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Neutral Real Interest Rates in Inflation Targeting Emerging and Developing Economies

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Abstract

With close to 30 emerging market and developing economies (EMDEs) using inflation targeting to determine monetary policy, and many of them for over 15 years, it is possible to create a meaningful measure of neutral real interest rates in these economies. The neutral real interest rate provides policymakers with a benchmark for the interest rate at which economic activity reaches its full potential and inflation will stabilize. The deviation of policy rates from this neutral rate determines whether monetary policy is accommodative or restrictive. This paper provides aggregate estimates of the neutral rate in 20 of these economies. EMDEs have seen a decline in the neutral rate of 4 percentage points, from over 6 percent in 2000 to closer to 2 percent at the end of 2019; advanced economies saw an above 2 percentage point decline over this period. The decline of neutral real interest rates in EMDEs can only partially be related to domestic drivers of desired savings and investment. The secular decline in the neutral rate of interest is limiting the ability of EMDEs to stimulate economies in the face of large shocks. The neutral real interest rate is unobservable and subject to a high degree of uncertainty, double the size of that for advanced economies. With such high uncertainty determining the stance of monetary policy in these economies is a challenge.

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Neutral Real Interest Rates in Inflation Targeting Emerging and Developing Economies

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1 Introduction

It is often the case that when the stance of monetary policy is discussed in the news, reference is made to the nominal policy rate and how much the central bank had changed this rate. Nominal interest rates matter to households and businesses who pay interest linked to the policy rate for a home, car, or working capital. It does not, however, say much about the stance of monetary policy and whether policy is stimulating or restricting growth of an economy in trying to control inflation. Interest rates are the instrument of choice for inflation targeting central banks to achieve their inflation and growth objectives. To determine its stance, three things need to be known: the nominal policy rate, a forecast or expectation of future inflation, and the neutral real interest rate.[1] The first part of understanding its stance in knowing where the real interest rate is; the nominal rate adjusted for inflation. The real interest rate can be calculated in many ways but generally refers to the difference between the nominal policy rate and expected or forecast inflation; that is, the ex ante real interest rate. This rate refers to the real cost of money. The third variable needed is the neutral interest rate which is the interest rate which stabilizes inflation at its target and keeps the economy growing at its potential (or at full employment).[2] Then the difference between the real interest rate and its neutral rate gives an indication of whether monetary policy is stimulatory–the real interest rate below neutral–or restrictive–the interest rate above neutral.

The concept of a neutral real interest rate dates back to Wicksell (1898), who linked the marginal product of capital with the interest rate (cost of borrowing money), and proposed that when the cost of borrowing is below the return on capital, entrepreneurs would borrow to buy capital (buildings and equipment) stimulating prices and demand. When these rates are equal, however, there would be no pressure on inflation. Following Wicksell's definition, Laubach and Williams (2003) estimated the neutral for the United States, and with a growing number of inflation targeters, sparked interest in estimates of the neutral real interest rate throughout the world.

This paper adds to the expanding literature on neutral real interest rates by providing estimates for the majority of inflation targeting emerging and developing economies (EMDEs) using three methods.[3] It provides an aggregated estimate of the neutral interest rate in EMDEs and assesses the stance of monetary policy. Much of the existing literature on neutral real interest rates has focused on advanced economies and individual EMDEs, and when discussing world neutral rates generally only focused on the former economies (see, for example, Holston et al., 2017 and Del Negro et al., 2019). Also it is one of few papers that incorporates an open-economy dimension in the estimation for EMDEs (Grafe et al., 2018; Kuhn et al., 2019). Understanding what drives changes in the neutral real interest rate is limited in the models used, particularly following Laubach and Williams (2003). This paper, therefore, also looks at potential drivers of shifts in the neutral through the lens of desired savings and investment using panel regression.

Although EMDE monetary policy is less homogeneous than advanced economies, an aggregate measure of the neutral real interest rate and their monetary policy stance is useful for a number of

[1] The neutral rate of interest is sometimes referred to as the natural or equilibrium rate of interest.

[2] In the context of this paper this is a short-term concept that reflects the contemporaneous rate needed to achieve these objectives.

[3] Only Perrelli and Roache (2014b) and Beyer and Milivojevic (2020) analyze this many economies but using univariate filtering methods.

reasons. First, EMDEs are often subject to common global shocks which drive common inflation and output outcomes. For example, the role of global shocks in EMDE inflation outcomes has increased in importance over time, accounting for a larger share of domestic inflation variation now, compared to, in the early 2000s (Ha et al., 2019). Second, a number of global factors can explain similar dynamics across EMDE neutral real interest rates including changes in the global savings, changes in the risk perception of international investors, and changes in the global risk free rate. For example, a flight to safety in response to a crisis leads to similar exchange rate depreciations across EMDEs and shifts in monetary policy to stabilize inflation expectations. Similarly, shifts in commodity prices elicit common responses in commodity-exporting EMDEs. Finally, there is evidence of a global financial cycle which could drive similar outcomes across EMDEs.

This paper provides estimates of neutral real interest rates for 20 emerging market and developing economies that are inflation targeters with a particular focus on 10 economies that have been inflation targeters since the early 2000s.[4] The focus on inflation targeting EMDEs ensures that monetary policy can be approximated by the Taylor Rule, that the credit channel of policy is functioning and the banking system is sufficiently developed, and that interest rates are used as the instrument to achieve policy objectives. Three modeling approaches are used including the Laubach and Williams (2003) model in an open economy setting, a dynamic Taylor Rule, and a time-varying parameter vector autoregressive model. These approaches use different economic information and structures to help identify the neutral real interest rate.

The paper reports the following results. First, neutral real interest rates in inflation targeting EMDEs have followed the United States neutral rate lower over the past two decades. The neutral real interest rate in EMDEs declined from over 6 percent in 2000 to 2.2 percent at the end of 2019. This is 1.4 percentage points higher than that estimated for the United States in Laubach and Williams (2003). Declining neutral real interest rates is broad based occurring in three-quarters of EMDEs. Both commodity importers and exporters experienced a decline in the neutral rate of interest, but it was far greater in commodity exporters. Based on the Laubach-Williams approach, most of the decline in neutral rates are due to the unobserved factor instead of potential growth.

Second, beyond potential growth as a driver of the decline in neutral real interest rates in EMDEs, domestic and global factors encompassed in the loanable funds theory of desired savings and investment played a limited role over the last two decades. Domestic factors that are statistically significant drivers of the neutral real interest rate as identified by a panel regression include life expectancy and the relative price of capital. A 1 year increase in life expectancy is associated with a 0.2-0.4 percentage point decline in the neutral real interest rate, as desired savings increase. A 10.0-percentage-point rise in the relative price of capital increases the neutral real interest rate by 0.5 percentage point, as desired investment increase. Global factors such as the trend decline in U.S. neutral real interest rates or rising global savings do not help explain the EMDE decline. This leaves an unsatisfactory conclusion to the possible drivers of the EMDE neutral real interest rate and plausible explanations include changes in monetary regimes as suggested in Borio et al. (2017).

Third, the stance of monetary policy–the difference between real interest rates and its neutral rate–

[4]The ten economies are Brazil, Chile, Colombia, Mexico, Peru, Philippines, Poland, Thailand, Turkey, and South Africa.

has been appropriately countercyclical in most EMDEs. When inflation is below target and there is deficient demand, EMDE central banks run accommodative policy. This was most clearly seen during the 2009 global recession and its aftermath. In the early 2000s, in contrast, there was a positive output gap and inflation still needed to be anchored around established targets, and policy was restrictive with the real interest rate above the neutral. The policy stance may not always be appropriate for meeting both inflation and output objectives, which can move in opposite directions when hit by supply shocks. This is clearly evident in the procyclical tightening that occurred in many EMDEs during 2016 as global financing conditions tightened.

Fourth, there is a high degree of uncertainty in what the neutral real interest rate is in EMDEs complicating the determination of the stance of monetary policy. This uncertainty is twice as large, on average, as the rate of uncertainty seen for estimates in advanced economies. Estimates of the standard deviation are as large as 1.4 percentage points in EMDEs, compared to, 0.6 percent in advanced economies. This means that within a 90 percent confidence band we could expect the neutral real interest rate in EMDEs in 2019Q4 to be between 0.2 and 4.2 percent. The uncertainty surrounding estimates for commodity exporters is more than 40 percent larger than that for commodity-importing EMDEs. Such uncertainty makes determining the stance of monetary policy challenging.

Finally, monetary policy credibility effects the level of the neutral real interest rate in EMDEs with less credibility being associated with higher neutral real interest rate estimates. The channel through which this occurs is likely inflation risk premium and inflation volatility.

The paper proceeds as follows. First, a brief history of inflation targeting in EMDEs is provided, which summarizes its characteristics and design. Next, a literature review of papers that estimate neutral real interest rates in EMDEs are provided. This is followed by a discussion of the theoretical drivers of neutral interest rates. Then the models and data used are described. Then the results are discussed.

2 Inflation targeting in EMDEs

Inflation targeting was first adopted by some advanced economies in the early 1990s as a way to address the failures of earlier policy regimes (Masson et al., 1998; Mishkin, 2000).[5] While Chile was an early adopter, most EMDEs began implementing inflation targeting regimes in the early 2000s (table 1). In 1999, only three EMDEs were inflation targeters. The success of inflation targeting, however, to bring inflation under control and improve central bank transparency, communication and accountability, and the failure of exchange rate targets following many currency crises, made it a mainstay of many EMDEs.[6] By 2019, close to 30 EMDEs had adopted inflation targeting regimes. Inflation targeting EMDEs account for about 45 percent of overall EMDE output.

Inflation targeting is a policy framework that involves the following components:

- The public announcement of an inflation target, in practice, usually including a tolerance range;

[5] Many industrialized economies adopted monetary targeting in the 1970s to reign in high inflation. Monetary targets, however, were not successfully achieved in many years, abandoned entirely in some, and had a tenuous link to inflation and output objectives.

[6] Following the global financial crisis the efficacy of inflation targeting was questioned due to the limited focus on financial stability and the possibility of more effective targets (see, for example, Blanchard et al., 2010; Frankel, 2012; Woodford, 2012).

- Price stability as the primary goal of the central bank;
- Increased transparency on policy objectives and outcomes through communication with the public;
- And increased accountability in achieving an inflation target (Mishkin, 2000; Hammond et al., 2012).

The adoption of inflation targeting requires some prerequisites and may not be appropriate for all EMDEs, especially low-income countries. Inflation targeting is best implemented in EMDEs that have working channels of monetary policy transmission, an independent central bank, sufficient data, and some analytical capacity at their central banks (Ha et al., 2019; Masson et al., 1998; Mishkin, 2000). Moving toward an inflation targeting framework, however, could help to improve these conditions in EMDEs and build better institutional capacity.

Inflation outcomes in EMDEs have improved significantly in the last four decades (Ha et al., 2019). EMDEs have been able to bring average annual inflation down from double-digit rates in the 1990s to an estimated 3.1 percent in 2019. Part of this success is due to the adoption of inflation targeting in many EMDEs. Inflation targeting EMDEs have been more successful in providing a nominal anchor in some respects than their non-targeting counterparts by better anchoring inflation expectations (Ha et al., 2019). These central banks were also able to lower exchange rate passthrough, partly a consequence of the independence and credibility (Kabundi and Mlachila, 2019; Taylor, 2000) .

Inflation targeters are a natural focus of neutral real interest rate estimates; although such estimates are equally important in non-inflation targeting economies who use, in part, interest rates as an instrument and inflation as a nominal anchor. These economies have adopted a monetary policy framework that can be approximated by a Taylor Rule–one where interest rates respond to inflation from target and the business cycle, have more clear monetary policy transmission mechanisms, especially through the credit channel, use interest rates to guide policy objectives, and have more developed banking sectors.

3 Neutral real interest rate estimates in EMDEs

With the number of EMDEs embracing inflation targeting rising–which meant that EMDEs were using interest rates to guide inflation to a predetermined target–and the popularity of estimates of the neutral interest rate such as Laubach and Williams (2003), researchers started estimating neutrals for these EMDEs. These include estimates for large EMDEs such as Brazil (de Barcellos Neto and Portugal, 2009; Duarte, 2010; Perrelli and Roache, 2014a), India (Behera et al., 2017), Mexico (Carrillo et al., 2017), and Turkey (Öğünç, 2006; Öğünç and Batmaz, 2011; Çatik and Akdeniz, 2019) and smaller ones such as Peru (Humala and Briones, 2011). Other EMDEs that have neutral estimates include Chile (Fuentes et al., 2007), Colombia (González et al., 2013), Philippines (Austria, 2018), South Africa (Kuhn et al., 2019), Thailand and Indonesia (Zhu, 2016), Kyrgyz Republic (Teodoru et al., 2020), Hungary, Poland, and Russia (Grafe et al., 2018).

The methods used to estimate neutral real interest rates adopted in EMDEs have been numerous. These include those that follow Laubach and Williams (2003) in implementing a semi-structural model that builds on the New Keynesian framework of an intertemporal investment-savings (IS) relationship and a Phillips curve. This model has been implemented in Humala and Briones (2011) and also modified for the open economy setting (Kuhn et al., 2019; Grafe et al., 2018). Other methods include dynamic Taylor rules (Duarte, 2010), time-varying parameter vector autoregressive (VAR) models (Carrillo et al., 2017), consumption-smoothing models, uncovered interest parity, and filtering techniques (Magud and Tsounta (2012)). Dynamic Taylor Rules use the behavior of central banks when trying to keep inflation at target and output at its potential to try and identify the neutral real interest rate. Consumption-smoothing models link the supply and demand for credit of households over time and their desire to smooth consumption over their lifetime to determine the interest rate. Finally, uncovered interest parity equates movements in domestic interest rates with those in international interest rates and the exchange rate.

In general, however, the literature has focused on single country examples with only a few papers focusing on EMDEs as a whole. These include Grafe et al. (2018) who estimate neutral real interest rates for the CEEMEA region including Hungary, Poland, Turkey, South Africa and Russia. Magud and Tsounta (2012) estimate neutrals for 10 Latin American economies. Zhu (2016) estimate these for Asia Pacific economies including India, Indonesia, and Malaysia. Perrelli and Roache (2014b) also estimate neutral interest rates for emerging markets. Finally Beyer and Milivojevic (2020) estimate neutral real interest rates for 27 EMDEs using a univariate unobserved components model with stochastic volatility. In this paper, individual results for 20 EMDEs are aggregated using real GDP at 2010 prices and market exchange rates to generate an aggregate EMDE picture. Although there is significantly more heterogeneity in EMDEs than advanced economies, the period studied includes important global events that should ensure some commonality in economic conditions and policy stance.

4 Drivers of neutral real interest rates: Theory

The secular decline in real interest rates over the last few decades has sparked interest in what were the underlying drivers. A number of narratives have developed to explain these movements including the idea of a global savings glut (Bernanke, 2005), demand for safe assets (Caballero et al., 2008; Farhi et al., 2020), and changes in risk perceptions (Del Negro et al., 2017; Gourinchas and Rey, 2016; Marx et al., 2019). The overall theoretical link between these narratives and the neutral real interest rate is the theory of loanable funds; shifts in desired saving (the supply of funds) and investment (the demand for funds) that explain the real interest rate (the market clearing price). These narratives also highlight the importance of both domestic and global forces in shaping neutral real interest rates in economies. There are detractors to the broader focus of the literature on saving and investment. Borio et al. (2017) argue that the longer run link between saving and investment, and the real interest rate is tenuous with changes in monetary regimes and movements in global financial conditions the likely culprits in driving interest rates.

Saving and real interest rates are linked by the optimizing behavior of households who make consumption decisions based on preferences and expected growth in consumption. Other factors that can influence saving decisions include:

- Life expectancy as increases raise desired saving and lower real interest rates;
- Demography as a greater share of working-age population drive saving;

- Income inequality as richer households have a higher marginal propensity to save;
- Population growth which can affect demographics and the capital-labor ratio;
- And policy regimes as states with poor social safety nets may induce higher saving.

Investment decisions and real interest rates are linked to the profit maximizing motive of firms and include:

- Risk premiums as higher perceived risk lowers investment and the real interest rate;
- Profitability as higher profits stimulate investment and raise real interest rates;
- And the relative price of capital with an ambiguous but likely positive relationship (Rachel and Smith, 2015).

The factors that drive saving and investment are not mutually exclusive as demography and population growth can also affect investment and risk premiums can change household saving behavior. Beyond saving and investment is the demand and supply of safe assets which set the global risk-free rate. Caballero and Farhi (2014) show that the global financial crisis halved the supply of safe assets globally while demand increased significantly due to financial regulatory changes forcing financial institutions to hold more safe assets. These forces shifted the real interest rate lower.

5 The modeling approach

Three modeling approaches are used in this paper to estimate the neutral real interest rate, including an open economy version of Laubach and Williams (2003), a dynamic Taylor Rule, and a time-varying Vector Autoregressive model (TVP-VAR). The benefit of these three approaches are that they cover models that make both weak and strong assumptions about the structure of the economy. They also use different information to determine the neutral real interest rate. In the case of Laubach and Williams (2003), the neutral interest rate is based on potential growth. The Taylor Rule uses the behavior of the central bank to keep inflation at target and output at its potential to back out the neutral rate. Finally, the TVP-VAR exploits the empirical economic relationship between key variables to generate estimates of the neutral rate of interest using five-year-ahead forecasts.

5.1 Laubach-Williams model

The Laubach and Williams (2003) model is a semi-structural model based on the neoclassical growth model relationship between the interest rate, potential growth, and the preferences of consumers. Therefore, this approach defines the natural rate as the "real short-term interest rate consistent with the economy operating at its full potential once transitory shocks to aggregate supply or demand have abated" (Laubach and Williams, 2016).

A utility maximizing household has the following intertemporal constraint:

$$r = \sigma g + \theta \tag{1}$$

where r is the real interest rate, g is the per capita growth of consumption, σ is the inverse intertemporal elasticity of substitution for consumption, and θ is the rate of time preference. Laubach and Williams (2003) link the natural rate, r_t^*, to potential growth over time g_t, as well as z_t, which captures all other determinants of r_t^*:

$$r_t^* = cg_t + z_t \tag{2}$$

This formulation has been the subject of some criticism including its importance in explaining the natural rate, the sensitivity of estimates to the statistical properties of z, and it's role in generating significantly different output gap estimates for the U.S., depending on its specification (Pescatori and Turunen, 2015; Beyer and Wieland, 2017). Despite this, the methodology continues to play a critical role in the literature and estimates of the neutral interest rate. This paper modifies the model to account for the open-economy nature of emerging markets and to exploit additional information in a multivariate setting. It links the Laubach-Williams approach to estimates of the output gap using an augmented set of variables as in World Bank (2018). The output gap equation is estimated as:

$$\tilde{y}_t = \alpha_y \tilde{y}_{t-1} + \alpha_h(h_t - h_t^*) - \alpha_r(r_t - r_t^*) - \alpha_q(q_t - q_t^*) + \alpha_c(c_t - c_t^*) + \alpha_{com}(com_t - com_t^*) + \varepsilon_t^{\tilde{y}} \tag{3}$$

where the output gap, $\tilde{y}_t$, is the difference between real GDP and its potential (i.e. $\tilde{y}_t = y_t - y_t^*$), $h_t - h_t^*$ is the gap between house prices and their trend, $c_t - c_t^*$ is the gap between credit extension and its trend, $com_t - com_t^*$ is the gap between real commodity prices and its trend, $q_t - q_t^*$ is the gap between the real exchange rate and its equilibrium, and $r_t - r_t^*$ is the real interest rate from its equilibrium.[7] Trends for commodity prices, credit, house prices and the real exchange rate are the Hodrick-Prescott filter with a lambda of 1600. The model also includes capacity utilization and the unemployment rate–through Okun's law–to further help identify the output gap (See the multivariate model in World Bank (2018) for more details).

To account for the fact that not all EMDEs have data available for all variables of interest, the model employs switches for certain variables that "switch off" the portion of the model when the data is not available. These switches are included for house prices, credit extension, commodity prices, the real exchange rate, capacity utilization, and the unemployment rate.

The Phillips curve is modified to reflect the inflation process in an EMDE:

$$\pi_t = \beta_\pi(\beta_{\pi^e}\pi_{t+1}^e + (1-\beta_{\pi^e})\pi_t^*) + (1-\beta_\pi)\pi_{t-1} + \beta_y\tilde{y}_t + \beta_q\tilde{q}_t + \beta_{imp}\pi_t^{imp} + \varepsilon_t^\pi \tag{4}$$

where π_t is consumer inflation, π_t^* is the inflation target, $\tilde{y}_t$ is the output gap, $\tilde{q}_t$ is the real exchange rate gap, and π_t^{imp} is imported inflation.[8] Unlike Laubach and Williams (2003), the expectations-augmented

[7] House prices, credit extension, commodity prices, the exchange rate are modeled as autoregressive processes. Unlike Laubach and Williams (2003), only one autoregressive coefficient is used in the estimation step as it is more closely linked to the theoretical foundations of intertemporal optimization.

[8] The model does not include a time-varying standard deviation of the errors although evidence exists that this may be important in some EMDEs (Ha et al., 2019; Kabundi et al., 2019).

Phillips curve is used.[9]

Potential output and underlying potential growth are modeled as:

$$y_t^* = y_{t-1}^* + g_t/4 + \varepsilon_t^{y^*} \tag{5}$$

and

$$g_t \quad = \quad g_{t-1} + \varepsilon_t^g \tag{6}$$

where the (log) level of potential output (y_t^*) evolves by the quarter-on-quarter annualised underlying potential growth rate, g_t. In turn, g_t is a random walk. These equations allow for idiosyncratic factors such as droughts and strikes to affect the level of potential output, creating temporary deviations from the underlying growth process, g_t.[10]

The model is closed with a Taylor Rule:

$$i_t = \tau i_{t-1} + (1-\tau)(r_t^* + \pi_t^* + \gamma_\pi(\pi_{t+4} - \pi_t^*) + \gamma_{\tilde{y}}\tilde{y}_t) + \xi_t^i \tag{7}$$

where i_t is the nominal policy rate, and responds to the deviation of forecast inflation (π_{t+4}) from its target (π_t^*), and the output gap ($\tilde{y}_t$). The inflation target uses officially announced targets, or the mid-point of a target range, or an Hodrick-Prescott filter with a lambda of 15,000 if there is no available data.

5.2 Taylor rule

Another source of information to use to determine the neutral real interest rate is the behavior of the central bank. This is based on the widely used Taylor Rule formulation of policy that generally describes the behavior of inflation targeting central banks. This requires that the central bank use interest rates as its main policy variable–as is the case with inflation targeters–and that the central bank chooses to target inflation and the real economy (sometimes indirectly).

Taylor Rule estimation is pervasive in inflation targeting economies, including EMDEs. These rules form the foundation of small open economy models used by inflation targeting central banks (Clarida et al., 2001; Botha et al., 2017). They also have been found to appropriately capture the behavior of these central banks in general.[11] These rules have been estimated for:

- Brazil (Bogdanski et al., 2000; Moreira, 2015; Sánchez-Fung, 2011);
- Chile (Schmidt-Hebbel et al., 2002; Piedrabuena et al., 2005, Schmidt-Hebbel and Tapia, 2002);
- Colombia (Bernal et al., 2002; Villa et al., 2014; Misas et al., 2018);
- India (Eichengreen et al., 2020);
- Mexico (Cermeño et al., 2012; Torres, 2003; Ros, 2015);

[9] See Friedman (1968) for a Phillip's curve that incorporates inflation expectations.

[10] The seminal piece that applied this modeling structure was Clark (1987).

[11] See Moura and de Carvalho, 2010; Loayza et al., 2002; Caporale et al., 2018; Galimberti and Moura, 2013; Teles and Zaidan, 2010; Mehrotra and Sánchez-Fung, 2011.

- Philippines (Cagas et al., 2006; Salas, 2006);
- Poland (Sznajderska, 2014; Greszta et al., 2011,Nojković and Petrović, 2015);
- Thailand (Taguchi and Wanasilp, 2018; McCauley et al., 2006);
- Turkey (Gozgor, 2012;Kaytanci, 2009);
- And South Africa (Naraidoo and Paya, 2012; Ortiz and Sturzenegger, 2007; Naraidoo and Raputsoane, 2011; Steinbach et al., 2009; Aron et al., 2000).

The Taylor Rule used in this paper is specified as:

$$i_t = \tau i_{t-1} + (1-\tau)(r_t^* + \pi_t^* + \gamma_\pi(\pi_t^e - \pi^*) + \gamma_{\tilde{y}}\tilde{y}_t) + \xi_t^i \tag{8}$$

where i_t is the nominal policy rate, and responds to the deviation of inflation (π_t^e) from its target (π_t^*) and the output gap ($\tilde{y}_t$). The rule specified above is a forward looking version of the rule by Taylor (1993). This paper uses private sector inflation forecasts (π_t^e) as the variable targeted by the central bank because it is alternative source of information than model expectations, and since the model is more parsimonious. Although EMDE central banks have different horizons to achieve their inflation targets and can target slightly different definitions of annual inflation, the Taylor Rule specified above should be a good approximation of most central banks' behavior. Taylor Rules have also been extended in a number of directions for use in EMDEs including nonlinear specifications (Caporale et al., 2018) and additional variables such as the exchange rate (Taylor, 2001; Batini et al., 2003). While individual central banks' behavior may be better defined by a non-linear rule or one that includes other variables, the Taylor Rule as specified above should indirectly capture other variables including the exchange rate through its impacts on inflation and output.

The Taylor Rule is embedded in an unobserved components model that estimates the output gap based on:

$$\tilde{y}_t = \alpha_y \tilde{y}_{t-1} + \xi_t^{\tilde{y}} \tag{9}$$

in conjunction with equations 5 and 6 above. The output gap is defined as $\tilde{y}_t = y_t - y_t^*$. The neutral real interest rate is treated as another unobserved component to be estimated in conjunction with the output gap and model coefficients.

5.3 Time-varying vector autoregressive model

A third approach uses a time-varying parameter vector autoregressive (TVP-VAR) model to estimate the neutral real interest rate. Time-varying parameter models in economics started with the seminal work of Canova (1993) and Stock and Watson (1996) and was first applied to monetary policy by Primiceri (2005).[12] Subsequent work using this methodology included Cogley and Sargent (2005), Sims and Zha

[12] He used a TVP-VAR to model the time varying aspects of United States monetary policy proving that US monetary policy has evolved over time and become more aggressive towards inflation and unemployment since the 1970s and 1980s.

(2006), Canova and Gambetti (2009), Cogley et al. (2010), Koop and Korobilis (2013), Del Negro and Primiceri (2015), and Antonakakis et al. (2019).

The model is specified as:

$$Y_{it} = X_{it}B_t + \varepsilon_t \tag{10}$$

where Y_{it} is an $Nx1$ vector of endogenous variables, X_{it} is a matrix of lagged dependent variables including an intercept, B is a matrix of time-varying coefficients, and ε_t is a time-varying independently and identically distributed error.

The VAR includes four variables: real output, consumer inflation, real policy rates–defined as the policy rate less expected inflation–and the real effective exchange rate. The models are estimated on quarterly data from 2000Q1 with two lags. The benefit of the TVP-VARs is that it applies less structure than the Taylor Rule and Laubach and Williams (2003) model to expected economic relationships.

In order to generate neutral real interest rate estimates from the TVP-VAR, five-year ahead iterated forecasts of the real interest rate are used as in Lubik et al. (2015); that is $r_t^* = r_{t+20}$.[13]

6 Data

Table 2 describes the data, sources and transformations used in this paper. All data are quarterly and collected as available, therefore, time spans depend on country-specific availability. The modeling strategy employed uses switches which turn on and off portions of the models for each country depending on data availability. Not all data is seasonally adjusted. When only non-seasonally adjusted data is available, the data is seasonally adjusted by Haver or using X-13ARIMA-SEATS.

In the Taylor rule model, inflation expectations are used instead of contemporaneous inflation as the variable of interest to the central bank. This approach limits the country choice to only those that have consensus forecasts available and from 2005 onwards. Since consensus forecast reports fixed event forecasts every month that do not account for the time dimension of forecasts appropriately, the fixed horizon transformation in Siklos (2013) and Bordo and Siklos (2017) is used. For each month the forecasts are available, inflation is transformed using:

$$\pi_{m,t}^{FH} = [(13-m)/12]\pi_t^{FE} + [(m-1)/12]\pi_{t+1}^{FE} \tag{11}$$

where FH is the fixed horizon forecast which is a linear combination of the fixed event forecast at time t (e.g. 2020) and t+1 (e.g. 2021) for month m. This transformation ensures that the central bank is always targeting forecasts of annual inflation one-year ahead.

The VAR model uses output, inflation, interest rates, and the exchange rate. Output and the exchange rate are made stationary using a first difference log transformation. Inflation is the log annual change in consumer prices. The real interest rate is the ex ante real interest rate from the Laubach-Williams model.

[13] See Marcellino et al. (2006) for a discussion of directed versus iterated forecasts.

Finally, the panel regression model looks at the drivers of the unobserved component in Laubach and Williams (2003) and includes dependency ratios, population growth, life expectancy, income inequality, the relative price of capital, sovereign risk spreads, global savings, and the U.S. neutral real interest rate.

7 Results

This section presents results of the three estimation methods for aggregate EMDEs, the uncertainty around these results, the drivers of the neutral real interest rate, the stance of monetary policy in these EMDEs, and the role that monetary policy credibility may play. Results are presented for EMDEs as a whole aggregated using constant GDP at 2010 prices and market exchange rates. Limited data mean that TVP-VAR estimates are only provided for the ten EMDEs that started inflation targeting in the early 2000s. The economies covered in this paper include Albania, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Georgia, Hungary, Indonesia, India, Kazakhstan, Mexico, Paraguay, Peru, Philippines, Poland, Russia, South Africa, Thailand, and Turkey.

7.1 Neutral real interest rate estimates

EMDEs saw a significant drop in neutral real interest rates since the early 2000s (figure 1). In 2000, the neutral real interest rate averaged an estimated 6.2 percent declining to 2.2 percent by the end of 2019.[14] Based on the Laubach-Williams definition of neutral, the decline was partially attributable to a fall in potential growth (Kilic Celik et al., 2020). Potential growth in EMDEs peaked at 4.4 percent in 2005, declining to 3.8 percent in 2019Q4. The rest, and the majority of the decline, was driven by the unobserved component *z*–2 percentage points since 2005.

The decline in the neutral real interest rate has occurred in three-quarters of economies in the sample. Along with the decline in the neutral interest rate, the spread across countries has also declined–by more than half–over the sample period.

Estimates of the neutral real interest rate in EMDEs in this paper are higher than those found in Beyer and Milivojevic (2020), the only other available estimates for this group of countries. In the latter, the 2019 estimate for EMDEs is 0.5 percent, compared to the over 2 percent estimated here. Both estimates suggest a decline over time in the neutral real interest rate but by significantly different magnitudes.

The neutral real interest rate in EMDEs is statistically significantly higher than that of the United States. It averaged 3.8 percent in EMDEs since 2000. Over this same horizon Laubach and Williams (2003) estimate the neutral interest rate in the United States averaged 1.4 percent. In the early 2000s the gap between the two was 3.5 percentage points. However, over time this gap has declined to only 1.4 percentage points in 2019Q4.

7.2 Drivers of the neutral real interest rate

The unobserved component of the Laubach-Williams model explains a significant portion of the decline in the neutral real interest rate in most EMDEs (see Pescatori and Turunen, 2015 and Beyer and Wieland,

[14]The EMDE aggregate is a weighted average using real GDP at 2010 prices and market exchange rates.

2017 for a criticism of the unobserved component's role in advanced economies). For EMDEs on aggregate, z has fallen by over 4 percentage points since 2000. In the United States, by comparison, the neutral real interest rate has fallen by over 3 percentage points with z explaining about two-thirds of the decline (Holston et al., 2017). This section looks at what drives outcomes in z in EMDEs using a panel regression model on 15 EMDEs with sufficient data.[15] The focus on the unobserved component instead of the neutral real interest rate is an attempt to explain the part of the decline that is not directly related to potential growth. The following variables are used to try and explain movements in z:

- Dependency ratio;
- Population growth;
- Life expectancy;
- Income inequality;
- Relative price of capital;
- Sovereign risk spread;
- Global saving;
- And the U.S. neutral real interest rate.

These variables are identified in the literature as plausible drivers of the ex ante saving and investment schedules that would drive changes in the neutral interest rate based on the theory of loanable funds (see, for example, Borio et al., 2017 and Rachel and Smith, 2015). Global saving and investment tests the theory of a global savings glut driving interest rates. To avoid the possibility of the impact of cyclical factors, five-year periods are analyzed including 2000-04, 2005-09, 2010-14, and 2015-19.[16] Moreover, using the unobserved component extracted from the Laubach-Williams model reflects the slow and smooth neutral interest rate unlikely to have any cyclical variation.

Two model specifications are presented including a model with country fixed effects and one with country and time fixed effects (table 3).[17] There does not appear to be important time effects with the Breusch and Pagan test and an F-test for individual effects not rejecting the null hypothesis of no time effects.

The results suggest that only a few domestic saving and investment factors matter and global savings do not play a statistically significant role in driving neutral real interest rates. The relative price of capital and life expectancy are both statistically significant at a 5 percent level of significance. A one-percentage-point increase in the relative price of capital leads to a 0.05 percent increase in the neutral real interest rate. The sign is positive, as expected in theory, suggesting that a reduction in relative price of capital reduces demand for investment; less investment is needed to maintain a similar level of output (Borio et al., 2017; IMF (International Monetary Fund), 2014; Rachel and Smith, 2015). Life expectancy is also significant with a one year increase in life expectancy decreasing the neutral interest rate by 0.4 percentage point. Living longer increased desired savings, shifting the savings curve to the right and decreasing the neutral interest rate.

[15] The economies include Brazil, Chile, Colombia, Georgia, Hungary, Indonesia, Kazakhstan, Mexico, Peru, Philippines, Poland, Russia, Thailand, Turkey, and South Africa.

[16] The panel is unbalanced and some five-year averages use less than five years of data.

[17] The Hausman test supports the use of the fixed effects model.

To determine the relative importance of these drivers to the decline in z in EMDEs, a simple arithmetic using the estimated relationships and moves in the underlying variables is presented (figure 2). In line with the decline in the relative price of capital in advanced economies, the relative price also declined in EMDEs for much of the last two decades before reversing in recent years. The relative price of capital decline contributed 0.1 percentage point to the decline in the neutral interest rate in 2005-09 and 2010-14, compared to 2000-04 and 2005-09, respectively. The more recent rise has increased the neutral interest rate in EMDEs by 0.5 percentage point. The rise in life expectancy among EMDEs, from an average of below 70 years to closer to 74 years has also helped to decrease the neutral by a cumulative 1 percentage point over the past two decades.

Rachel and Smith (2015) analyze the drivers of the 4.5 percentage point drop is global real interest rates over the past three decades and find that global potential growth cannot explain much of the decline, a similar outcome found here for EMDEs. Also the authors find that demographic forces, reflected in this paper by life expectancy, explains about 0.9 percentage point of the decline. The global savings glut played a marginal role according to Rachel and Smith (2015) and IMF (International Monetary Fund) (2014), whereas for EMDEs it does not. Unlike in Rachel and Smith (2015), this paper does not find a meaningful role (although statistically significant) for the relative price of capital in driving declines in the neutral real interest rate in EMDEs. Finally, in contrast to that paper, inequality is not a significant driver of the decline in EMDEs as is the case in the global context.

The inclusion of time fixed effects removes the statistical significance of life expectancy, suggesting that there may be other factors that could explain the decline in the neutral real interest rates beyond shifts in desired savings and investment. One possible explanation is that adoption of inflation targeting during this period and improved transparency and credibility led to a decrease in the real interest rate, as suggested in Borio et al. (2017). Indeed, including the U.S. neutral real interest rate as a proxy for the trend decline in global neutral interest rates does not provide a satisfying explanation of the decline.

7.3 Uncertainty

The neutral real interest rate is unobservable and therefore subject to significant uncertainty. The degree of uncertainty surrounding estimates of the neutral real interest rate plays an important role in the ability of a central bank to determine its monetary policy stance, or the difference between the real interest rate and its neutral. Central bank's with high estimates of uncertainty are unlikely to meaningfully be able to determine whether their policy stances are helping or hurting economic growth and hence inflation.

Uncertainty can be represented by the differences between methodologies (a measure of model uncertainty, although limited) or the standard error estimate of the models (a measure of parameter uncertainty). These measures of uncertainty are by no means all encompassing. Excluded from this paper are uncertainty generated by real time data (Orphanides and Williams, 2002) and the likely scope of model uncertainty (see, for example, Jarociński and Lenza, 2018 and Levin et al., 2003).

In the context of the Laubach-Williams model, uncertainty around estimates of the neutral real interest rate are high and average 1.2 percentage points from 2000 to 2019 (figure 3). In 2019Q4, the uncertainty estimate was 1.4 percentage points meaning that the neutral real interest rate in EMDEs was likely anything between 0.2 and 4.2 percent at a 90 percent confidence band. Uncertainty, however, differs significantly by economy and ranges from 0.6 to 3.0 percentage points. In advanced economies the uncertainty around the neutral interest rate is less than half that of EMDEs at 0.6 percentage point.

Uncertainty based on differences between methodologies provides a different perspective of possible drivers of uncertainty. On average, the absolute difference between the three methodologies is 0.7 percentage points, the largest difference being between the Laubach-Williams and Taylor Rule estimates and the smallest difference between Laubach-Williams and the TVP-VAR. The difference between the Laubach-Williams and Taylor Rule estimates is 0.9 percentage point while the difference between the Laubach-Williams and TVP-VAR models is 0.5 percentage point. Much of these difference occur in the early part of the sample, with the difference narrowing throughout the sample and converging after 2016 in the case of Laubach-Williams and the Taylor Rule and 2008 between Laubach-Williams and the TVP-VAR.

7.4 Stance of monetary policy

Having an aggregate measure of the neutral real interest rate provides a way to measure the stance of monetary policy in EMDEs as a whole. Differences between the real interest rate and the neutral interest rate show either an accommodative (neutral above the interest rate) or restrictive (neutral below the interest rate) stance.[18] In an inflation targeting setting, the central bank is reacting to the deviation of inflation from its target and the business cycle, represented by the output gap.

The Laubach-Williams model provides a useful and appropriate narrative of policy developments in EMDEs over the past few decades (figure 4). In the early 2000s, EMDE monetary policy was restrictive responding to inflation above its target and a positive output gap. In 2002Q1, more than two-thirds of EMDEs were running restrictive policies. As inflation shifted towards its target–reaching it in 2004–and the output gap was close to zero, policy shifted to a neutral or accommodative stance. An increasingly excessive demand environment in 2007 led more EMDEs to shift policy toward a contractionary policy stance despite inflation on aggregate near its target range. When the global financial crisis hit, EMDEs in aggregate shifted to an accommodative stance, reacting to a large negative output gap despite a temporary spike in inflation. Policy remained accommodative until around 2014 when inflation and the output gap started creeping up. From 2014, as global financing conditions tightened, EMDEs were running restrictive policy. By 2019Q1, eight-tenths of EMDEs had a restrictive policy stance. However, at the end of 2019, as inflation fell below target, and the output gap was negative but close to zero, policy again had space to begin easing.

7.4.1 Credibility

The effectiveness of an inflation targeting central bank is linked to its credibility in achieving its set target. Without credibility its neutral real interest rate is likely to be higher and may be an inappropriate guide to the stance of monetary policy as real interest rates are misaligned, and modeling the story of the monetary policy stance as gaps from equilibrium values, as done in this paper, misleading.[19] A

[18] Analysis on the stance of monetary policy going forward is based on the Laubach-Williams models.

[19] In the context of the Laubach-Williams model, when inflation deviates substantially from the announce target an implicit target is used.

credible central bank enjoys lower inflation outcomes, less sensitivity of inflation to external shocks, lower exchange rate passthrough, and is more likely to avoid de-anchoring inflation expectations (Ha et al., 2019, Kabundi et al., 2019).

One way to test the credibility of a central bank's inflation target is through the link of inflation expectations to its announced target and past inflation:

$$\pi_t^e = \rho \pi_{t-1} + (1-\rho)\pi_t^* + \varepsilon_t \tag{12}$$

where inflation expectations of the private sector are a function of the central banks announced target–the midpoint in the context of ranges–and lagged annual inflation. This methodology was first implemented in King et al. (1996) and more recently in Kabundi and Mlachila (2019). The higher ρ, the less credible the central bank's inflation target, with 1 meaning that inflation expectations are fully backward looking to past inflation outcomes. There is a positive relationship between the size of ρ and the level of the neutral real interest rate (figure 5). Economies that achieved a low ρ value, indicating a relatively higher importance of the inflation target is determining inflation, tend to have lower neutral real interest rate estimates. Those with a higher ρ are associated with higher neutral real interest rates. Using another possible measure of credibility–the average gap between inflation and the inflation target–shows an equally strong positive relationship with the level of the neutral real interest rate. This suggests that the inflation risk premium and inflation volatility may be important drivers of the neutral real interest rate.

8 Conclusion

With close to 30 EMDEs, accounting for 45 percent of EMDE output, using inflation targeting to determine monetary policy, it is possible to create a meaningful measure of neutral real interest rates in these economies. To this end this paper provides an estimate of the neutral interest rate in EMDEs and highlights declining neutral interest rates in line with what has happened in advanced economies. This estimated decline has been in the order of 4 percentage points, from over 6 percent to closer to 2 percent at the end of 2019. EMDEs neutral real interest rate is 1.4 percentage points higher than that estimated for the United States, a typical proxy for the global neutral interest rate. A number of factors have helped to explain the decline in EMDEs neutral real interest rates including the fall in potential growth, increases in life expectancy which raises the desired level of savings, and decreases in the relative price of capital. Only the relative price of capital, however, is robust to the inclusion of time fixed effects. This suggests that other possible explanations including the shift to inflation targeting and the credibility gained during this transition.

The precipitous fall in neutral interest rates in EMDEs may complicate the ability of these economies to provide stimulus in the face of large shocks, a common problem in advanced economies since the global financial crisis. Unfortunately, the neutral real interest rate is unobservable and subject to a high degree of uncertainty. Estimates of this uncertainty suggest that the range of possible outcomes for EMDEs is wide with a standard deviation of 1.4 percentage points. This uncertainty is higher for commodity-exporters than for commodity-importers and double that of advanced economies.

Estimates of the neutral real interest rate also provide a useful narrative of the stance of monetary policy in EMDEs. This stance, measured as the difference between real interest rates and its neutral rate, has generally been appropriately countercyclical in most EMDEs. When inflation is below target and there is deficient demand, EMDE central banks run accommodative policy. This was most clearly seen during the 2009 global recession and its aftermath. In the early 2000s, in contrast, there was a positive output gap and inflation still needed to be anchored around established targets, and policy was restrictive with the real interest rate above the neutral. The policy stance may not always be appropriate for meeting both inflation and output objectives, which can move in opposite directions when hit by supply shocks. This is clearly evident in the procyclical tightening that occurred in many EMDEs during 2016 as global financing conditions tightened.

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Table 1: Inflation targeting emerging and developing economies

Country	Year adopted	Target variable	Target	Instrument
Albania	2008	Annual CPI (headline)	3%	Repurchase Agreement rate
Brazil	1999	Headline Broad National Consumer Price Index (IPCA)	4.5% ± 2 percentage points	Overnight interest rate (SELIC)
Chile	1999	Annual CPI (headline)	3% ± 1 percentage point	Overnight interbank rate
Colombia	2000	Headline CPI	3% ± 1 percentage point	Intervention interest rate
Costa Rica	2018	Headline CPI	3% ± 1 percentage point	Integrated Liquidity Market interest rate
Dominican Republic	2011	Headline CPI	4% ± 1 percentage point	Policy rate
Georgia	2009	Headline CPI	3%	One-week refinancing rate
Hungary	2008	CPI	3%	Interest rate on two-week central bank bond
Indonesia	2005	Headline CPI	4.5% ± 1 percentage point	BI rate
India	2014	Headline CPI	4% ± 2 percentage point	overnight repo rate
Kazakhstan	2015	Headline CPI	4-6%	Interbank short-term money market rate TONIA
Mexico	2001	Headline CPI	3 % ± 1 percentage point	overnight interbank rate
Paraguay	2012	Total CPI	4% ± 2 percentage point	Interbank Loan Interest Rate (TIB)
Peru	2002	Headline inflation	2% ± 1 percentage point	Reference interest rate
Philippines	2000	Headline CPI	3.0% ± 1 percentage point	Overnight reverse repo among others
Poland	2000	Headline CPI	2.5% ± 1 percentage point	Reference rate
Russian Federation	2014	Headline CPI	3%	1-week repo rate
Thailand	2000	Headline CPI	2.5% ± 1.5 percentage point	One-day repurchase transaction rate
Turkey	2002	Annual CPI	5% ± 2 percentage point	One week repo auction rate
South Africa	2000	Headline CPI	4.5% ± 1.5 percentage points	Repo rate

Source: Hammond et al. (2012); International Monetary Fund Annual Report on Exchange Arrangements and Exchange Restrictions.

Note: This table only includes the 20 EMDEs used in this paper. For a list of all EMDE inflation targeters see Ha et al. (2019)

Table 2: Data

Variable	Description	Source	Transformation	Model
y	Constant gross domestic product in local currency unit	Haver Analytics	Seasonally adjusted	LW,TR,TVPVAR
i	Nominal official/policy interest rate	Haver Analytics	N.A.	LW,TR,TVPVAR
q	Real effective exchange rate, CPI based.	Bruegel	Seasonally adjusted	LW,TR,TVPVAR
q^*	Equilibrium real exchange rate	Author calculations	Hodrick-Presscott filter	LW,TR
π	Consumer price index	Haver Analytics	Seasonally adjusted	LW,TR,TVPVAR
π^e	Inflation expectations	Consensus Economics	Transformed to fixed horizon	LW,TR
π^*	Inflation target	Haver Analytics	N.A.	LW,TR
imp	Import price index	Haver Analytics	Seasonally adjusted	LW
com	Real commodity prices	Comtrade; World Bank; Federal Reserve of St. Louis	Export weighted index of 15 commodities deflated using U.S. CPI	LW
com^*	Trend commodity prices	Author calculations	Hodrick-Presscott filter	LW
c	Private sector credit extension	Haver Analytics	Seasonally adjusted	LW
c^*	Trend credit extension	Author calculations	Hodrick-Presscott filter	LW
h	Residential property prices	BIS	Seasonally adjusted	LW
h^*	Trend house prices	Author calculations	Hodrick-Presscott filter	LW
$capu$	Capacity utilization rate	Haver Analytics	Seasonally adjusted	LW
unr	Unemployment rate	Haver Analytics	Seasonally adjusted	LW
$depend$	Dependency ratio	World Bank	Five-year average	PR
pop	Population growth	World Bank	Five-year average	PR
$life$	Life expectancy	World Bank	Five-year average	PR
$gini$	Gini coefficient	World Bank	Interpolated; Five-year average	PR
Rel_price	Ratio of investment deflator to consumption deflator	Penn World Table	Five-year average	PR
$Saving$	Global saving to GDP	World Bank	Five-year average	PR
r_{*f}	U.S. neutral interest rate	Laubach and Williams (2003)	N.A.	PR
$risk$	Emerging Market Bond Index (EMBI) sovereign spread	Haver	Five-year average	PR

Source: Author

Note: LW = Laubach-Williams model; TR = Taylor Rule model; TVPVAR = Time-varying parameter vector autoregressive model; PR = Panel regression.

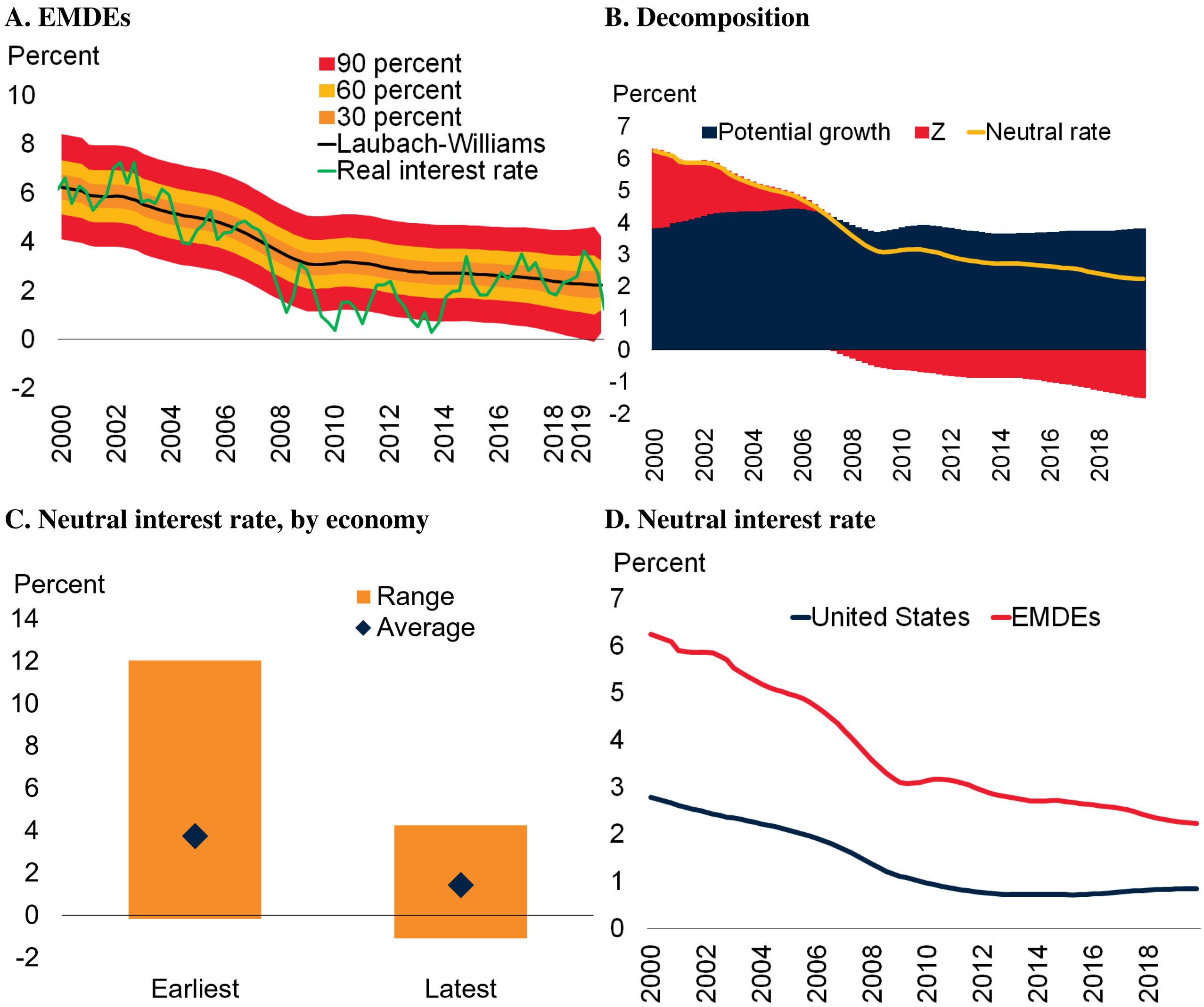
Table 3: Panel regression results: Drivers of Z

	(1)	(2)	(3)
Dependency ratio	-0.003	-0.028	-0.028
	(0.040)	(0.052)	(0.052)
Life expectancy	-0.376***	-0.231	-0.231
	(0.082)	(0.173)	(0.173)
Income inequality	6.479	5.022	5.022
	(7.735)	(7.979)	(7.979)
Sovereign risk	-0.027	-0.017	-0.017
	(0.088)	(0.091)	(0.091)
Relative price of capital	0.052***	0.054***	0.054***
	(0.014)	(0.015)	(0.015)
Population growth	1.21	1.134	1.134
	(0.737)	(0.753)	(0.753)
Global saving	-0.377	-1.920	
	(0.287)	(1.618)	
U.S. neutral interest rate			0.445
			(0.375)
2005-09		1.469	-0.299
		(1.490)	(0.282)
2010-14		0.273	0.216
		(0.351)	(0.329)
Observations	55	55	55
No. of economies	15	15	15
Adj R^2	0.46	0.44	0.44
F-Test	9.46	7.26	7.26

Source: Author.

Note: Model (1) includes country fixed effects and model's (2) and (3) include country and time fixed effects. *** reflects statistical significance at a 1 percent level of significance, ** at a 5 percent level of significance, and * at a 10 percent level of significance.

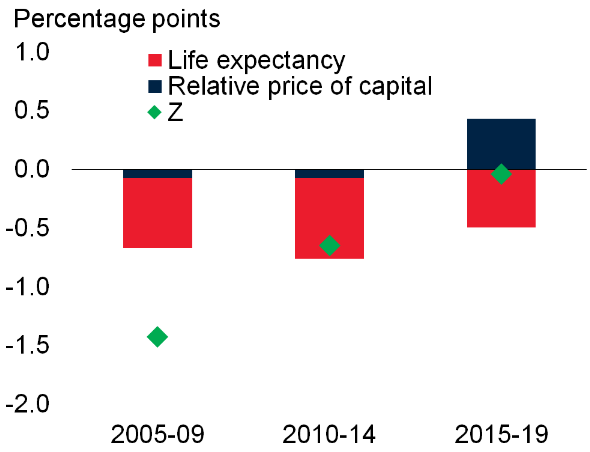
Figure 1: Neutral real interest rates



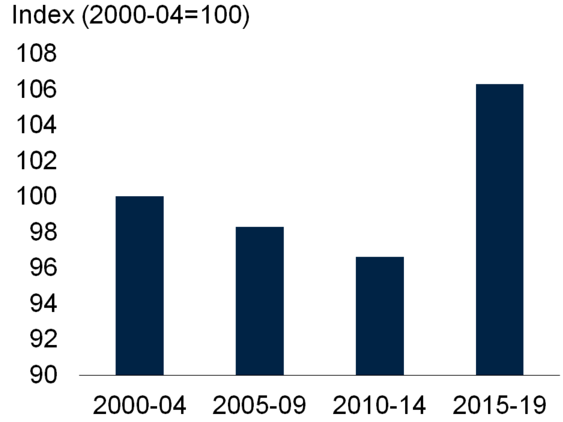
Source: Haver Analytics; World Bank.
Note: Estimates based on a semi-structural model of Laubach and Williams (2003). Weighted using GDP at 2010 prices and market exchange rates. EMDEs are based on 20 inflation targeting economies.
C. Unweighted average of 20 economies. "Earliest" reflects earliest available observation by country and "Latest" reflects 2019Q4. Range is the minimum and maximum estimate across countries.

Figure 2: Drivers of Z

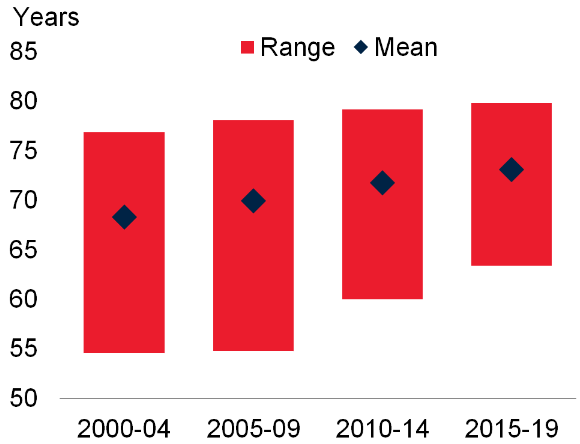
A. Change in Z



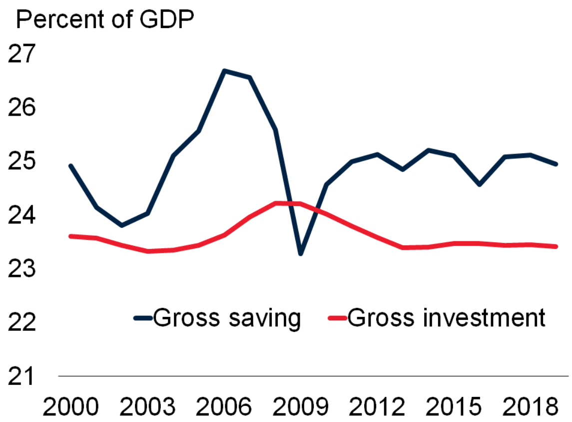
B. Relative price of capital in EMDEs



C. Life expectancy in EMDEs

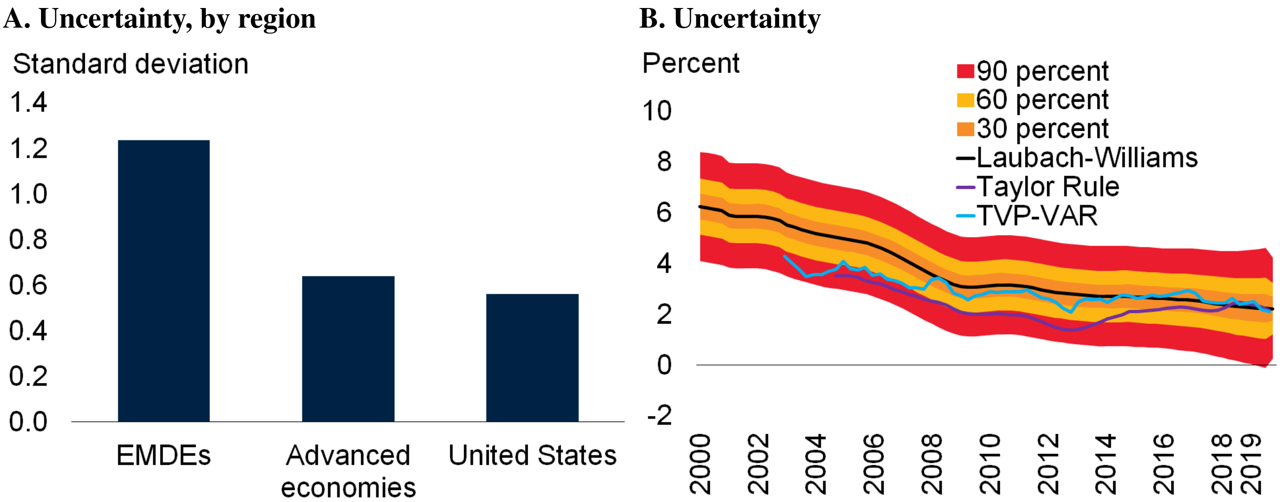


D. Global saving and investment



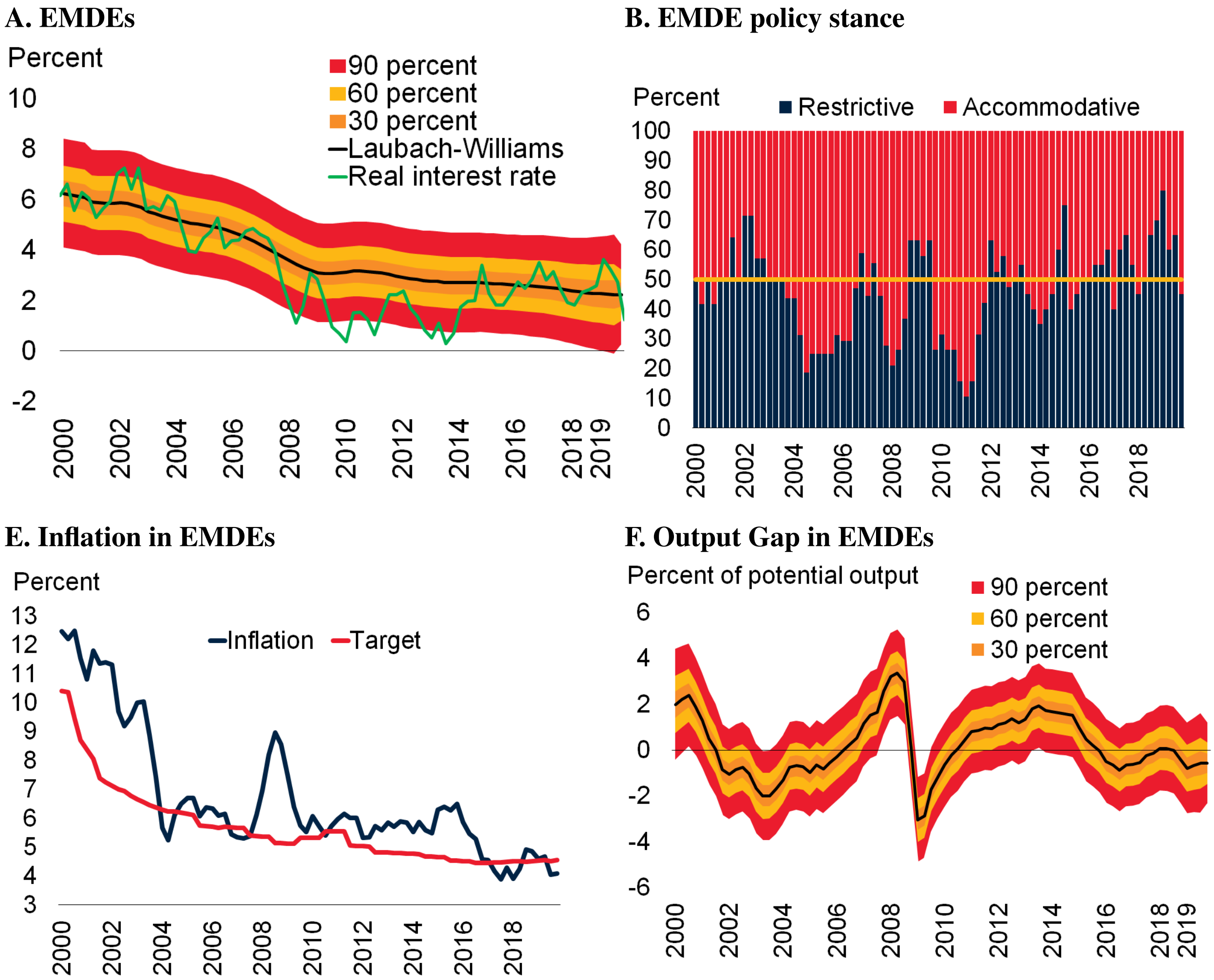
Source: Penn World Table; World Bank.
A. Based on the panel regression results in model 1.
B.C. Based on a weighted average of 15 EMDEs using constant gross domestic product at 2010 prices and exchange rates.

Figure 3: Uncertainty in neutral interest rate estimates



Source: Haver Analytics; World Bank.
Note: Estimates based on a semi-structural model of Laubach and Williams (2003), Taylor Rule, and TVP-VAR. Weighted using GDP at 2010 prices and market exchange rates. EMDEs are based on 20 inflation targeting economies for the first two methods and 10 EMDEs for the last. Advanced economy estimate based on 36 economies.

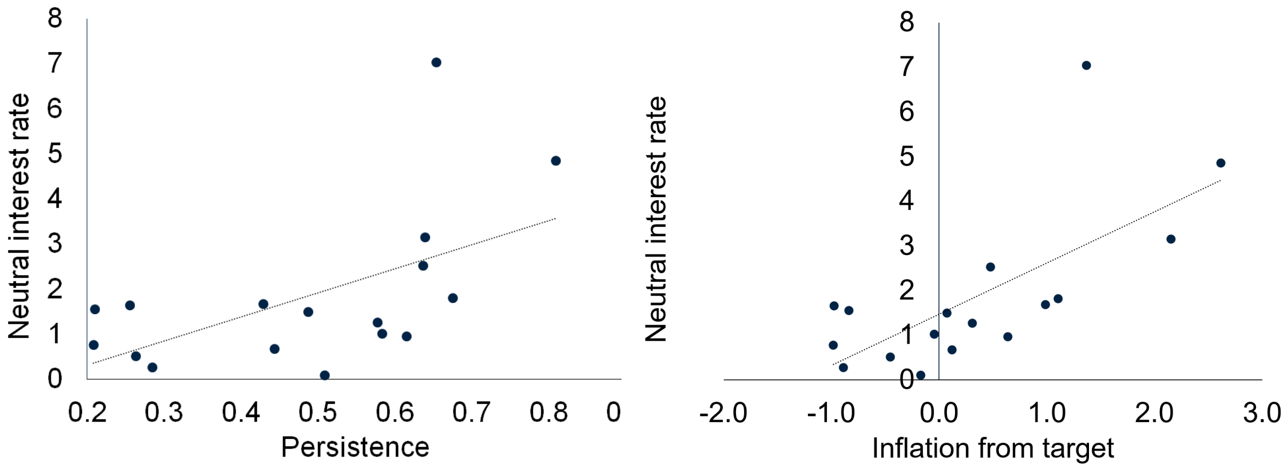
Figure 4: Monetary policy in EMDEs



Source: Haver Analytics; World Bank.
Note: Estimates based on a semi-structural model of Laubach and Williams (2003). Weighted using GDP at 2010 prices and market exchange rates. EMDEs are based on 20 inflation targeting economies.
B. Share of EMDEs who have a restrictive of accommodative policy stance. “Restrictive” policy stance is defined as the real interest rate above its neutral rate and the opposite for “accommodative”.

Figure 5: Credibility

A. Neutral interest rate and persistence **B. Neutral interest rate and inflation gap**



Source: Haver Analytics; World Bank.
Note: Estimates of the neutral interest rate based on a semi-structural model of Laubach and Williams (2003).
B. "Inflation from target" reflects the average gap between annual inflation and the inflation target (midpoint in countries with a range) from 2000Q1.