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Impossible Trinity in a Small Open Economy: A State-Space Model Informed Policy Simulation

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Guna Raj Bhatta

School of Business, Faculty of Business and Law, University of Wollongong

Rabindra Nepal

School of Business, Faculty of Business and Law, University of Wollongong
Centre for Applied Macroeconomic Analysis, ANU

Kankesu Jayanthakumaran

School of Business, Faculty of Business and Law, University of Wollongong

Charles Harvie

School of Business, Faculty of Business and Law, University of Wollongong

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Keywords

Monetary Policy Independence, Impossible Trinity, State Space Model, Calibration, Policy Simulation

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Address for correspondence:

(E) cama.admin@anu.edu.au

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Guna Raj Bhatta*
Rabindra Nepal&
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Should monetary policy independence be maintained when the exchange rate is fixed under closed capital account conditions in a small open economy? We apply the Kalman filter at State Space model to test the Nepalese economy's policy trilemma condition involving restricting capital flow, maintaining policy independence and fixing the exchange rate over the period 1989-2019. Accounting for two-thirds of Nepal's total trade, Nepal is heavily trade-dependent to India in South Asia, which underwent economic liberalisation during the early 1990s. We modify the traditional Taylor-rule-based monetary policy reaction function to more closely represent Nepal's economic characteristics by mixing backward-looking and forward-looking strategies and incorporating a fixed exchange rate in the monetary policy reaction function. The simulation results provide strong evidence of policy trilemma failure and inevitable policy trade-offs. In the monetary policy reaction function of both domestic and foreign conditions, the parameter value of domestic condition needs to be close to zero, to get the simulated interest rate close to observed. The loss of monetary policy independence raises a range of policy issues for the Nepalese economy: the rationale for fixing the exchange rate, and the efficacy of capital account closure which might deteriorate the effectiveness of monetary policy.

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* PhD Candidate, Economics Discipline; Faculty of Business and Law; University of Wollongong. For communications, grb494@uowmail.edu.au; bhatta.gunaraj@gmail.com.

& Senior Lecturer, Economics Discipline; Faculty of Business and Law; University of Wollongong & Centre for Applied Macroeconomic Analysis (CAMA), Australian National University (ANU), Australia.

@ Associate Professor, Economics Discipline; Faculty of Business and Law; University of Wollongong

I. INTRODUCTION

Does a country maintain monetary policy independence when its exchange rate is fixed, and its capital account is closed? This question has gained increased attention across small open economies since the global financial crisis (GFC) of 2008. Prominent scholars such as Edwards (2015) and Rey (2015) have proposed contrasting views on monetary policy independence¹ and capital controls. These studies challenged the trilemma approach of Fleming (1962) and Mundell (1963), widely known as Mundel-Fleming's impossible trinity². The trinity proposes an optimal policy mix among the exchange rate, external capital flows and monetary policy independence.

The validity of Mundel-Fleming's impossible trinity however, is still ambiguous despite extensive application and studies undertaken across various economies. Prior studies by Bleaney et al. (2013); Chakraborty (2016); Goh and McNown (2015); Kawai and Liu (2015); Majumder and Nag (2021); Obstfeld et al. (2005); Ohanian and Stockman (1997) and You et al. (2014) have supported the trilemma constraint. Nevertheless, Aizenman et al. (2013); Fry et al. (1988); Kim and Lee (2008); Marc (1978); Rey (2015) and Takagawa (2013) show contrasting evidence on this policy trilemma. The turning point in the literature was underscored in a study by Rey (2015), with a new strand in the literature arguing that there is a policy dilemma and not a trilemma. Therefore, the implication of the policy trilemma and optimal policy mix is still a hotly contested topic in the literature with mixed empirical evidence in small open economies.

Past studies in the Nepalese context have shown that monetary policy's effectiveness is limited (Budha 2011, 2015; Maskay & Pandit 2010). Nepal is a small open economy in South Asia and has imposed capital account restrictions in order to maintain its monetary policy independence, given the historical peg in the exchange rate with India. On the other hand, studies reveal that about half of the inflation in Nepal is explained by Indian inflation (Institute for Sustainable Development 1994; Nepal Rastra Bank 2007; Neupane

¹ The independence of monetary policy is the ability of the central bank to absorb internal and external shocks by using its policy instruments. In our study, we assume that monetary policy independence is maintained if the central bank is able to set the policy instrument: short term interest rate, based on domestic economic conditions.

² The trilemma model of (Fleming 1962; Mundell 1963) shows that an economy can achieve monetary policy independence while maintaining a fixed exchange rate regime and if capital mobility is restricted. In a triangle of independent monetary policy, a fixed exchange rate and capital account openness, we can choose only one corner with two policy choices and impossible to have all three policy choices. This is further discussed in the theoretical context of the study.

1992; Shrestha & Bhatta 2017). Therefore, based on findings from existing studies, it is argued that Nepal can import the price stability goal of monetary policy. Success in attaining the price stability goal supports the exchange rate as a nominal anchor³ and has a significant role in keeping Nepalese inflation at a low level, as argued by scholars such as Barro and Gordon (1983); Fratianni and von Hagen (1993); Giavazzi and Giovannini (1989).

Studies show that Nepalese monetary policy cannot influence domestic economic conditions through its transmission channels⁴ (Budha 2011, 2015; Maskay & Pandit 2010). The fixed exchange rate creates stability in the exchange rate but risks the loss of independence of monetary policy. Restricting capital flows given the fixed exchange rate may still not be an optimal policy alternative, but rather, be motivated by the 'fear of floating', as explained by Calvo and Reinhart (2002).⁵

The monetary policy independence literature only has limited studies covering small open developing economies like Nepal. Most of the available empirical literature also only apply Ordinary Least Square (OLS) based estimation for monetary policy reaction function⁶ models. An earlier study by Bhatta et al. (2021) has shown that the OLS based estimate is biased when the uncovered interest parity (UIP) does not hold in Nepal. To the best of our knowledge, there are also no studies to date on monetary policy independence considering the Nepalese economy, thereby presenting a gap in the literature. Available empirical studies primarily focus on trade competitiveness and the overvaluation of the exchange rate. Therefore, in this paper, we explore monetary policy independence in a small open developing economy. We apply the maximum likelihood

³ Nominal anchor is an approach to tie the general price level of an economy to another nominal variable such as nominal exchange rate, inflation, or money supply such that price stability is not derailed. For a detailed discussion, refer to Mishkin (2007, p. 4).

⁴ Monetary policy has four transmission channels to transmit monetary impulses to the real economy. These are: i) interest rate: lowered interest rate boosting the investing and thereby output; ii) asset price: increased asset price boosting consumption and then output; iii) exchange rate: lowered interest rate depreciating exchange rate thereby boosting export and output; and iv) credit: higher bank loan leading to higher investment and output. For the details, refer to Mishkin (1996) and Taylor (1995).

⁵ Calvo and Reinhart (2002) discusses that countries choose sub-optimal policy of managed float/soft peg to stabilize the inflation through controlling the exchange rate fluctuations. These could be fear of output loss or the poor policy credibility to float. Authors argue that such behaviour will promote the discretion rather than the policy rule, not allowing the market to adjust itself through the risk premium and money demand shocks.

⁶ Monetary policy reaction function is a New Keynesian economics based Taylor (1993) rule which determines how the central bank should set its short-term policy rate.

Similarly, You et al. (2014) show that capital controls help improve a country's monetary independence when fixing the exchange rate. Kawai and Liu (2015) show that China is losing its monetary policy independence due to the reduced capital controls but a rigid exchange rate regime. Goh and McNown (2015) show that the US and Malaysian interest rates were cointegrated during the fixed exchange rate regime (2001 – 2005) while not during the managed floating regime (1991 – 1998), providing strong evidence of achieving the impossible trinity in Malaysia. Chakraborty (2016) shows that monetary policy independence was compromised in the post-global financial crisis period in India due to heightened capital controls at this time. In a more recent study, Majumder and Nag (2021) find that the trilemma constraint did hold in the post-reform period in India, and the trilemma has been translated into the quadrilemma⁷. However, all the abovementioned studies do not include an economy with similar characteristics to that of Nepal: fixed exchange rate and closed capital account. Lessons from these studies, therefore, cannot be derived in the context of the Nepali economy.

Several other studies have criticised the evidence against the impossible trinity model. For example, Marc (1978) showed that monetary independence is impossible if residents can substitute between domestic and foreign currency. Aizenman et al. (2013) developed a new policy trilemma index and showed a middle ground of three policy choices. In the era of higher capital mobility, developed countries are converging towards more exchange rate stability, compromising monetary policy independence (Aizenman et al. 2013, p. 456). This finding is more promising in small open economies. A small economy's monetary policy conditions are highly affected by foreign financial conditions. Thus, it implies that fixing the exchange rate alone may not inhibit monetary policy independence.

Having a flexible exchange rate policy may also not ensure noticeable policy independence. Following Aizenman et al. (2013), Rey (2015) provided new evidence : monetary policy independence is constrained by free capital mobility between countries, no matter what the exchange rate policy is. Rey (2015) argues that the global financial crisis of 2008 has transformed the trilemma (the impossible trinity) into a dilemma,

⁷ Quadrilemma is an extension in the Mundel-Fleming trilemma model with a fourth component : financial stability, along with other three trilemma components. See Aizenman (2019) for details.

providing substantial criticisms of the impossible trilemma theory. The argument here is that the exchange rate regime has a minor role to play, but capital flow management maintains monetary policy independence. The conclusion of Rey (2015) is significant as economic variables such as capital flows, leverage, and asset prices converge in line with the world's major financial centres, eliminating the role and importance of exchange rate policy. Edwards (2015) also has a similar finding to that of Rey (2015). However, these study findings are not representative to that of economies like Nepal. The Aizenman et al. (2013) result is also based upon simple correlation ordinary least squares (OLS) analysis, which can be argued are incomplete as well as biased⁸. Likewise, Rey (2015)'s argument cannot apply to the case of small open developing economies as the findings from this study are mainly based on advanced and large emerging market economies.

Against the trilemma proposition, Kim and Lee (2008) find that flexible exchange rates with free capital mobility provide greater monetary independence for the East Asian economies. Similar results were obtained by Lim and Goh (2016) for the case of Malaysia and Paul (2012) for the case of India, where both argue that monetary policy independence is a matter of the exchange rate regime adopted rather than financial globalisation. De Waal et al. (2018) show that monetary policy for South Africa is not independent, as domestic interest rate decisions are affected by foreign shocks, emanating from the US, Brazil, China, and India. These studies are still not representative enough of small and partially closed economies with a fixed exchange rate. These studies primarily focus on observing the relationship through interest rate co-movements by applying OLS based models. However, this may require incorporating additional domestic economic conditions with a complete monetary policy reaction function model.

The practices in the area of exchange rate management by the central banks also support the lesser possibility of monetary independence to influence the foreign exchange market. Mendoza (2004) finds a significant increase in the reserve holdings of developing countries post-Asian financial crisis. Svensson (1994), using Swedish data, shows that a finite band for the fixed exchange rate provides greater monetary independence even when free capital mobility is allowed. Similar results were obtained by Rose (1996) using

⁸ For the detailed methodology of monetary independence index within the trilemma index, see (Aizenman et al. 2013, 2015).

data between 1967 and 1992 for 22 countries: a significant correlation was found between the degree of exchange rate volatility and the exchange rate band-width. The results show that after due consideration for capital flows and interest rates, having an upper and lower band for the exchange rate holds better monetary policy independence than having the fixed exchange rate. Nevertheless, there has been broader criticisms of using such an intermediate exchange rate regime. These being that they are crisis-prone and complex in their implementation with a higher possibility of speculative attacks and loss of central bank credibility (Calvo & Mishkin 2003; Eichengreen 1998; Fischer 2001; Obstfeld & Rogoff 1995). Thus, the exchange rate band and monetary policy independence arguments are rejected in our analysis.

Other than studies for and against holding a policy trilemma, alternative empirical findings are available on monetary policy independence. You et al. (2014), based on a panel dataset of 88 countries covering the period 1995–2010, finds that capital controls help enhance monetary policy independence, and the exchange rate regime adopted impacts the effectiveness of capital controls. Montiel et al. (2019) show that the impact of monetary policy shocks on the interest rate diminishes in a country with higher financial integration to the world regardless of the choice of exchange rate regime. Their findings show the reconciliation between the policy dilemma of Rey (2015) and that of policy dilemma and Mundell (1961, 1963)'s trilemma. Evidence for emerging and developing economies show that strict capital controls and moderate exchange rate flexibility can achieve monetary autonomy (Klein & Shambaugh 2015). Hosny et al. (2015) find a time-varying nature of interest coefficients when countries switch between different exchange rate regimes and/or capital controls. They suggest applying a time-varying parameter model to better capture the relationship between monetary policy independence, exchange rate regimes, and capital mobility restrictions. In a recent study, Gülşen and Özmen (2020) find consistent results for Rey (2015). Domestic interest rates are determined by the US interest rate in the emerging market economies in the long run, even when the exchange rate was flexible. They also noticed that spillover sensitivity from the US interest rate substantially increased after the GFC.

These studies, and their criticisms, imply that monetary policy independence is a complex issue with no clear conclusions as yet. The findings are also country-specific, indicating that no one size fits all. Monetary policy independence can, therefore, be affected by

several other country-specific factors beyond those in the established models. The incorporation of additional country-specific variables may provide more comprehensive and reliable results. Therefore, our study fills a gap in identifying the monetary policy independence of small open developing economies based on a single country-specific approach using time series econometrics.

III. RESEARCH METHODOLOGY

3.1 Theoretical Framework

The theoretical basis of this research comes from the IS-LM model⁹, purchasing power parity (PPP)¹⁰ and the international Fisher Effect¹¹. The general equilibrium of the macroeconomy is shown in the IS-LM model. The new Keynesian economics also considers market imperfections and assumes that prices are sticky¹². Combining this phenomenon in a monetary policy setting, Taylor (1993, p. 202)¹³ proposed a monetary policy rule (Taylor rule) for central banks as follows :

$$i = \pi^* + r^* + \beta (\pi^e - \pi) + \chi (Y - \bar{Y}) \quad (1)$$

In this equation, i is the nominal interest rate set by the central bank, i.e., short term interest rate; r^* is some real interest rate target, π is the current rate of inflation as measured by the GDP deflator, π^e is the inflation rate target as measured by the GDP deflator, $(\pi - \pi^e)$ is the inflation gap between actual inflation and targeted inflation, and

⁹ The IS-LM model is a Keynesian macroeconomic model developed by Hicks (1937) that shows how investment-saving (goods) market equilibrium combined with the money market equilibrium can achieve overall macroeconomic equilibrium in a closed economy.

¹⁰ The basic PPP theory states that in a free trade world, once two currencies have been exchanged a basket of goods should have the same value.

¹¹ The Fisher effect, named after the economist Irving Fisher, argues that the real interest rate equals the nominal interest rate minus the expected inflation rate. The international Fisher Effect (IFE) argues that the exchange rate between two currencies should be equal to the change in the interest rate of the respective countries. The Fisher Effect and the IFE are related models but are not interchangeable. The Fisher Effect claims that the combination of the anticipated rate of inflation and the real rate of return are represented in the nominal interest rates. The IFE expands on the Fisher Effect, suggesting that because nominal interest rates reflect anticipated inflation rates and currency exchange rate changes are driven by inflation rates, then currency changes are proportionate to the difference between the two nations' nominal interest rates.

¹² For the details about new Keynesian economics, see Gordon (1990).

¹³ According to Taylor's original version of the rule, the nominal interest rate should respond to divergences of the actual inflation rates from targeted inflation rates and of actual Gross Domestic Product (GDP) from potential GDP.

$Y - \bar{Y}$ is the output gap between actual GDP (Y) and potential or targeted GDP (\bar{Y}). Equation (1) is a 'monetary policy reaction function' that shows how the central bank should fix the short-term monetary policy rate.

This rule can be extended by including the exchange rate in the monetary policy rule. The exchange rate depends upon the demand for and supply of the domestic currency, and the demand for such currency is affected by the interest rate, real income, and inflation. We know that the domestic money supply is determined by domestic price level, output and interest rate. A similar argument applies to the foreign money supply. This approach of the monetary theory of exchange rate determination is further explained by Frenkel (1976) and empirically examined by Bilson (1978). We apply the concept of Bulir (2014) to revise the equation (1) as follows:

$$i_t = f_1 i_{t-1} + (1 - f_1)(i_t^n + f_2(\pi_t^e - \pi^T) + f_3 \hat{y}_t) + \varepsilon_t^i \quad (2)$$

Where i_t is the short-term interest rate, f_1 is a smoothing component, i_t^n is the neutral nominal interest rate which is obtained as trend real interest rate plus model-consistent inflation expectations: $i_t^n = \bar{r} + \pi_t^e$. The $\pi_t^e - \pi^T$ is the deviation of expected inflation from the target, \hat{y}_t is the output gap and ε_t^i is a monetary policy shock.

Equation (2) works only in a full market economy. However, Nepal has a fixed exchange rate, and capital mobility is officially restricted. We must modify it to reflect the partial control of the interest rate by the NRB. With the uncovered interest parity (UIP) and monetary policy reaction function, we modify equations (1) and (2) to develop the final analytical model. For this purpose, we add backward-looking and forward-looking behaviour of equation (1) in equation (2), considering that the interest rate is determined partially by domestic economic conditions and partially by the UIP condition. With this notion, equation (2) is re-written as:

$$i_t = (1 - c_1) \left(\frac{1}{1 - b_1} \Delta e_{t+1} - \frac{b_1}{1 - b_1} \Delta e_t + i_t^* + prem_t \right) + c_1 (f_1 i_{t-1} + (1 - f_1)(i_t^n + f_2(E_t \pi_{t+1} - \pi^T) + f_3 \hat{y}_t)) + \varepsilon_t^i \quad (3)$$

In this equation, one additional smoothing parameter c_1 is added to represent the central bank's degree of control over the money market. If $c_1 = 1$, the central bank has a full

control for greater monetary policy independence. We now represent both c_1 and b_1 by a single parameter c_1 and re-write equation (3), following the approach of Bulir (2014):

$$i_t = (1 - c_1)(\Delta e_{t+1} + i_t^* + prem_t) + c_1(f_1 i_{t-1} + (1 - f_1)(i_t^n + f_2(\pi_{t+1}^e - \bar{\pi}) + f_3 \hat{y}_t)) + \varepsilon_t^i \quad (4)$$

In equation (9), $\Delta e_{t+1} = 0$ implies that the foreign interest rate determines the domestic interest rate and $i_t = i_t^* + prem_t$. In the fixed exchange rate version, $\Delta \bar{e} = 0$; so that the inflation target is consistent with the trend in the real exchange rate. For the NRB, the long-run average value of inflation $\bar{\pi}$ depends upon foreign inflation. Thus, $\bar{\pi} = \bar{\pi}^* - \Delta \bar{q}$ ¹⁴. that provides the features of the current Nepalese monetary policy. The policy choice for the NRB is either the exchange rate (foreign exchange market) or interest rate (money market).

To test for monetary policy independence, we see what value c_1 should take to get a simulated interest rate close to the observed. We thus see the response of the short-term interest rate when we change the value of c_1 . *If the model-calibrated interest rate is close to the observed when $c_1 \rightarrow 1$, the NRB has a higher degree of control over the short-term interest rate, indicating greater monetary policy independence.* If the value of $1 > c_1 > 0$ or around the middle, then short term interest rates will be influenced "partly" by the UIP condition, indicating that the interest rate is determined by forward-looking and backward-looking behaviour. However, *if the model-calibrated interest rate is close to the observed when $c_1 \rightarrow 0$, the NRB has no control over the short-term interest rate, indicating a loss of monetary policy independence.*

The monetary policy reaction function of equation (4) is calibrated using a State Space Model in Matlab software. As explained in section 3.1, the State Space model takes two forms of model calibration: measurement equation and transition equation. We define the transition variables, transition shocks, parameters, and then equations for each transition variable for the transition equation. The initial data of the *cpi*, *cpi_star*, *ni*, *ni_star*, *nx*, *rx* and *gdp* has been used to generate numerous other variables, the log of

¹⁴ $\Delta \bar{q}$ is the deviation in the RER equilibrium, such that $q_t = e_t + p_t^* - p_t$. Likewise, \hat{q}_t is the gap in the RER and calculated as $\hat{q}_t = q_t - \bar{q}_t$. It shows that given the fixed exchange rate policy, the NRB cannot have an independent target for inflation.

index variables, growth, equilibrium values, gaps, trends, and shocks. The parameter values are imposed on the equations using economic logic, macroeconomic policy direction, and observation of past trends. The steady-state values of inflation target, trend real interest rate, the real exchange rate, and GDP growth are the long-run parameters. The variable definitions, the data; measurement/transition variables and equations; and the parameter values are shown in Annex – A.

3.2 Data and Methods

The study uses published annual time series data from 1989 to 2019 for both Nepal and India. Nepal started implementing modern monetary policy by introducing open market operations in 1989 (Nepal & Paija 2020). Most financial sector reforms gained momentum from the mid-1980s and economic liberalisation from the early 1990s in Nepal. Thus, the sample covers the early liberalisation periods to date. The interest rate data comes from Nepal's central bank - Nepal Rastra Bank (NRB) and India's central bank: Reserve Bank of India (RBI). The study uses consumer price index (CPI) data from the International Financial Statistics database of the International Monetary Fund (IMF) and the gross domestic product (GDP) of the World Development Indicator database of the World Bank, due to the same base year and data compatibility. We use the nominal effective exchange rate (NEER) and real effective exchange rate (REER) data from Darvas (2012). Darvas (2012)'s data is a comprehensive NEER and REER series covering 178 World economies and considers all the world economies Nepal has made the trade.

In this study, NEER (nx) represents Nepal's nominal exchange rate variable. The nominal exchange rate of NPR and INR is fixed, and the nominal exchange rate of NPR and USD is the cross rate of INR and USD. Thus, an alternative representation of the nominal exchange rate is NEER¹⁵ for the complete analysis¹⁶. Likewise, REER represents Nepal's real exchange rate, rx , in the model. Even if we use the effective exchange rates in the study, this variable's choice is valid because a higher trade concentration of Nepal with India will result in the largest weighting in the currency basket's comparative exchange rate index. We refer to the 'exchange rate' for the NEER and 'real exchange rate' for the

¹⁵ NEER is the trade-weighted geometric average of the bilateral nominal exchange rates of the home currency in terms of foreign currencies. REER is the CPI based price-adjusted effective exchange rate.

¹⁶ Tee (2013) also uses NEER as a nominal exchange for his study of Singapore and highlights that NEER can equally represent as nominal exchange rate if the exchange rate is fixed.

REER in the study to simplify the analysis. We include the national consumer price index (*cpi*) of Nepal and India (*cpi_star*) for the price data.

The interest rate variable is the 91-day weighted average government treasury bill (T-bill) rate for both economies. Nepal's interest rate, '*ni*', is the nominal interest rate of Nepal and India's, *ni_star* is the foreign interest rate. The T-bill rate represents the short-term interest rate because it is an auction-based (market-determined), more frequent rate that can genuinely reflect money market conditions. Furthermore, Nepal's monetary policy strategy is still the Taylor-rule-based monetary targeting (Nepal Rastra Bank 2018), lacking the interest (policy) rate as an operating target. The market-based T-bill rate can be a proxy variable for expected inflation (Jones et al. 1995). In addition, T-bill auction does have the features of a cut-off rate for low-high bidding rate adjustments. Thus, T-bill can better represent a short-term policy rate variable of the central bank. Economic output (*y*) is the real gross domestic product (GDP) growth rate. We apply annual data frequencies for the study as output is available only in annual frequency before 2005.

We apply the State Space (SS) modelling framework with the Kalman filter for data analysis. The OLS estimation method becomes spurious when the UIP condition does not hold because errors in the forecast cannot be from an exchange rate shock. The shock is not orthogonal to domestic and foreign interest rates¹⁷. Furthermore, OLS based models do not provide valid coefficients in the presence of unobserved data, such as the risk premium and gap variables. Therefore, the SS model provides an adaptive strategy to calibrate the MLE parameters, whereas the Kalman filter is a powerful tool for policy simulation and observing the relationship (Harvey 1987; Kalman 1960). Besides, this model addresses unstable time-varying coefficients (Basdevant 2003; Nepal & Foster 2016). Moreover, the unit root test results show the mixed order of integration in the study variables with a zero to two order of integration, with the possibility of cointegration (Table 1). When the data can possibly be cointegrated along with if the data has noise and outliers, the Kalman filter is preferred over the OLS-based estimation

¹⁷ The importance of shocks in forecasting the exchange rate is explained by Forbes et al. (2018) and Smets (1997).

techniques as the technique can handle series integrated of any orders (Bomhoff 1992; Nepal & Foster 2016).

Based on Harvey (1990) and Durbin and Koopman (2012), a measurement equation is specified as follows:

$$Y_t = K_t\beta_t + HA_t + \varepsilon_t \quad (5)$$

Where Y_t is a measured variable, K_t is an observed parameter with an $n \times p$ matrix, β_t is an unobserved state variable, with $p \times 1$ matrix, A_t is an exogenous regressor and ε_t is a white noise error term with $\varepsilon_t \approx N(0, \sigma_\varepsilon)$. The transition or state equation identifies the dynamics of the unobserved variables as:

$$\beta_t = \mu_t + GB_{t-1} + \vartheta_t \quad (6)$$

Where μ_t is a steady-state growth rate or drift, GB_{t-1} is an autoregressive process for the state variable, and ϑ_t is an error term with $\vartheta_t \approx N(0, \sigma_\vartheta)$. Annex-A provides the data and the parameter values used in the model.

Table 1: Augmented Dicky Fuller (ADF) Unit Root Test

Variable	t-Statistic		
	Level	First Difference	Second Difference
cpi	- 0.077	- 3.032	- 5.861*
cpi_star	- 1.00	- 2.385	- 4.949*
ni	- 3.778*	-	-
ni_star	- 2.329	- 3.809*	-
nx	- 5.125*	-	-
rx	- 3.185	- 4.678*	-
GDP	2.036	-4.372*	-
GDP_star	2.103	- 3.464	- 6.039*

Note: Values shown are the ADF test statistics using the Akaike Information Criterion (AIC). The test equation includes both Trend and Intercept. All the data are without seasonal adjustment.

*: Null hypothesis 'the variable has a unit root' is rejected at the 5 per cent level, with a critical value - 3.574. The ADF test for a unit root shows that *ni* and *nx* are I(0); *cpi*, *ni_star*, *rx* and *GDP* are I(1); and *cpi*, *cpi_star*, and *GDP_star* are I(2).

Finally, a Kalman Filter is a recursive approach based on the MLE developed by Kalman (1960). We have a state vector β_t . Using the available information, the conditional distribution of β_t at time s , and the matrix of mean and variance is:

$$\beta_{t|s} \equiv E_s(\beta_t) \quad (7)$$

$$P_{t|s} \equiv E_s[(\beta_t - \beta_{t|s})(\beta_t - \beta_{t|s})'] \quad (8)$$

The filter's application occurs in the recursive algorithm form, wherein the conditional probability density of state variables gets updated based on observed variables. Using the mean square error estimator of the one-step-ahead conditional mean and variance, we calibrate a one step ahead estimate of Y_t and ε_t^{18} .

IV. FINDINGS AND DISCUSSIONS

4.1 Monetary Policy Independence: Traditional Thought

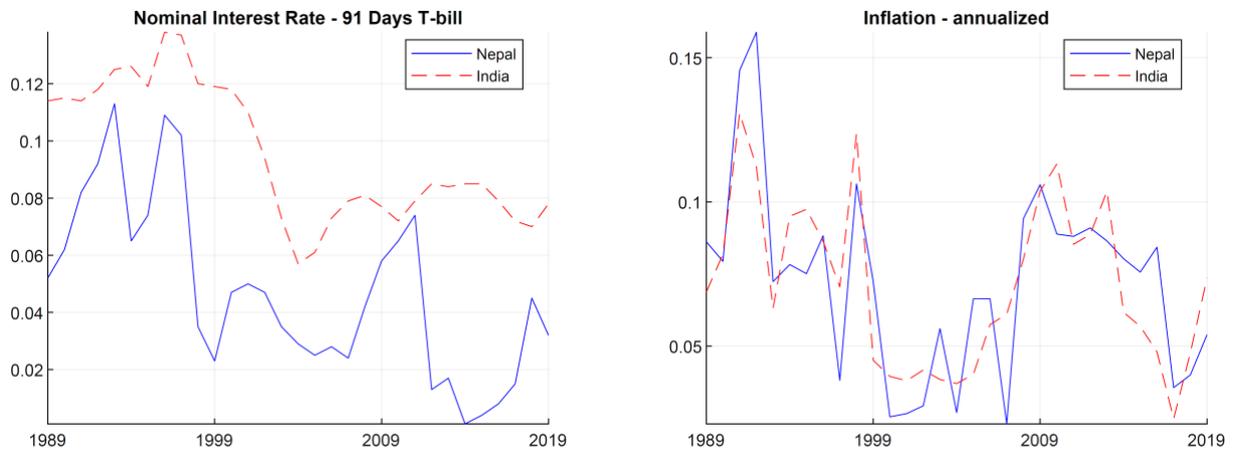
Nepal has opted for a closed-capital account policy and fixed its exchange rate, in line with the impossible trinity approach. With this condition, Nepal exists inside number three within the three sides of the triangle (see Figure 1 in Section 2), giving up the free capital mobility triangle. This means that Nepal should have maintained monetary policy independence as per the Mundell-Fleming model.

The interest rate and inflation differential between domestic and foreign economies also provide the relationship between monetary policy independence and the policy goal. On the left side of Figure 2, the short-term interest rate shows a broader gap between Nepal and India. Even if the trend was similar until the early 2000s, the rate between the two countries substantially diverged after that. However, on the right side of Figure 2, the inflation data shows a relative movement between Nepal and India. The graphical plots indicate the achievement of the price stability goal of monetary policy, ignoring the interest rate. Figure 3 further validates this data when we plot the interest rate differential and the real interest rate. The left side of Figure 3 shows a positive real

¹⁸ The model is calibrated using IRIS Macroeconomic Toolbox at MATLAB version R2020b; developed by Global Projection Model Network.

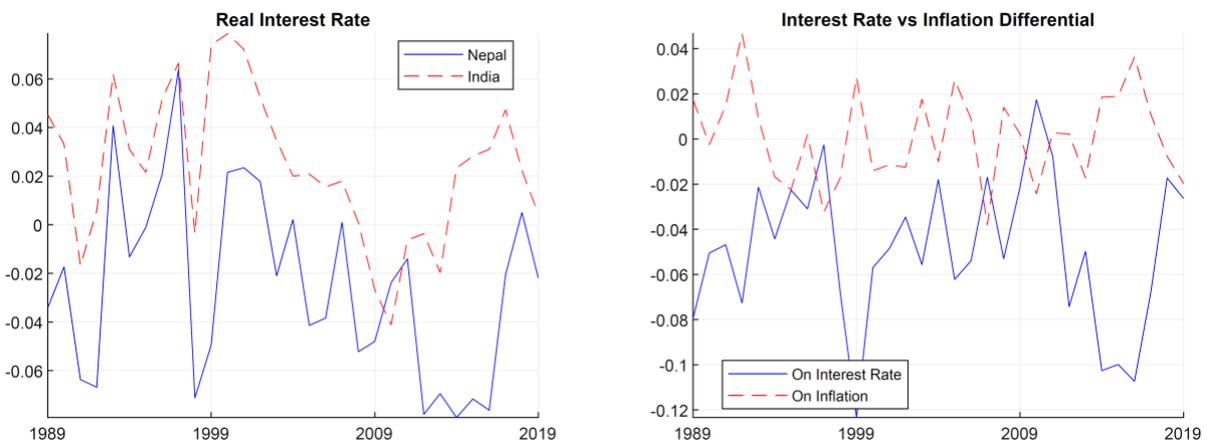
interest rate gap in India most of the time, while it is negative in Nepal. The right side of the graph shows a smaller gap in the inflation differential compared to a larger and broader gap in the real interest rate (Figure 3).

Figure 2: Interest rate and inflation: Nepal and India



Source: Based on the actual data, MATLAB Graph output.

Figure 3 : Interest rate and inflation differential: Nepal and India



Source: Based on the actual data, MATLAB Graph output.

4.2 Model Calibration

We start the simulation of the monetary policy reaction function of equation (4) with a value of 0.9 for c_1 . Then, the value was lowered by ten percentage points for each simulation. We observe the simulation results on the inflation, GDP growth and the short-term interest rate, keeping foreign inflation and exchange rates exogenous. The model simulates the domestic inflation, interest rate and GDP growth rates. The risk premium is endogenously determined within the model framework. The calibration process for

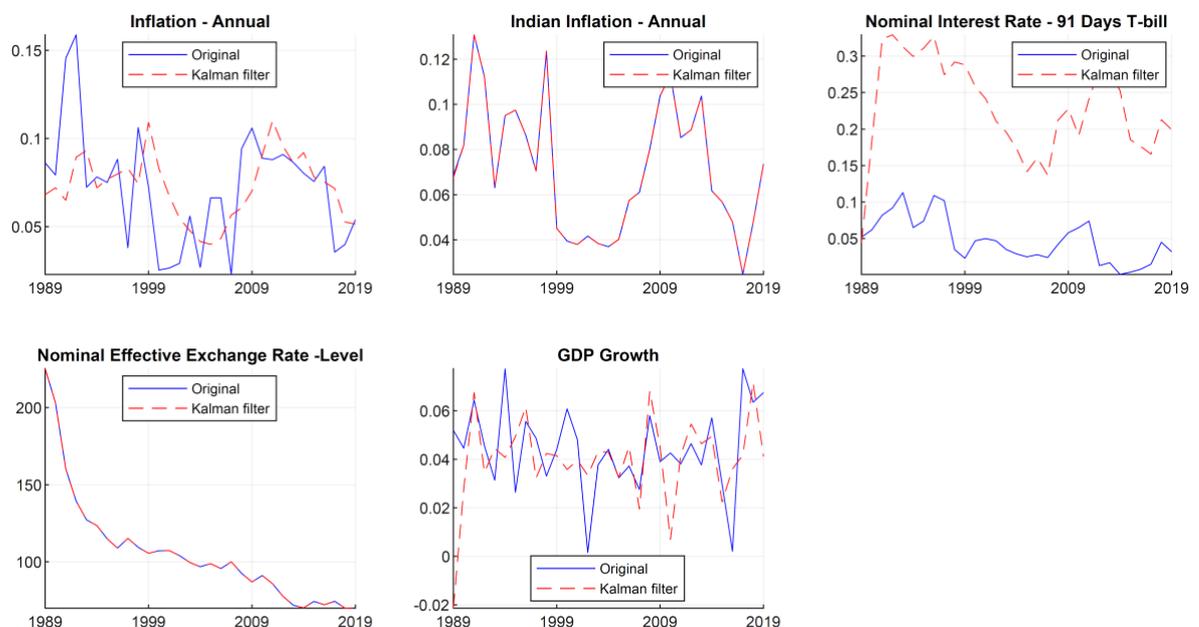
inflation and GDP remains the same while we change the parameter for the short-term interest rate. The output when c_1 is 0.9, 0.5 and 0.1 are discussed below.

4.2.1 When c_1 is 0.9:

When $c_1 \rightarrow 1$, we believe that domestic monetary policy is fully independent. In the monetary policy reaction function of equation (4), the forward-looking UIP component will have a negligible impact on the short-term interest rate, while the domestic economic condition will have a substantial impact. Thus, we restrict the value of c_1 to be 0.9 and then simulate the model. The calibrated output from the model is shown in Figure 4, Figure 5, and Figure 6.

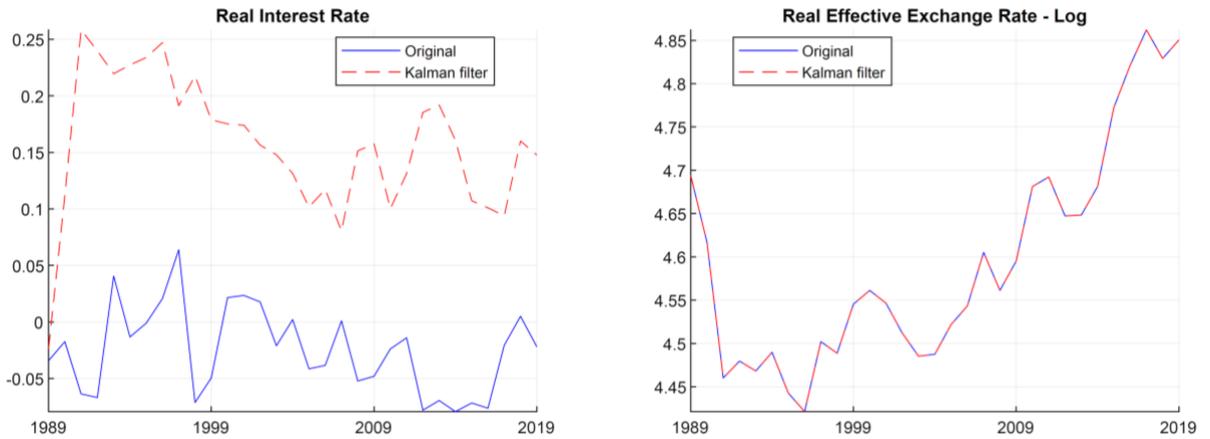
The MATLAB output shows a substantial variation between the calibrated and observed interest rate data, while inflation and economic growth closely follow each other (Figure 4). The considerable variation indicates that when $c_1 \rightarrow 1$, the model does not fit, being unable to predict the short-term interest rate – an operating target variable of monetary policy. The real interest rate data in Figure 5 also shows the similar result. The risk premium estimates from Figure 6 also report different results compared to the results obtained by Bhatta et al. (2021), showing the average risk premium of about zero. With this evidence, we cannot reject the null hypothesis that monetary policy is not independent.

Figure 4: Simulation Result: c_1 being 0.9 | Nominal Variables



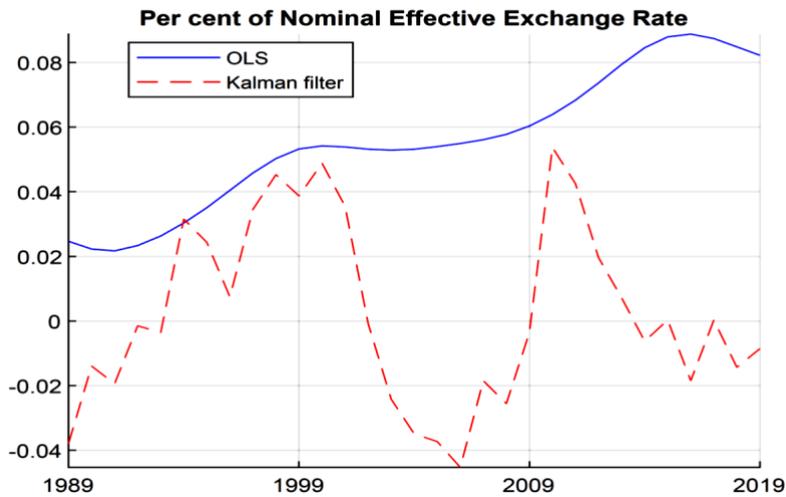
Source: MATLAB output of the model.

Figure 5 : Simulation Result: c_1 being 0.9 | Real Variables/Trends



Source: MATLAB output of the model.

Figure 6: Simulation Result: c_1 being 0.9 | Risk Premium.



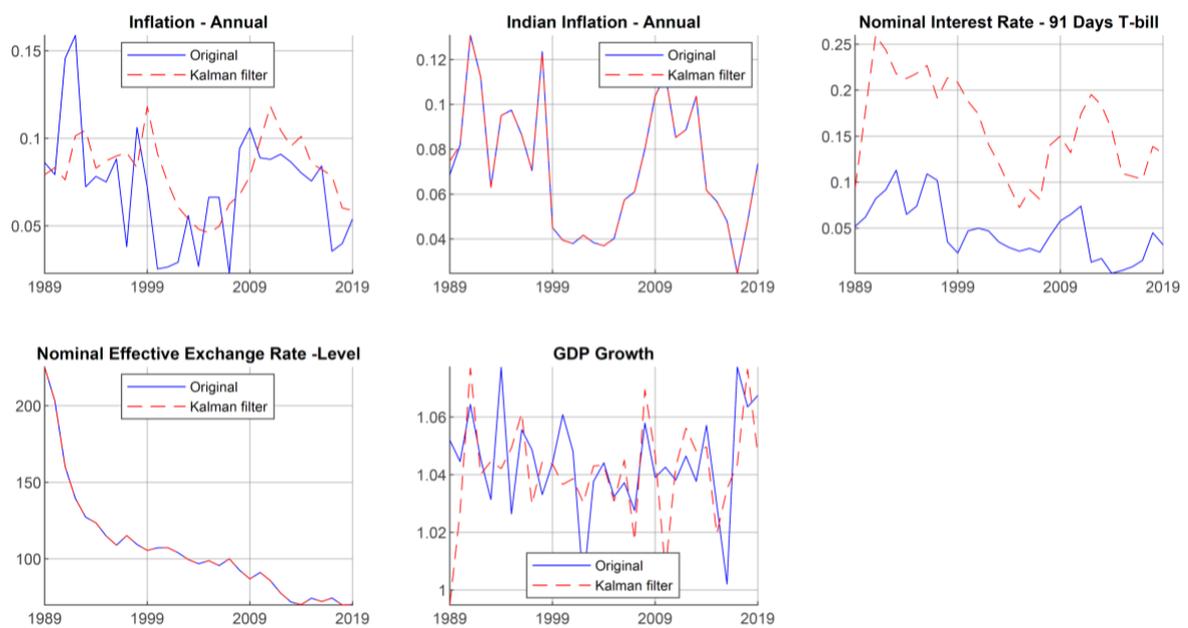
Source: MATLAB output of the model.

4.2.2 When c_1 is 0.5:

From the value of $c_1 = 0.9$, we calibrated the model by reducing ten percentage points on each simulation. When $0.9 > c_1 > 0.1$, we define that domestic monetary policy is determined partly by forward-looking (UIP) conditions and partly by backward-looking (domestic conditions): a mixed monetary policy strategy.

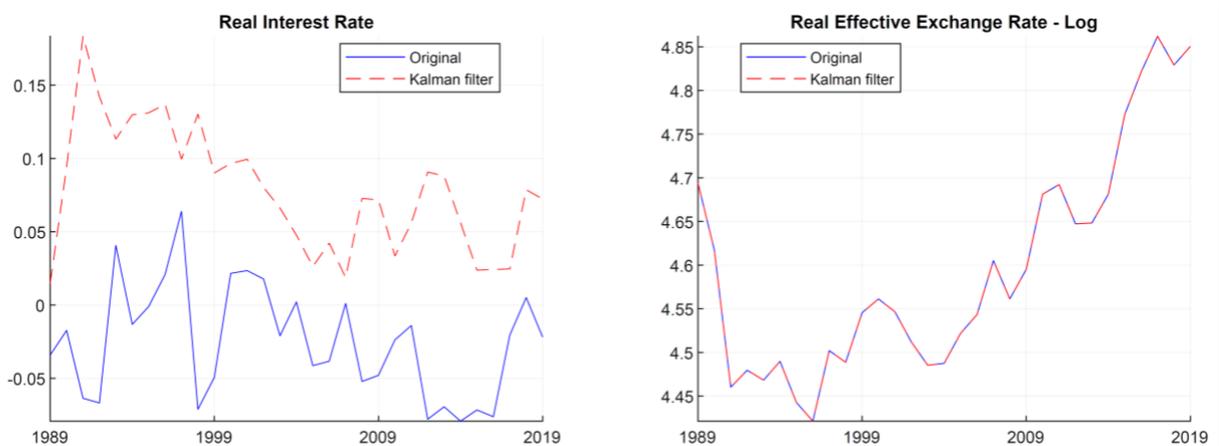
When we lower the value of the c_1 parameter, we find that the calibrated model data and observed data for the interest rate fits better on each percentage point reduction, keeping the inflation, exchange rate and economic growth simulations as is. In Figure 7, the calibrated nominal interest rate and the actual interest rate are still being closer compared to Figure 4. The real interest rate gap is also narrowed down in Figure 8 compared to Figure 5, along with the risk premium result of Figure 9. Even if the model is closer with observed data in $c_1=0.5$, the simulated interest rate still does not follow the observed data, motivating us to continue the model calibration to find the best fitting relation.

Figure 7: Simulation Result: c_1 being 0.5 | Nominal Variables



Source: MATLAB output of the model.

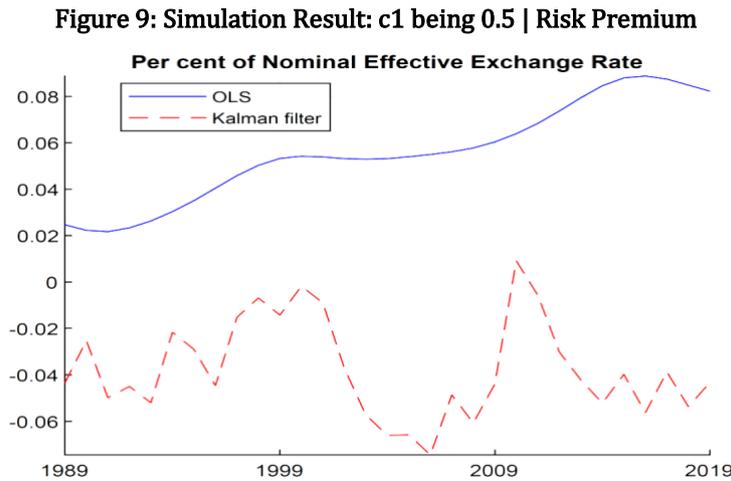
Figure 8 : Simulation Result: c_1 being 0.5 | Real Variables/Trends



Source: MATLAB output of the model.

4.2.3 When c_1 is 0.1:

When $c_1 \rightarrow 0$, it indicates that domestic monetary policy is entirely dependent on the foreign monetary policy, with a negligible effect on domestic economic conditions. We continued to reduce the value of c_1 from 0.5 to the lowest possible level and simulated the model.



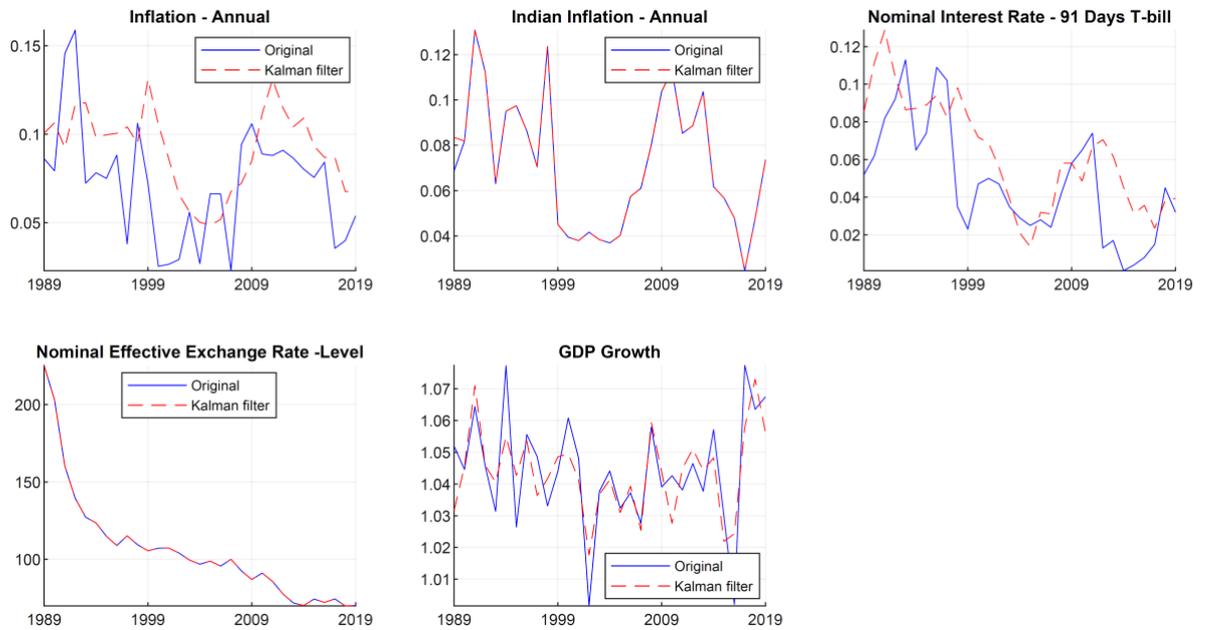
Source: MATLAB output of the model.

When the value of c_1 is 0.1, we get the observed and simulated interest rate in a similar trend nearing each other. The calibrated value of inflation and economic growth remained the same. In Figure 10, the calibrated data of the 91 days T-bill rate closely follows the observed interest rate. Figure 11 shows that the real interest rate calibration by the Kalman filter is a perfect fit. The risk premium calibration of Figure 12 also reports that the Kalman filter's risk premium simulation is closer to the risk premium simulated by Bhatta et al. (2021). Thus, it provides strong evidence not to reject the null hypothesis that Nepal's monetary policy is not independent. In a recent study, Cevik and Zhu (2020) found that monetary independence negatively affects inflation; thus, greater monetary autonomy is needed to manage inflation dynamics better. In Nepal, price stability is imported by fixing the exchange rate at the cost of foregone interest rate settings.

These findings show that the impossible trinity does not hold in Nepal, with Nepal's short-term interest rate being determined by India's. When monetary policy is not

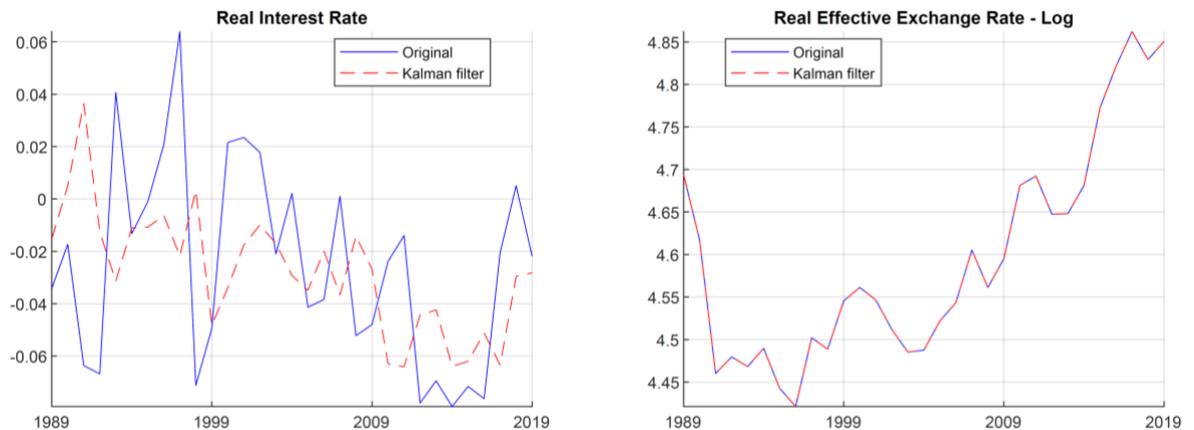
independent, even if Nepal fixes the exchange rate and closes the capital account, it raises questions on the efficacy and rationale of the policy choices that Nepal has been implementing.

Figure 10: Simulation Result: c_1 being 0.1 | Nominal Variables.



Source: MATLAB output of the model.

Figure 11: Simulation Result: c_1 being 0.1 | Real Variables/Trends

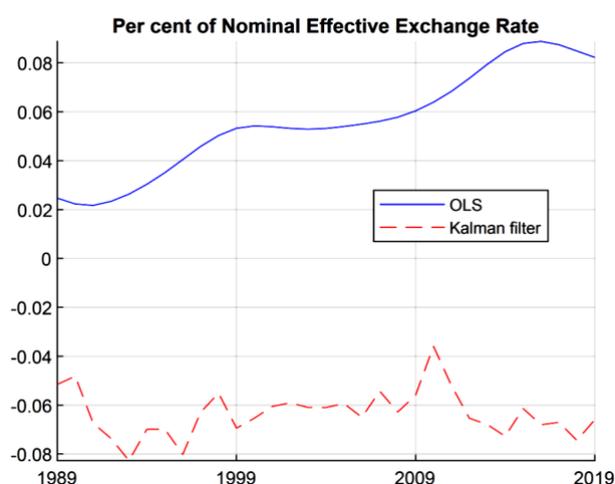


Source: MATLAB output of the model.

4.3 Discussions

Based on the empirical evidence discussed in section 4.2, we confirm that Nepal is not confined to the policy trilemma of the Mundell-Fleming model. The policy mix that has been opted for over a long time in the country raises serious questions on its policy effectiveness. The belief that fixing the exchange rate is the only available option for Nepal to have a stable and transparent nominal anchor for monetary policy (International Monetary Fund 2010, 2012, 2017a; Yelten 2004) is still strong in the central bank and amongst the government policymakers. Furthermore, as the fixed exchange rate is rather explicit and relatively easier to enforce, the issue can also be raised on the capital account policy. When the current account is fully convertible, illicit capital flows can take place through this window (Ajayi 2014; Nitsch 2012). Nepal does have sizeable informal transactions in remittances, trade, and investment. For instance, Taneja *et al.* (2004, p. 45) estimated that informal trade from Nepal to India is about 38 per cent of total formal trade, while such informal trade is more than the formal trade from India to Nepal. Likewise, the illicit financial flow from Nepal is about 32 per cent of total trade (Global Financial Integrity 2019, p. 31). The illicit financial and trade flows make a substantial share of informal financial transactions. In this context, Nepal may not be closing the capital account as presumed by the impossible trinity theory.

Figure 12: Simulation Result: c_1 being 0.1 | Risk Premium



Source: MATLAB output of the model.

The impossible trinity might have further deteriorated when Nepal receives a larger volume of remittances. Studies show that monetary policy and remittance relationships become complex in the presence of informal remittances. Informal remittance flows are

substantial for Nepal¹⁹, exacerbated by the unmonitored and open border with India. Such informal remittances affect the sterilisation of the foreign currency market and money supply projections. Partial sterilisation of remittances is even severe for monetary policy effectiveness (Vacaflores 2012) which further deteriorates in the presence of informal remittances. However, unless we incorporate remittances in the study variables, it would not be very objective to come to any conclusions about their role.

V. CONCLUSION

Continuous financial globalisation has pressured the need for dynamic reforms in the conduct of the macroeconomic policy mix. Such dynamism in a socio-economic context might also require a change in traditional economic theories and assumptions. With this in mind, we have studied whether the traditional policy trilemma of the Mundell-Fleming model should be changed in a small open landlocked developing (SOLD) economy. We choose Nepal: a heavily trade-dependent landlocked South Asian country that historically fixes its exchange rate with India. We covered the period when monetary policy liberalisation was initiated in both economies. We applied the Kalman filter in a State Space model to test this policy trilemma condition over the period 1989-2019. We modified the traditional Taylor-rule-based monetary policy reaction function to represent Nepal's economic characteristics and to mix backward-looking and forward-looking strategies incorporating a fixed exchange rate. We simulate the short-term interest rate, inflation, and economic growth to compare the simulated and the observed data.

The model calibration results provided strong evidence on the policy trilemma's failure, showing that when the parameter value of the domestic condition is close to zero, we find a better match of the simulated short-term interest rate with the observed one. The model is more predictable to the real interest rate as well, while we keep inflation and economic growth stagnant in the initial condition of the model. The calibration of the risk premium is consistent with an earlier study by Bhatta et al. (2021), and the predictability of the

¹⁹ It has been estimated that informal remittance flows account for between 35 to 75 per cent of formal flows in developing countries (Freund & Spatafora 2005).

interest rate, inflation, and economic growth and the response of the model to shocks confirm the validity and reliability of the calibrated model.

The loss of monetary policy independence has raised a couple of policy issues for the Nepalese central bank and government. The choice of a closed capital account and a fixed exchange rate with India cannot maintain the independence of domestic monetary policy. If these two are not working, the rationale of fixing the exchange rate and efficacy on the closure of the capital account might bear high costs to the economy. A policy revisit is recommended on both the fixed exchange rate policy and capital flow management policy.

This research can be extended to investigate the cause of impossible trinity failure and optimal exchange rate policy. The foremost issue being the identification of the influence of remittances on monetary policy independence in a small open remittance dependent developing economy.

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Appendix A

1. Data and Their Sources

Variable	Definition	Data Source
REER	Real effective exchange rate (CPI-based) considering the 38 trading partners, both annual and monthly	Darvas, Zsolt (2012a) 'Real effective exchange rates for 178 countries: A new database', <i>Working Paper</i> 2012/06, Bruegel, 15 March 2012. Updated series
NEER	Nominal effective exchange rate, considering the 38 trading partners, both annual and monthly	http://www.bruegel.org/publications/publication-detail/publication/716-real-effective-exchange-rates-for-178-countries-a-new-database/
CPI: Nepal and India	Prices, Consumer Price Index, All items, Index; both annual and monthly	International Financial Statistics, International Monetary Fund.
Interest Rate: Nepal	Weighted average 91 day's T-bill rate	Nepal Rastra Bank, Quarterly and Monthly Reports
Interest Rate: India	Weighted average monthly T-bill rate, 91 day	Reserve Bank of India HBS_Table_No._215__Auctions_of_91-Day_Government_of_India_Treasury_Bills The author averages the daily cut-off rate of every transaction in each Month to calculate the average monthly T-bill rate.

2. Parameters

Parameter	Value	Variable
a1	0.45	Weight between Nepal's and India's inflation. Nepal's inflation is assumed to be explained about 55% by India, based on the empirical evidence.
c1	0.6	captures the exchange rate persistency; a higher value means a backward-looking strategy with higher persistency.
h0	0.5	persistent shock to risk premium, the value of h0 is the parameter for the past values of shock premium
h1	0.5	persistence in the convergence of trend variables to their steady-state levels for real interest rate and real exchange rate.
h2	0.5	persistence in the nominal interest rate, foreign interest rates and foreign inflation
t1	0.5	Speed of inflation target adjustment to the medium-term target (higher values mean slower adjustment)
target_ss	7.0	Domestic inflation target
ss_ri_eq	0.2	Trend level of domestic real interest rate
ss_dot_rx_eq	2.0	Trend changes in the real effective exchange rate
ss_dot_cpi_star	5.0	Equilibrium/trend inflation of India
ss_ri_star_eq	2.0	Equilibrium/trend foreign real interest rate