for 2000 and 2018 (quarterly averages), respectively. Base countries b considered are the U.S., E.U., and Japan.

Table A.3: Peg Intensities to Base Currencies (cont.)

#	Country/FX	USD (2000)	USD (2018)	EUR (2000)	EUR (2018)	JPY (2000)	JPY (2018)
26	KWD	0.85	0.82	0.04	0.03	0.04	0.02
27	LKR	0.87	0.74	0.09	0.01	0.04	0.06
28	MKD	0.39	0.25	0.15	0.05	0.01	0.08
29	MXN	0.98	0.27	0.14	0.53	0.09	0.23
30	MYR	0.93	0.48	0.07	0.10	0.03	0.01
31	NOK	0.30	0.00	0.74	0.47	0.09	0.01
32	NPR	0.99	0.82	0.06	0.41	0.01	0.18
33	NZD	0.32	0.16	0.31	0.62	0.09	0.10
34	OMR	1.00	1.00	0.00	0.00	0.00	0.00
35	PEN	0.95	0.68	0.05	0.16	0.07	0.02
36	PHP	0.83	0.95	0.20	0.32	0.12	0.05
37	PKR	0.87	0.96	0.00	0.24	0.09	0.11
38	PLN	0.34	0.00	0.33	0.94	0.00	0.03
39	QAR	1.00	1.00	0.00	0.00	0.00	0.00
40	RON	1.00	0.04	0.11	0.95	0.03	0.03
41	RSD	0.47	0.00	0.14	0.33	0.14	0.13
42	RUB	0.99	0.43	0.08	0.27	0.12	0.00
43	SAR	1.00	1.00	0.00	0.00	0.00	0.00
44	SEK	0.20	0.00	0.68	0.44	0.04	0.08
45	SGD	0.73	0.14	0.06	0.17	0.08	0.04
46	THB	0.76	0.06	0.07	0.08	0.16	0.02
47	TRY	0.59	0.67	0.44	0.60	0.07	0.00
48	TTD	0.96	0.88	0.03	0.03	0.04	0.02
49	TWD	0.92	0.32	0.10	0.04	0.06	0.06
50	UAH	0.96	0.69	0.00	0.31	0.00	0.05
51	UYU	1.00	0.76	0.05	0.33	0.04	0.14
52	ZAR	0.44	0.03	0.39	0.49	0.08	0.26

Estimates of W^b_{it} from Equation 1 for 2000 and 2018 (quarterly averages), respectively. Base countries b considered are the U.S., E.U., and Japan.

Table A.4: Spillover Effects across Peg Intensity Bins: Pooled Model (Equation 6) with Exchange Rate Regime Dummies

Bin	1	2	3	4	5	6
$\hat{W}_{it}^{US}$ (RA, 2)	[0,0.1]	(0.1,.30]	(0.30,.50]	(0.50,0.70]	(0.70,0.90]	(0.90,1]
All Countries						
$\hat{\gamma}_{US}$	-0.011	0.182	-0.046	0.022	0.127*	0.389***
	(0.065)	(0.160)	(0.157)	(0.213)	(0.065)	(0.141)
$\hat{\gamma}_{EU}$	0.285*	0.257	0.614***	0.998**	-0.060	0.418***
	(0.156)	(0.212)	(0.235)	(0.404)	(0.248)	(0.119)
Advanced Economies						
$\hat{\gamma}_{US}$	0.080*	0.098	0.168***	0.305***	0.376***	0.771***
	(0.041)	(0.104)	(0.056)	(0.066)	(0.050)	(0.211)
$\hat{\gamma}_{EU}$	0.444***	0.303***	0.399**	1.039***	0.332***	0.566***
	(0.081)	(0.066)	(0.171)	(0.199)	(0.096)	(0.085)
Emerging Markets						
$\hat{\gamma}_{US}$	-0.210	0.271	-0.198	-0.064	0.076	0.292**
	(0.159)	(0.552)	(0.348)	(0.304)	(0.073)	(0.135)
$\hat{\gamma}_{EU}$	0.198	0.136	0.773**	0.309	-0.771	0.401**
	(0.209)	(0.336)	(0.386)	(1.252)	(0.701)	(0.171)

***,**,* refer to significance at the 1%, 5% and 10% level, respectively. Robust standard errors clustered at the Country level. Regression specification of Equation 6, using dummy variables for values of $\hat{W}_{it}^{US}$ (RA, 2). Estimation period Q2 2000 - Q4 2018. Country Fixed Effects included.

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Table A.5: Spillover Effects across IRR (2019) Ilzetzki et al. [2019] Exchange Rate Regimes: Pooled Model (Equation 13) with Exchange Rate Regime Dummies

	Floating				Fixed
IRR Classification	**1**	**2**	**3**	**4**	**5**
All Countries					
$\hat{\gamma}_{US}(IRR)$	0.019	0.208***	-0.126	0.474***	0.516**
	(0.107)	(0.069)	(0.084)	(0.162)	(0.211)
Advanced Economies					
$\hat{\gamma}_{US}(IRR)$	0.194***	0.328***	0.768***	0.268***	1.069***
	(0.056)	(0.047)	(0.216)	(0.075)	(0.025)
Emerging Markets					
$\hat{\gamma}_{US}(IRR)$	-0.235	0.160	-0.213***	0.862***	0.282
	(0.214)	(0.102)	(0.006)	(0.276)	(0.181)

***,**,* refer to significance at the 1%, 5% and 10% level, respectively. Robust standard errors clustered at the Country level. Estimation period Q2 2000 - Q4 2016. Country Fixed Effects included.

Table A.6: Imputing Shadow Rates at the ZLB

	(1)	(2)	(3)
	All Countries	Advanced Economies	Emerging Markets
$\hat{\gamma}_{US}$	0.319***	0.643***	0.220**
	(0.087)	(0.116)	(0.089)
$\hat{\gamma}_{EU}$	0.189***	0.233***	0.142
	(0.067)	(0.079)	(0.110)
Adj. R^2	0.14	0.39	0.13
F-Statistic	57.11	50.85	39.03
N×T	2,532	644	1,887
Country FE	Y	Y	Y
Time FE	N	N	N

***,**,* refer to significance at the 1%, 5% and 10% level, respectively. Robust standard errors clustered at the Country level. Regression specification of Equation 6, with R_{bt} values for U.S. and E.U. at the ZLB imputed using Wu and Xia [2016] shadow rates. Estimation period: Q2 2000 - Q4 2018. Peg intensity estimate used is $\hat{W}^b_{it}$ (RA, 2). Within adjusted R-squared reported.

Table A.7: FOMC Monetary Policy Shocks

	(1)	(2)	(3)
	All Countries	Advanced Economies	Emerging Markets
$\hat{\gamma}_{US}$	0.944**	1.049***	0.867
	(0.392)	(0.281)	(0.534)
$\hat{\gamma}_{EU}$	0.535***	0.817***	0.239
	(0.128)	(0.117)	(0.168)
Adj. R^2	0.13	0.33	0.13
F-Statistic	54.85	42.61	38.88
N×T	2,532	644	1,887
Country FE	Y	Y	Y
Time FE	N	N	N

***,**,* refer to significance at the 1%, 5% and 10% level, respectively. Robust standard errors clustered at the Country level. Regression specification of Equation 14. Estimation period: Q2 2000 - Q4 2018. Peg intensity estimate used is $\hat{W}^b_{it}$ (RA, 2). FOMC monetary policy shocks are implied yield changes from front month Fed Funds Futures contracts over the day of an FOMC announcement. Changes are aggregated to quarterly frequency. Within adjusted R-squared reported.

Table A.8: Omitting the 2008 Global Financial Crisis

	(1)	(2)	(3)
	All Countries	Advanced Economies	Emerging Markets
$\hat{\gamma}_{US}$	0.522***	0.616***	0.474***
	(0.127)	(0.121)	(0.166)
$\hat{\gamma}_{EU}$	0.398***	0.575***	0.183
	(0.152)	(0.102)	(0.343)
Adj. R^2	0.12	0.39	0.11
F-Statistic	42.88	44.78	28.91
N×T	2,120	539	1,580
Country FE	Y	Y	Y
Time FE	N	N	N

***,**,* refer to significance at the 1%, 5% and 10% level, respectively. Robust standard errors clustered at the Country level. Regression specification of Equation 6. Estimation period: Q2 2000 - Q4 2018 but omitting crisis window of Q1 2008 - Q4 2010. Peg intensity estimate used is $\hat{W}^b_{it}$ (RA, 2). Within adjusted R-squared reported.

Table A.9: Before the Yuan entered the SDR (Pre-2016)

	(1)	(2)	(3)
	All Countries	Advanced Economies	Emerging Markets
$\hat{\gamma}_{US}$	0.367***	0.754***	0.255**
	(0.126)	(0.217)	(0.166)
$\hat{\gamma}_{EU}$	0.497***	0.766***	0.186
	(0.135)	(0.115)	(0.343)
Adj. R^2	0.13	0.46	0.14
F-Statistic	48.55	56.83	32.10
N×T	2,157	556	1,600
Country FE	Y	Y	Y
Time FE	N	N	N

***,**,* refer to significance at the 1%, 5% and 10% level, respectively. Robust standard errors clustered at the Country level. Regression specification of Equation 6. Estimation period: Q2 2000 - Q4 2015, omitting period with the Yuan entering the SDR Basket (as of 2016). Peg intensity estimate used is $\hat{W}^b_{it}$ (RA, 2). Within adjusted R-squared reported.

Table A.10: Including lower-dimension interaction terms (Equation 15)

	(1)	(2)	(3)
	All Countries	Advanced Economies	Emerging Markets
$\hat{\gamma}_{1,US}$	-0.608**	-0.535***	-0.534
	(0.274)	(0.118)	(0.346)
$\hat{\gamma}_{4,US}$	0.592*	0.408	0.538
	(0.315)	(1.488)	(0.382)
$\hat{\gamma}_{5,US}$	0.635**	0.562***	0.407
	(0.301)	(0.120)	(0.427)
$\hat{\gamma}_{7,US}$	-0.293	0.213	-0.151
	(0.398)	(1.570)	(0.475)
$\hat{\gamma}_{1,EU}$	0.127	-0.053	0.171
	(0.203)	(0.388)	(0.210)
$\hat{\gamma}_{4,EU}$	0.209	-0.570	0.286
	(0.395)	(1.556)	(0.475)
$\hat{\gamma}_{5,EU}$	0.162	0.460	-0.004
	(0.278)	(0.411)	(0.327)
$\hat{\gamma}_{7,EU}$	-0.119	0.825	-0.328
	(0.504)	(1.613)	(0.691)
Adj. R^2	0.15	0.46	0.133
F-Statistic	26.98	30.25	17.90
N×T	2,532	644	1,887
Country FE	Y	Y	Y
Time FE	N	N	N

***,**,* refer to significance at the 1%, 5% and 10% level, respectively. Robust standard errors clustered at the Country level. Regression specification of Equation 15. Estimation period: Q2 2000 - Q4 2018. For peg intensities using 2-quarter rolling average, $\hat{W}_{it}^{b}$ (RA, 2). Estimated peg intensities are from Equation 1. Within adjusted R-squared reported.