IMPOSSIBLE TRINITY IN A SMALL OPEN ECONOMY: A STATE–SPACE MODEL SIMULATION

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ABSTRACT

Should monetary policy independence be maintained when the exchange rate is fixed under closed capital account conditions in a small open economy? In this study, we simulate the impossible trinity condition during 1989 to 2019 on the Nepalese economy that restricts capital flows and fixes the exchange rate with India. We modify the traditional Taylor rule based on the monetary policy reaction function to characterize Nepal's economic conditions more closely. The state–space model simulation shows that the policy trilemma does not hold in Nepal, such that the model can predict interest rate when the weight for domestic conditions is assigned at a substantially lower level. Therefore, the existing policy mix may need to be revisited to maintain monetary policy independence. Nepal might consider devaluing its currency to neutralize the adverse effects of the negative risk premium and ameliorate the real exchange rate appreciation in the short run and explore alternative arrangements in the long run.

Contribution/Originality: A maximum likelihood estimation-based state–space model is applied to calibrate the customized monetary policy reaction function. As far as we are concerned, this is the first study to simulate a modified monetary policy function to observe the impossible trinity condition, particularly in a small open developing economy context. The study's findings are significant to test the policy trilemma hypothesis in other similar economies.

1. 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 a contrasting view on monetary policy independence[1] and capital controls. These studies have challenged the trilemma approach of Fleming (1962) and Mundell (1963), widely known as Mundell–Fleming's impossible trinity.[2] While the trinity proposes an

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[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 this study, it is assumed that monetary policy independence is maintained if the short-term interest rate is determined by domestic economic conditions.

[2] The trilemma model of Fleming (1962) and Mundell (1963) argues that an economy can achieve monetary policy independence while maintaining a fixed exchange rate regime, even if capital mobility is restricted. In a triangle of independent monetary policy, fixed exchange rate and capital account openness, we can only choose one corner with two policy choices, and it is impossible to have all three policy choices. The trilemma condition is further discussed in Section 3 of this study.

optimal policy mix among exchange rate, external capital flows and monetary policy independence, in recent debates, for example, Rey (2015), the focus is on the policy dilemma rather than the policy trilemma.

The validity of Mundell–Fleming's impossible trinity is still ambiguous despite extensive application and studies undertaken across various economies. For instance, prior studies by Bleaney, Lee, and Lloyd (2013); Chakraborty (2016); Goczek and Mycielska (2019); Goh and McNown (2015); Kawai and Liu (2015); Klein and Shambaugh (2010); Majumder and Nag (2021); Obstfeld, Shambaugh, and Taylor (2005); Ohanian and Stockman (1997) and You, Kim, and Ren (2014) have all supported the trilemma constraint. Nevertheless, Aizenman, Chinn, and Ito (2013); Fry, Lilien, and Wadhwa (1988); Kim and Lee (2008); Marc (1978); Rey (2015) and Takagawa (2013) have shown contrasting evidence on the validity of the policy trilemma. The turning point in the literature was underscored in a study by Rey (2015), who argued that there is a policy dilemma, not a trilemma. The implication of such a trilemma and optimal policy mix is still a hotly contested topic in the literature with mixed empirical evidence in small open economies, which merits further investigation.

Past studies in the Nepalese context have shown that the effectiveness of monetary policy is limited (Budha, 2011; Budha., 2015; Maskay & Pandit, 2010). Nepal is a small open economy in South Asia that has imposed capital account restrictions to maintain monetary policy independence given its historical exchange rate peg with India. On the other hand, studies have revealed that about half of inflation in Nepal can be explained by imported Indian inflation (Institute for Sustainable Development, 1994; Nepal Rastra Bank, 2007; Neupane, 1992; Shrestha & Bhatta, 2017). Based on findings from existing studies, Nepal seems to be importing the price stability goal of monetary policy. Success in attaining the price stability goal, therefore, supports using the exchange rate as a nominal anchor[3] for Nepal (see, for example, (Barro & Gordon, 1983; Fratianni & von Hagen, 1993; Giavazzi & Giovannini, 1989)). While a fixed exchange rate can create stability, the trade-off might be a loss in the implementation of monetary policy independence, although this has not yet been tested for Nepal. On the other hand, restricting capital flows and fixing the exchange rate still may not be an optimal policy alternative for Nepal but, instead, be motivated by a 'fear of floating', a phenomenon explained by Calvo and Reinhart (2002).[4] Fear of floating is also relevant to the trilemma condition if an economy strictly manages its floating exchange rates, giving up monetary autonomy (Klein & Shambaugh, 2010).

In this context, a key issue is whether Nepal maintains its monetary policy independence in the trilemma framework. If not, is there any evidence that Nepal has been adopting a mixed strategy with both forward-looking and backward-looking approaches? We examine this question, which is essential for the following reasons: First, there is a limited number of studies in the literature on monetary policy independence in small, open, developing economies, and second, most of the available empirical literature applies the ordinary least squares (OLS) estimation for monetary policy reaction function[5] models. An earlier study by Bhatta, et al (2021), however, has shown that OLS-based estimates produce biased risk premium data when uncovered interest parity (UIP) does not hold in Nepal. To the best of our knowledge, there are no studies to date on monetary policy independence considering the Nepalese economy, thereby presenting a gap in the literature that our research aims to address.

Previous studies have mostly focused on identifying the relationship between the domestic interest rate and the foreign interest rate in order to observe monetary policy independence. For instance, Ohanian and Stockman (1997);

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

[4] Calvo and Reinhart (2002) argue how countries choose a sub-optimal policy of managed float/soft peg to stabilize inflation through controlling exchange rate fluctuations. This could be due to fear of output loss or poor policy credibility regarding float. The authors argue that such behaviour will promote discretion rather than policy rules, not allowing the market to adjust itself through risk premium and money demand shocks.

[5] A monetary policy reaction function is a New Keynesian economics based rule (Taylor, 1993), which determines how the central bank should set its short-term policy rate.

Kim and Lee (2008); Paul (2012); You et al. (2014); Kawai and Liu (2015); Goh and McNown (2015); Chakraborty (2016); Lim and Goh (2016) and De Waal, Gupta, and Jooste (2018) studied the effect of the foreign interest rate, either the London interbank offered rate (LIBOR) or the central bank policy rate, on the domestic interest rate. Most of these studies assume a reciprocal relationship between the home and foreign interest rates. However, a reciprocal-based analysis is not possible between Nepal and India due to differences in economic size, historical exchange rate peg, policy divergence, and the overly India-dependent Nepalese economy. Thus, observing the mere effect of the Indian interest rate on Nepal's interest rate will not fulfil the objective of this study.

On the other hand, a recent strand of literature has questioned whether a policy trilemma exists in today's globalized world. Rey (2015) argued that the trilemma hypothesis does not hold in the presence of free capital mobility; the post-GFC period has transformed the trilemma into a dilemma, providing substantial criticism of the impossible trilemma theory. However, the argument put forward by Rey (2015) on the convergence of capital flows, leverage, and asset prices in the world's major financial centers is only representative of a few advanced economies and has no direct implication for economies such as Nepal's. Moreover, new evidence suggests that the trilemma does not transform into a dilemma, and the presence of globally influencing investors and banks further aggravate the impact of the trilemma at the initial phase (Ligonnière, 2018). Using the same dataset as Rey (2015), Ligonnière (2018) further showed that the trilemma is only valid during an economic boom but may morph into a dilemma during a bust. Furthermore, Rohit and Dash (2019) critiqued the approach of Rey (2015), demonstrating that the trilemma hypothesis is still valid. A recent study of the Indian economy by Majumder and Nag (2021) identified financial stability as the fourth component in addition to the trilemma, rejecting the dilemma hypothesis of Rey (2015). Majumder and Nag (2021) found that the trilemma constraint did hold in the post-reform period in India, which translated into a quadrilemma in recent years.[6] Although the existence of a quadrilemma is beyond the scope of this research, the possibility of a dilemma does not apply to Nepal due to restrictions over capital flows and the exchange rate peg.

Aizenman et al. (2013) developed a new policy trilemma index of world countries, including Nepal. The authors constructed a trilemma constraint based on the monetary independence (MI) index, an exchange rate stability (ERS) index and a capital account openness (KO) index. However, the trilemma index for Nepal cannot be used as an indicator of monetary policy independence because Aizenman et al. (2013) used the Chinn and Ito (2006) KAOPEN index of financial openness for Nepal. This index remained constant at 0.1657 from 1970 to 2019, although openness has been gradually increasing over this period. The authors also followed the reciprocity of annual correlation between domestic and foreign interest rates to construct the monetary independence index.

In the reciprocal case, comparing domestic and foreign interest rates may provide evidence of policy independence. Two economies, Nepal and India, however, are not in a reciprocal position with each other. Likewise, we argue that the traditional monetary policy reaction function does not fit Nepal's context. In this study, the standard reaction function is customized to represent Nepal's key economic characteristics; the gap variables and identities need to be generated endogenously, which is not possible with an OLS estimation-based analysis. We have made two major changes to the rule set by Taylor (1993): i) Nepal borrows a foreign inflation target in their domestic inflation target to maintain the policy trilemma (due to the pegged exchange rate aimed at price stability), and ii) the uncovered interest parity condition does not hold[7] (based on our earlier study, see Bhatta et al. (2021)). The purpose of this study is to observe how Nepal's central bank, Nepal Rastra Bank, should react to get a simulated short-term interest rate close to the observed rate to compare the actual interest rate with a counterfactual reaction function. Therefore, a maximum likelihood estimation-based state–space model is applied to calibrate the customized monetary policy

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[6] A quadrilemma is an extension to the Mundell–Fleming trilemma model with a fourth component, financial stability, along with three other trilemma components. See Aizenman (2019) for details.

[7] The uncovered interest parity model is embedded into the monetary policy reaction function, which is explained in the theoretical framework section of this paper.

reaction function. As far as we are concerned, this is the first study to simulate a modified monetary policy function to observe the impossible trinity condition, particularly in a small open developing economy context. Thus, the study's findings are significant to test the policy trilemma hypothesis in other similar economies.

The remainder of the paper is organized as follows: Section 2 discusses the relevant literature on the policy trilemma; Section 3 provides the theoretical framework used in this paper; Section 4 explains the data and empirical methodology employed; Section 5 presents and discusses the major empirical findings; and Section 6 concludes the paper.

2. LITERATURE REVIEW

The popular Mundell–Fleming model (Fleming, 1962; Mundell, 1960) has been widely implemented across economies and broadly tested in the empirical literature. The model was first criticized by Niehans (1975) and later by Dornbusch (1976a). Dornbusch (1976b) reformulated the model in a dynamic framework incorporating capital mobility, flexible exchange rates and forward-looking expectations. Dornbusch (1976a) highlighted that the UIP condition dominates in the short run, but the reattainment of purchasing power parity in the long run favors the Mundell–Fleming approach. These theoretical foundations and the empirical observations by Obstfeld et al. (2005) and Klein and Shambaugh (2010) provide a firm conclusion that an economy can only choose two of the three corners of the policy trilemma triangle (see Figure 1). The assumption is that, by fixing the exchange rate and controlling the capital flow, Nepal has maintained monetary policy independence, as per the assumptions of the Mundell–Fleming model.
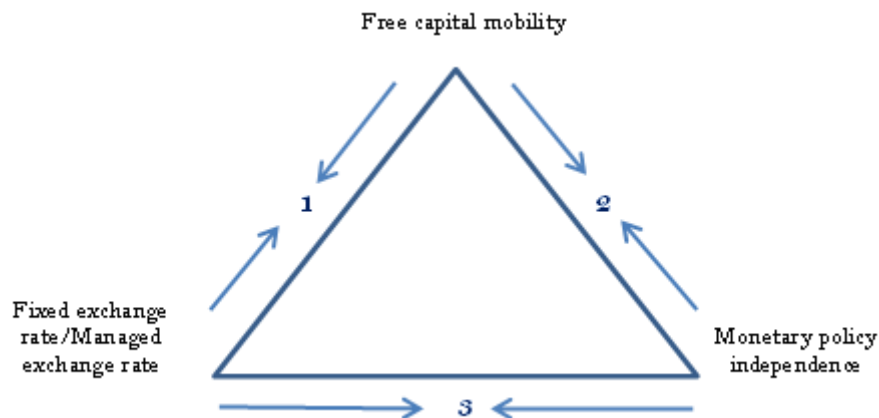

Figure 1. The impossible trinity of monetary policy.
Source: Mundell (1960) and Fleming (1962) and also explained in Obstfeld et al. (2005) and Klein and Shambaugh (2010).

The first strand in the literature favors the policy trilemma hypothesis. Ohanian and Stockman (1997) showed more robust short-term monetary policy independence when the exchange rate is fixed, supporting the trilemma condition. Clarida, Galı, and Gertler (1998) showed that while the United States, Germany, and Japan, who floated their currencies, followed their own interest rate shocks, other countries in the European Monetary System followed the German interest rate to analyze domestic or international factors influencing the policy interest rate. Klein and Shambaugh (2010) found evidence in favor of the policy trilemma across eras and the modern era, arguing that countries lose their monetary autonomy when the exchange rate is fixed in conjunction with an opened financial market. Similarly, You et al. (2014) found evidence that capital control helps to improve a country's monetary independence if the exchange rate is fixed. Goczek and Mycielska (2019) showed that Poland lost its policy independence with a floating exchange rate and highly liberalized capital flows. Goczek and Partyka (2019) also showed that non-Euro members also followed the interest rate of the European Central Bank (ECB), using the 'too small to be independent' argument. While evidence shows the existence of the impossible trinity, such empirical

findings have no direct implications for developing economies like Nepal, which significantly differ in economic characteristics and the extent of global financial integration.

Evidence from emerging market economies (EMEs) also supports the impossible trilemma hypothesis. Kawai and Liu (2015) identified that China is losing its monetary policy independence due to reduced capital controls and a rigid exchange rate regime. Goh and McNown (2015) showed that the US and Malaysian interest rates cointegrated during the fixed exchange rate regime period of 2001–2005 but not during the managed float regime period of 1991–1998, providing strong evidence in favor of the impossible trinity hypothesis. Furthermore, Chakraborty (2016) demonstrated that monetary policy independence was compromised in the post-global financial crisis period in India due to heightened capital controls. A more recent study by Majumder and Nag (2021) found that the trilemma constraint did hold in the post-reform period in India and that the trilemma has translated into a quadrilemma, which was also discussed by Aizenman (2019). While these studies confirm the existence of a policy trilemma, the approach taken in this study is different in terms of the reaction function and estimation methods. The aforementioned studies do not include an economy with similar characteristics to those of the Nepalese economy: a single-currency fixed exchange rate[8] and closed capital account. Lessons from these studies, therefore, cannot be applied to the context of the Nepalese economy and hence require a country-specific examination.

The second strand in the literature argues against the impossible trinity model. For example, Marc (1978) showed that monetary independence is impossible if residents can switch between domestic and foreign currencies. Aizenman et al. (2013) developed a new policy trilemma index and documented a middle ground that could be adopted among the three policy choices. In an era of higher capital mobility, developed countries are converging toward more exchange rate stability and compromising monetary policy independence (Aizenman et al., 2013). This finding may be promising for Nepal since small economies' monetary policy conditions are highly affected by foreign financial conditions.

Having a flexible exchange rate policy may not ensure noticeable policy independence. For example, Rey (2015) provided new evidence that perturbed the impossible trinity hypothesis: monetary policy independence is constrained by free capital mobility between countries, no matter the exchange rate policy. Rey (2015) argument that the global financial crisis of 2008 transformed the policy trilemma into a dilemma, providing substantial criticisms of the impossible trilemma theory. The exchange rate regime only has a minor role in monetary policy independence but plays a significant role in capital flow management. However, the argument by Rey (2015) is only valid when economic variables such as capital flows, leverage, and asset prices converge in line with the world's major financial centers, eliminating the role and importance of exchange rate policy. The results from a recent study by Gülşen and Özmen (2020) were also consistent with Rey (2015). They demonstrated that the US interest rate determines the domestic interest rate of EMEs in the long run, even when the exchange rate is flexible. Spillover sensitivity from the US interest rate substantially increased after the GFC. However, the dilemma hypothesis is rejected for Nepal because the capital account is closed and global financial integration is still at a nascent stage. While Rey (2015) uses the Chicago Board of Exchange (CBOE)'s stock volatility index (VIX) to run the vector autoregression (VAR) model, but the VIX index is not relevant enough for a direct implication for Nepal, since Nepalese investors are not allowed to invest in foreign assets. Likewise, the argument of Rey (2015) has been empirically criticized, for instance, by Aizenman (2019) and Rohit and Dash (2019).

Kim and Lee (2008) found that flexible exchange rates with free capital mobility provide greater monetary independence for 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 monetary policy independence was shown to be a matter of the exchange rate regime adopted rather than financial globalization. De Waal et al. (2018) showed that monetary policy for South Africa is not independent, as domestic interest rate decisions are affected by foreign shocks emanating from the US,

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[8] Most countries fix their exchange rate to the USD, while Nepal fixes its currency to the Indian rupee.

Brazil, China, and India. These studies are still not representative enough for small economies with a fixed exchange rate, such as Nepal. These studies primarily focused on observing the relationship through interest rate co-movements in an OLS-based estimation framework. Although comparing the interest rate co-movements provides a preliminary idea, a simulation based monetary policy reaction function incorporating additional domestic economic conditions would be more appropriate to answer the endogenous policy actions altogether as will be attempted in this study.

Central banks' exchange rate management practices also support the lesser possibility of monetary independence to influence the foreign exchange market. Mendoza (2004) observed a significant increase in the reserve holdings of developing countries after the Asian financial crisis, indicating a 'lean against the wind' tendency to forex market intervention in response to adverse exchange rate shocks. Svensson (1994), using Swedish data, showed that a finite band for a fixed exchange rate provides greater monetary independence, even when free capital mobility is allowed. A significant correlation between the degree of exchange rate volatility and the exchange rate bandwidth was obtained by Rose (1996) using data between 1967 and 1992 for 22 countries. This result demonstrated that an exchange rate band achieves better monetary policy independence than a fixed exchange rate after considering capital flows and interest rates. Nevertheless, using an intermediate exchange rate regime has been widely criticized in recent years because it is prone to crisis, is complex in implementation, and there is a higher possibility of speculative attacks on currency and loss of central bank credibility (Calvo & Mishkin, 2003; Eichengreen, 1998; Fischer, 2001; Obstfeld & Rogoff, 1995). This study does not pursue the exchange rate band and monetary policy independence arguments.

Other than studies supporting or not supporting the policy trilemma hypothesis, alternative empirical analyses are also available. You et al. (2014), based on a panel dataset of 88 countries, found that capital controls help enhance monetary policy independence and the exchange rate regime adopted impacts the effectiveness of capital controls for the period from 1995–2010. Similarly, Montiel and Pedroni (2019) showed that the impact of the domestic monetary policy shocks on the interest rate diminishes in a country with higher financial integration with the rest of the world, regardless of the choice of the exchange rate regime. Klein and Shambaugh (2015), using the data of most of the world's economies, showed that strict capital controls and moderate exchange rate flexibility could achieve monetary autonomy. Rohit and Dash (2019) also supported this argument. Nonetheless, the above findings cannot be generalized to the Nepalese economy for two reasons. First, the paper assumes that the UIP condition holds, and if not, the risk premium is not considered in the estimation. Second, the Chinn and Ito (2006) KAOPEN index is used as a measure of the extent and degree of capital control, which has remained constant at 0.1657 from 1970 to 2019 for both Nepal and India. Such an assumption is unrealistic because it does not reflect the actual openness of both economies arising from financial reforms and increased openness during this period. By applying the state–space model in the Kalman filter, Hosny, Kishor, and Bahmani-Oskooee (2015) found time-varying interest rate coefficients when countries switch between different exchange rate regimes and/or capital controls. The authors suggested applying a time-varying parameter model to better capture the relationship between monetary policy independence, exchange rate regimes, and capital mobility.

In a recent study on India, Kumar, Mallick, and Sinha (2021) showed that while an uncertainty shock is a demand shock in the US, it is a supply shock in EMEs that has an inflationary effect. Kumar et al. (2021) argued that inflation in India is primarily dominated by supply-side constraints. The effect of monetary policy, which focuses on the demand side to lower the interest rate, would be less effective in containing inflation. When inflation becomes a supply shock, the standard monetary policy reaction function does not work due to the differences in the shocks between domestic and foreign economies.

The above studies and their criticisms imply that monetary policy independence in small, open, developing economies is complex with ambiguous conclusions. The findings are also largely country-specific, indicating that no one size fits all. Several other country-specific factors can affect monetary policy independence beyond those considered in the already established models. The incorporation of additional country-specific variables may provide more comprehensive and reliable results. Therefore, this study fills a gap in identifying the monetary policy

independence of small, open, developing economies based on a single country-specific approach that simulates a modified monetary policy reaction function as conducted in the following section.

3. THEORETICAL FRAMEWORK

3.1. Theoretical Base and the Modified Monetary Policy Reaction Function

The IS-LM model, the purchasing power parity (PPP)[9] condition, and the international Fisher effect provide the theoretical foundation[10] of this study. Specifically, the following three specifications provide the building blocks for the study along with Taylor (1993):

$$\hat{y}_t = \alpha \hat{y}_{t-1} - \beta \, mci_t + \gamma \, \hat{y}_t^* + \varepsilon_t^y \tag{1}$$

$$mci_t = \lambda \, (\hat{r}_t + cr\_prem_t) - (1 - \lambda)\hat{q}_t \tag{2}$$

$$\pi_t = \rho \pi_{t-1} + (1 - \rho) \, E\pi_{t+1} + \tau \, rmc_t + \varepsilon_t \tag{3}$$

$$rmc_t = \delta \hat{y}_t + (1 - \delta) \, \hat{q}_t \tag{4}$$

In Equation 1, $\hat{y}_t$ is the domestic output gap at time t, mci is the real monetary conditions index, $\hat{y}_t^*$ is foreign output gap, and ε_t^y is the demand shock. In Equation 2, $\hat{r}_t$ is the long-run real exchange rate, cr_prem_t is the credit premium, and $\hat{q}_t$ is change in the real effective exchange rate (REER). Likewise, in Equation 3, π is consumer price inflation, and $E\pi_{t+1}$ is the expected inflation in the following period $t+1$. In Equation 4, rmc_t is the real marginal costs for business in period t, which is determined by the output gap ($\hat{y}_t$) for domestic production and change in the REER $\hat{q}_t$ for imported goods. We use a reduced-form model under New Keynesian economics assumptions involving market imperfections and sticky prices. Combining this phenomenon in a monetary policy setting, (Taylor, 1993)[11] proposed a monetary policy rule for central banks as follows:

$$i = \pi^* + r^* + \beta \, (\pi^e - \pi) + \chi \, (Y - \overline{Y}) \tag{5}$$

In Equation 5, i is the nominal interest rate set by the central bank, i.e., short-term interest rate; r^* is the real interest rate target; π is the current rate of inflation as measured by the GDP deflator; π is the inflation rate target; $(\pi$ - $\pi)$ is the inflation gap between actual inflation and targeted inflation; and $Y - \overline{Y}$ is the output gap between actual GDP (Y) and potential or targeted GDP ($\overline{Y}$). Equation 5 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 to include the exchange rate. The exchange rate depends upon the demand for, and supply of, domestic currency, and the demand for domestic currency is affected by the interest rate, real income, and inflation. The domestic money supply is determined by the domestic price level, output, and interest rate. A similar argument applies to the foreign money supply. This monetary theory of exchange rate determination is further explained by Frenkel (1976) and was empirically examined by Bilson (1978). By mixing the new Keynesian model and the monetary model for the central banks, as proposed by Berg, Karam, and Laxton (2006a); Berg, Karam, and Laxton (2006b) and discussed further by Bulir (2014), the standard Taylor rule is thus revised as follows:

$$i_t = f_1 i_{t-1} + (1 - f_1)(i_t^n + f_2(\pi_t^e - \pi^T) + f_3 \hat{y}_t) + \varepsilon_t^i \tag{6}$$

Where i is the short-term interest rate, f_i is a smoothing component, i_t^n is the neutral nominal interest rate, which is obtained as a trend in real interest rate plus model-consistent inflation expectations, i.e., $i_t^n = \bar{r} + \pi_t^e$. The $\pi_t^e - \pi^T$ is a deviation of the expected inflation from the target, $\hat{y}_t$ is the output gap, and ε_t^i is a monetary policy shock. Equation 6 works only in a full market economy. However, Nepal has a fixed exchange rate and capital mobility is officially restricted. Therefore, we must modify Equation 6 to reflect the partial control of the interest rate by the NRB and restricted capital mobility.

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[9] 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.

[10] Equations 1 and 2 represent an open economy version of the IS-LM model, and Equations 3 and 4 represent an aggregate supply curve in the a form of Phillips curve.

[11] 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 the actual GDP from potential GDP.

206

The standard UIP condition states that changes in a currency exchange rate are determined by differences in domestic and foreign interest rates. In an estimating model, the UIP condition can be expressed as (Engel, 1996; Goodhart, McMahon, & Ngama, 1992):

$$e_{t+1} - e_t = \alpha + \beta(i_t - i_t^*) + \varphi_{t+1} \tag{7}$$

In Equation 7, e_t is the natural log of the nominal exchange rate at period t, i_t is the domestic interest rate in percent at period t, i_t^* is the foreign interest rate in percent at period t, e_{t+1} is the exchange rate at period $t+1$, and φ_{t+1} is an exogenous interest rate shock in period $t+1$. The exchange rate expectation is therefore $E_t(e_{t+1})$.

Due to the impossible trinity, central banks attempting to control the exchange rate volatility through either foreign exchange interventions or fixed exchange rates cannot control both interest and exchange rates. The evolution of the interest rate should depend upon the forward-looking behavior of foreign exchange market agents. If the exchange rate is fixed, agents might behave with a backward-looking strategy. Therefore, the standard UIP model is revised to include both strategies. In the growth version of Equation 7, the standard version of the UIP is written as:

$$e_{t+1} - e_t = b_1 \Delta e_t + (1 - b_1)(i_t - i_t^* - prem_t) + \varepsilon_t \tag{8}$$

In Equation 8, e is the nominal exchange rate, while the new term *prem*$_t$ appears as a risk premium component of the UIP condition. If the UIP condition holds, '*prem*$_t$ is 0. Likewise, Δe_t is a change in the exchange rate $(e_t - e_{t-1})$. When $b_1 = 0$, we get the standard UIP condition with a risk premium. We argue that the domestic interest rate, i_t, is determined partly by the domestic condition and partly by the UIP condition, following the lead of earlier studies, such as Berg et al. (2006a) and Berg et al. (2006b). The final specification of the model is represented by Equation 9, where we combine the UIP condition derived from Equation 8 with the monetary policy reaction function of Equation 5. We also add backward-looking behavior (set by domestic economic conditions) and forward-looking behavior (set by the UIP conditions) to consider both forward-looking and backward-looking components. Hence, Equation 5 is rewritten as:

$$i_t = (1 - c_1)\left(\frac{1}{1 - b_1}\Delta e_{t+1} - \frac{b_1}{1 - b_1}\Delta e_t + i_t^* + prem_t\right) \\ + c_1\left(f_1 i_{t-1} + (1 - f_1)(i_t^n + f_2(E_t \pi_{t+1} - \pi^T) + f_3 \hat{y}_t)\right) + \varepsilon_t^i \tag{9}$$

In Equation 9, coefficient c_1 expresses the central bank's ability to control the domestic interest rate. When c_1 is 0, the domestic interest rate is determined only by the forward-looking UIP condition, showing that the central bank completely loses control of the interest rate. In contrast, when $c_1 = 1$, the standard reaction function determines the domestic interest rate. Thus, a lower value (closer to zero) of c_1 means that the central bank focuses on stabilizing inflation through the exchange rate. When $c_1 = 0$, the determination of the domestic interest rate is surrendered, and Equation 8 is reduced to:

$$i_t = \left(\frac{1}{1 - b_1}\Delta e_{t+1} - \frac{b_1}{1 - b_1}\Delta e_t + i_t^* + prem_t\right) + \varepsilon_t^i \tag{10}$$

A forward-looking agent who knows that the exchange rate peg is being continued in period $t+1$, assumes that $b_1 = 0$ for economies like Nepal that are operating with a fixed exchange rate regime. Equation 10 now transforms into the following:

$$i_t = \Delta e_{t+1} + i_t^* + prem_t + \varepsilon_t^i \tag{11}$$

Equation 11 is a simplification of Equation 9 which shows that the domestic interest rate is now determined by the foreign interest rate, expectations of an exchange rate change and a risk premium. Assuming a fixed exchange rate, we now get the final monetary policy reaction function, as discussed by Berg et al. (2006a); Berg et al. (2006b) and Bulir (2014):

$$i_t = (1 - c_1)(\Delta e_{t+1} + i_t^* + prem_t) + c_1(f_1 i_{t-1} + (1 - f_1)(i_t^n + f_2(\pi_{t+1}^e - \bar{\pi}) + f_3 \hat{y}_t)) + \varepsilon_t^i \tag{12}$$

In Equation 12, c_1 is the degree of control the central bank holds over the money market interest rate. A higher value of c_1 indicates a higher degree of control. Assuming $\Delta e_{t+1} = 0$, this implies that the foreign interest rate

determines the domestic interest rate by $i_t = i_t^* + prem_t$. In the fixed exchange rate version, $\Delta \bar{e} = 0$ since rational market agents know that the exchange rate will not change in the future, which is a forward-looking behavior. The inflation target is consistent with a trend in the real exchange rate, as represented in our model by the coefficient $\bar{q}$, which is a part of the $\bar{\pi}$. The long-run average value of inflation $\bar{\pi}$ depends on foreign inflation, implying that $\bar{\pi} = \bar{\pi}^* - \Delta \bar{q}$. Thus, the policy choice for the NRB is either the exchange rate (foreign exchange market) or the interest rate (domestic money market).

Monetary policy independence depends on the value of c_i such that a simulated interest rate gets closer to the observed interest rate. The response of the short-term interest rate is assessed by changing the value of c_i. *The NRB has a higher degree of control over the short-term interest rate, indicating greater monetary policy independence if the model-calibrated interest rate is closer to the observed of $c_i \rightarrow 1$.* If the value of c_i is not closer to either one or zero (i.e., in between 1 and 0), short-term interest rates are influenced partly by the UIP condition, indicating that the interest rate is determined by forward-looking and backward-looking behavior. However, *if the model-calibrated interest rate is closer to the observed interest rate when $c_i \rightarrow 0$, then the NRB loses control over the short-term interest rate, indicating a loss of monetary policy independence.*

The monetary policy reaction function in Equation 12 cannot be estimated using OLS-based methods. First, we want to observe the reaction of the short-term interest rate, while we provide different values for c_i in Equation 12, which is not feasible with an estimation-based analysis. As the variable risk premium is never observed, calibrating the risk premium in Equation 8 is the first step in our model estimation. Once the calibrated risk premium data is obtained, this output is used in Equation 12 as an input. Furthermore, the gap variables, such as output gap, interest rate gap, inflation gap and exchange rate gap, are also not observed. We have a limited data span with a series of policy reforms during the study period, with regime shifts and endogenous policy action demanding a method that addresses these time-varying structural breaks.

3.2. The State–Space Model

The standard OLS model needs to fulfil the Gauss–Markov assumptions to get the best unbiased linear estimates. However, there are several reasons why unbiased estimate assumptions are violated. The OLS-based estimation methods become spurious when the UIP condition does not hold[12] because errors in the forecast cannot be from an exchange rate shock but from unobserved variables. Thus, the exchange rate shock is not orthogonal to the domestic and foreign interest rates.[13] Likewise, policymakers face challenges when interest rates of a foreign economy to which a domestic economy fixes the exchange rate move in different directions (Klein & Shambaugh, 2015). It is possible to move in a different direction when exchange rate expectations differ and the risk premium exists while the expectations and the risk premium are unobserved. Since OLS-based models do not provide valid coefficients in the presence of unobserved data, an ML-based model simulation is necessary to calibrate the unobserved data. (Da Silva Bejarano Aragon & de Medeiros, 2015) show that monetary policy reaction function parameters are time-varying and endogenous and need to be considered, even by the Kalman filter. For this reason, we apply a state–space (SS) modelling framework based on the Kalman filter analysis to simulate the model. The SS model provides an adaptive strategy to calibrate the MLE parameters, whereas the Kalman filter simulates the given condition and observes the relationship (see (Harvey, 1987; Kalman, 1960)). Additionally, this model addresses unstable time-varying coefficients (Basdevant, 2003; Nepal & Foster, 2016), which were witnessed in an earlier study by Bhatta et al. (2021) for risk premium data. Based on studies by Harvey (1990) and Durbin and Koopman (2012), the measurement equation is specified as follows:

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[12] Bhatta et al. (2021) showed that the UIP condition does not hold in Nepal, having a negative time-varying risk premium. They also show a biased result while applying the OLS model in estimating the risk premium.

[13] The importance of shocks in forecasting the exchange rate is explained by Forbes, Hjortsoe, and Nenova (2018) and Smets (1997).

$$Y_t = K_t\beta_t + HA_t + \varepsilon_t \tag{13}$$

Where Y_t is a measured variable, K_t is an observed parameter with an n × p matrix, β_t is an unobserved state variable with p × 1 matrix, A_t is an exogenous regressor with H parameters, 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:

$$\beta_t = \mu_t + GB_{t-1} + \vartheta_t \tag{14}$$

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 $\vartheta_t \approx N(0, \sigma_\vartheta)$.

Embedding the UIP condition in a monetary policy rule when the official capital flow is regulated is justifiable depending on the extent of capital restrictions, modelling techniques, and the exchange rate policy (Berg et al., 2006a; Berg et al., 2006b). The necessary theoretical assumptions of covered interest parity (CIP) conditions, such as free capital mobility, have been ruled out in favor of uncovered interest parity conditions by Ito (1988). Furthermore, the UIP condition's failure does not imply a lack of perfect capital mobility (Kuen & Song, 2007). The economic liberalization occurring during the 1990s introduced a window of foreign direct investment in Nepal, and continuous reforms have taken place since then, for instance, the Foreign Investments and Technology Transfer Act (FITTA) 1992, which was subsequently replaced by FITTA 2019 based on a new Foreign Investment Policy in 2015. Furthermore, when the current account is fully convertible, illicit capital flows can occur through this window (Ajayi, 2014; Nitsch, 2012). The data confirms the current account convertibility and illicit capital flow relationship for about 32% of total illicit trade flowing to India in 2019 (Global Financial Integrity, 2019).

4. DATA AND METHODOLOGY

4.1. Data

This study primarily uses published annual time series data from 1989 to 2019 for 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 liberalization developed from the early 1990s in Nepal. Thus, the sample covers the early liberalization periods to the recent reforms. The interest rate data comes from Nepal's central bank, Nepal Rastra Bank (NRB), and India's central bank, the 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 gross domestic product (GDP) data from the World Development Indicator database of the World Bank. Such data is compatible since the base year is the same. We use the nominal effective exchange rate (NEER) and the real effective exchange rate (REER) data from Darvas (2012), whose data has a comprehensive NEER and a REER series covering 178 world economies and considers all the world economies that Nepal conducts trade with.

NEER (*nx*) represents Nepal's nominal exchange rate variable in this study. The nominal exchange rate of the Nepalese Rupee (NPR) and Indian Rupee (INR) is fixed, and the nominal exchange rate of the NPR and USD is the cross rate of the INR and USD. Thus, an alternative representation of the nominal exchange rate is NEER[14] for our analysis.[15] Likewise, REER represents Nepal's real exchange rate, *rx*, in the model. The use of the effective exchange rates is valid in the study 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 REER to simplify the analysis. We include Nepal's and India's national consumer price indices, *cpi* and *cpi_star*, for the price data.

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[14] 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.

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

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

4.2. Model Simulation Methods

We apply the state–space modelling framework based on the Kalman filter to simulate the monetary policy rule. Our objective is to simulate a model by fixing the specific policy actions and playing with the parameter values, which is not possible with estimation-based techniques such as OLS.[16] The unit root test results show a mixed order of integration among the study variables ranging from a zero (I(0)) to a maximum of two orders of integration (I(2)) (see Table 1). The Kalman filter is preferred over the OLS-based estimation techniques as this technique can handle series integrated in any order when the data has different orders of integration and the possibility of cointegration exists (Bomhoff, 1992; Nepal & Foster, 2016). Therefore, we apply the Kalman filtration process as a reduced form model based on a state–space representation to calibrate all the unobserved variables, gaps, and trends using the observed variables and the model structure. A Gaussian distribution is assumed for the random vectors and the initial state values. The measurement equations are as follows:

$$LGDP_t = \lambda_{LGDP}B_t + \varepsilon_{LGDP,t}$$

(15)

$$LRX_t = \lambda_{LRX}B_t + \varepsilon_{LRX,t} \tag{16}$$

$$LNX_t = \lambda_{LNX}B_t + \varepsilon_{LNX,t} \tag{17}$$

$$DOT\_CPI_t = \lambda_{DOT\_CPI}B_t + \varepsilon_{DOT\_CPI,t} \tag{18}$$

$$LCPI\_STAR_t = \lambda_{LCPI\_STAR}B_t + \varepsilon_{LCPI\_STAR,t} \tag{19}$$

$$NI\_STAR_t = \lambda_{NI\_STAR}B_t + \varepsilon_{NI\_STAR,t} \tag{20}$$

$$LGDP\_STAR_t = \lambda_{LGDP\_STAR}B_t + \varepsilon_{LGDP\_STAR,t} \tag{21}$$

The transition equations and assumptions are below:

$$B_{i,t} = \mu_i B_{i,t-1} + \vartheta_{B,it} \text{ with } \vartheta_t \approx N(0, \sigma_\vartheta) \tag{22}$$

Where, *i*, is the transition variable[17]

$$\varepsilon_{i,t} = \varphi_i \varepsilon_{i,t} + \vartheta_{i,t}, \tag{23}$$

where *i* represents the measurement variables

$$i = [LGDP, LRX, LNX, DOT\_CPI, LCPI\_STAR, NI\_STAR, LGDP\_STAR].$$

We define the transition variables, transition shocks, parameters, and then the equations for each transition variable while simulating the model. The initial data of the *cpi*, *cpi_star*, *ni*, *ni_star*, *nx*, *rx* and *gdp* have been used to generate numerous other variables, the log of 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 the inflation target, trend real interest rate, real exchange rate, and GDP growth are the long-run parameters. The variable definitions, data, measurement/transition variables and equations, and the parameter values are shown in Appendix A.

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[16] The reason behind the usage of a state–space model and Kalman filter is explained in section 3.2.

[17] The transition variables are listed in Appendix A at the end of the paper.

Table 1. Augmented Dickey–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: 1) 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 not seasonally adjusted.
2) * indicates that the null hypothesis (that the variable has a unit root) is rejected at the 5% 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).

5. FINDINGS AND DISCUSSION

5.1. Monetary Policy Independence: Traditional Thought

Nepal has historically maintained a closed capital account policy and fixed its exchange rate, which is in line with the impossible trinity approach. Equilibrium in the exchange rate market is possible only if the interest rate is the same in both countries and if investors are allowed to freely move money to either Nepal or India and they expect that the exchange rate will continue to be fixed (Klein & Shambaugh, 2010). A rational investor will not hold a lower returning asset (which is risk-free by assumption) in either country. If the interest rate is not the same, market participants will sell lower-returning assets and buy higher returning ones in both countries, which will ultimately not sustain the peg. We now graphically discuss the current scenario of a short-term interest rate differential (as an operating target for monetary policy) and inflation differential (as a goal for monetary policy) between Nepal and India. The interest rate and inflation differential between Nepal and India show a relationship between monetary policy independence and policy goals. On the left-hand side of Figure 2, the short-term interest rate shows a broader gap between Nepal and India. The interest rate trend between the two countries was similar until the early 2000s and substantially diverged after that. However, the right-hand side of Figure 2 shows a relative convergence of inflation between Nepal and India to a lower rate. The graphic plots indicate achievement of the price stability goal of the monetary policy, while Nepal's central bank has ignored the interest rate, being successful in the reduction of interest rate well below that of India. Figure 3 further validates this data by plotting the interest rate differential and real interest rate. The left-hand side of Figure 3 compares the real interest rate between the two economies, showing a positive real interest rate in India most of the time, while it is negative in Nepal.

On the other hand, the real interest rate differences between Nepal and India are larger and prolonged. The inflation differences between Nepal and India are negligible compared to a wider difference over a longer period of time for the real interest rate (Figure 3, right). This implies that although the interest rate is divergent between the two economies, Nepal closely follows the inflation trend of India. The divergence in the interest rates between Nepal and India suggests independence between two monetary policies, while convergence in inflation rate indicates an import of India's price stability into Nepal through the exchange rate peg. This increases the ambiguity of monetary policy independence in the policy trilemma as the price stability goal is achieved without any synchronization to interest rate.

5.2. Model Calibration

We start the simulation of the monetary policy reaction function (i.e., Equation 10 above) with an initial value for c_i of 0.9. We then subsequently, and arbitrarily, lower the value by ten percentage points[18] for each simulation.

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[18] It was possible to use any value between 1 and 0 during the simulation. We chose to simulate by reducing by ten percentage points so as not to be so low that no changes are noticed or so high that a larger jump is noticed in the results.

We observe the simulation results on inflation, GDP growth and the short-term interest rate, keeping foreign inflation and exchange rates exogenous. The model simulates domestic inflation, the 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 outputs when c_i is 0.9, 0.5 and 0.1 are respectively discussed below.
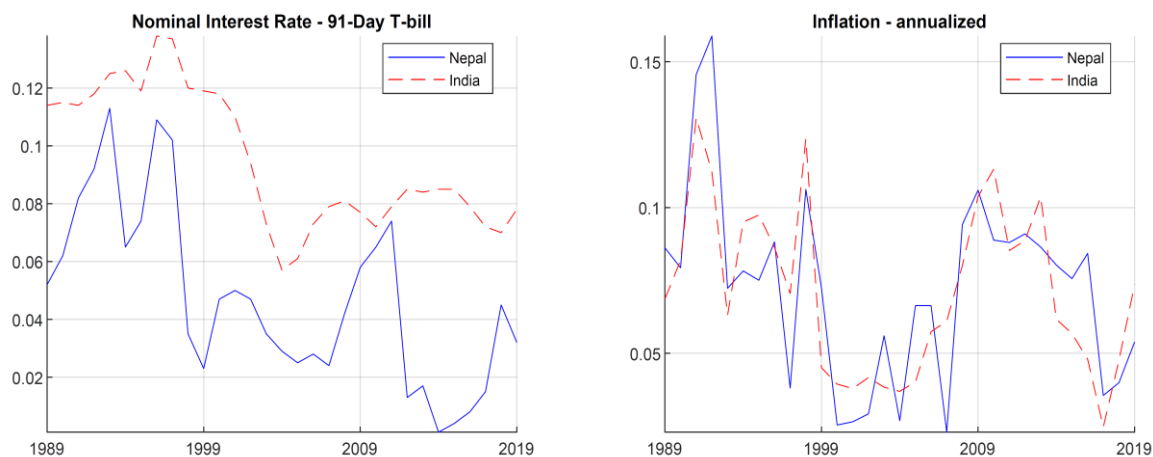

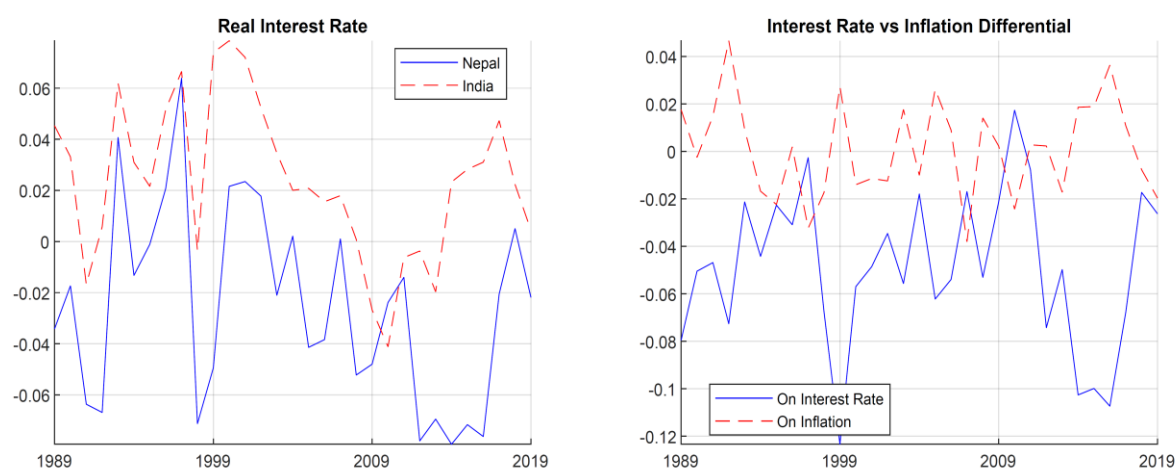**Figure 2.** Interest rate and inflation for Nepal and India.

Figure 3. Interest rate and inflation differential for Nepal and India.

5.2.1. When c_i is 0.9

Domestic monetary policy is fully independent when $c_i \rightarrow 1$. The forward-looking UIP component will have a negligible impact on the short-term interest rate in Equation 10, while the domestic economic condition will have a substantial impact. Thus, we restrict the value of c_i to be 0.9 and then simulate the model. The calibrated output from the model is shown in Figures 4–6

The MATLAB output shows a substantial variation between the calibrated and observed interest rate data, while inflation and economic growth closely follow each other (see Figure 4). The considerable variation indicates that when $c_i \rightarrow 1$, the model does not fit and is unable to predict the short-term interest rate, which is an operating target variable of monetary policy. The real interest rate data in Figure 5 also shows a similar result. The risk premium estimates in Figure 6 also report different results compared to the results obtained by Bhatta et al. (2021), showing an average risk premium of about zero. We cannot reject the null hypothesis that monetary policy is not independent based on this evidence.
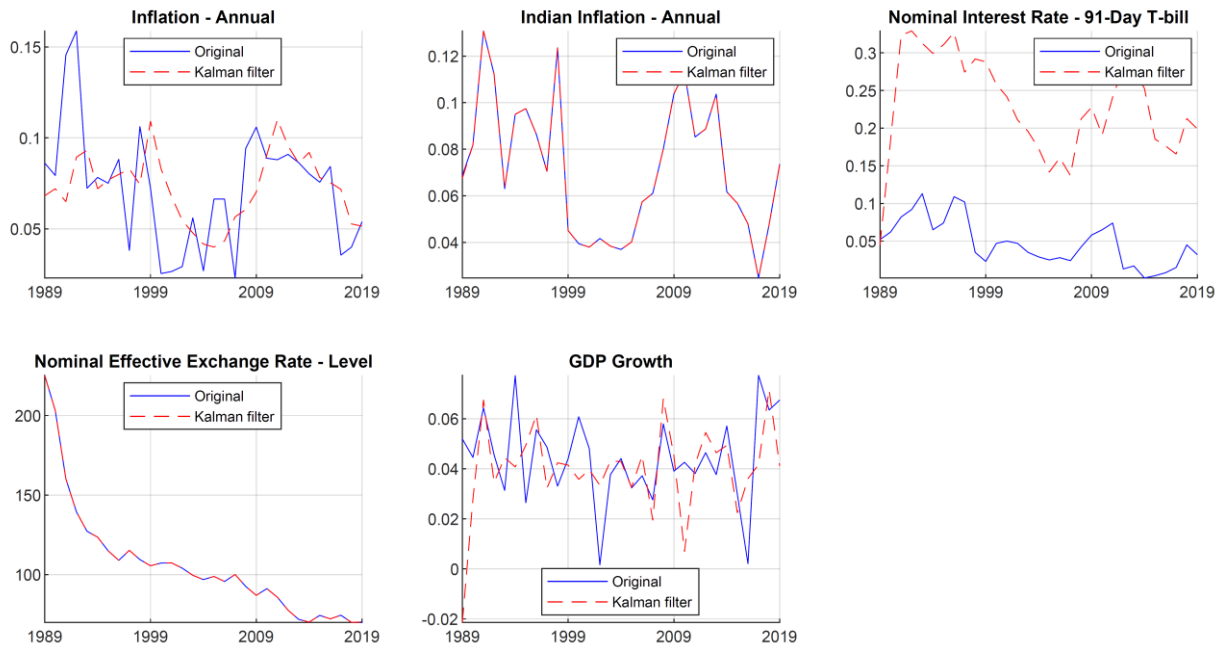
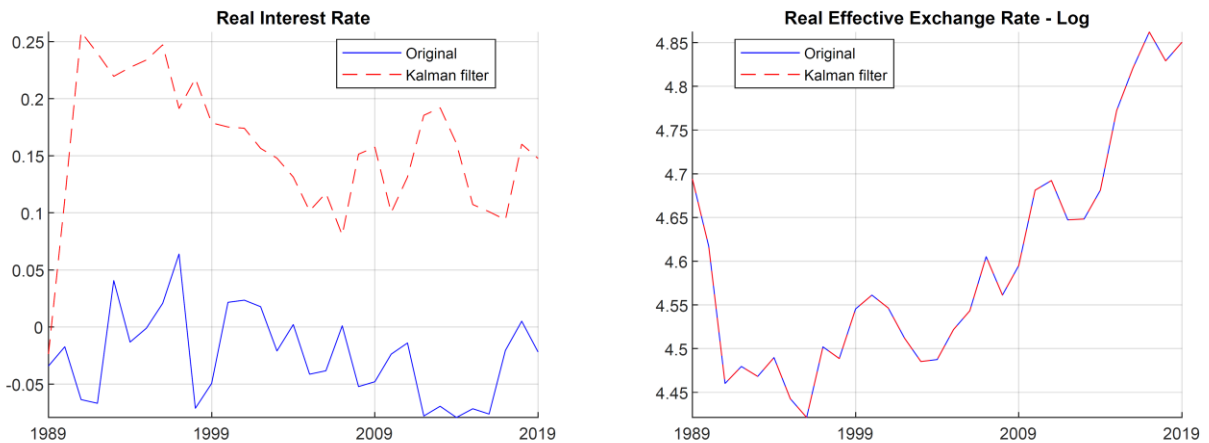**Figure 4.** Simulation result: c1 being 0.9 | Nominal variables.

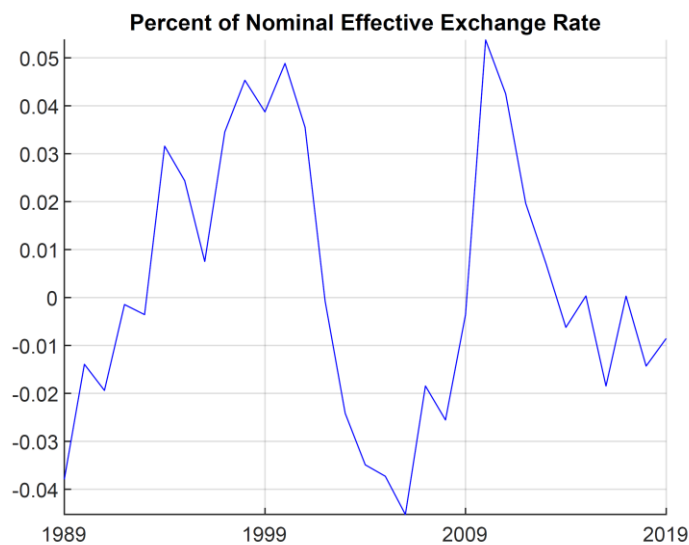**Figure 5.** Simulation result: c1 being 0.9 | Real variables/trends.

Figure 6. Simulation result: c1 being 0.9 | Risk premium.

213

5.2.2. When c_i is 0.5

Domestic monetary policy is determined partly by forward-looking (UIP) conditions and partly by backward-looking (domestic) conditions and is a mixed monetary policy strategy when c_i is between 0.9 and 0.1. We find that the calibrated model and observed interest rate data fits better on each percentage point reduction on the value of the c_i parameter, ceteris paribus. In Figure 7, the calibrated nominal interest rate and the actual interest rate are still closer than in Figure 4. The real interest rate gap is narrowed down in Figure 8 compared to Figure 5, along with the risk premium result demonstrated in Figure 9. The simulated interest rate still does not follow the observed data, even if the model is closer to the observed data in $c_i = 0.5$, motivating us to continue the model calibration to find the best fitting relation.
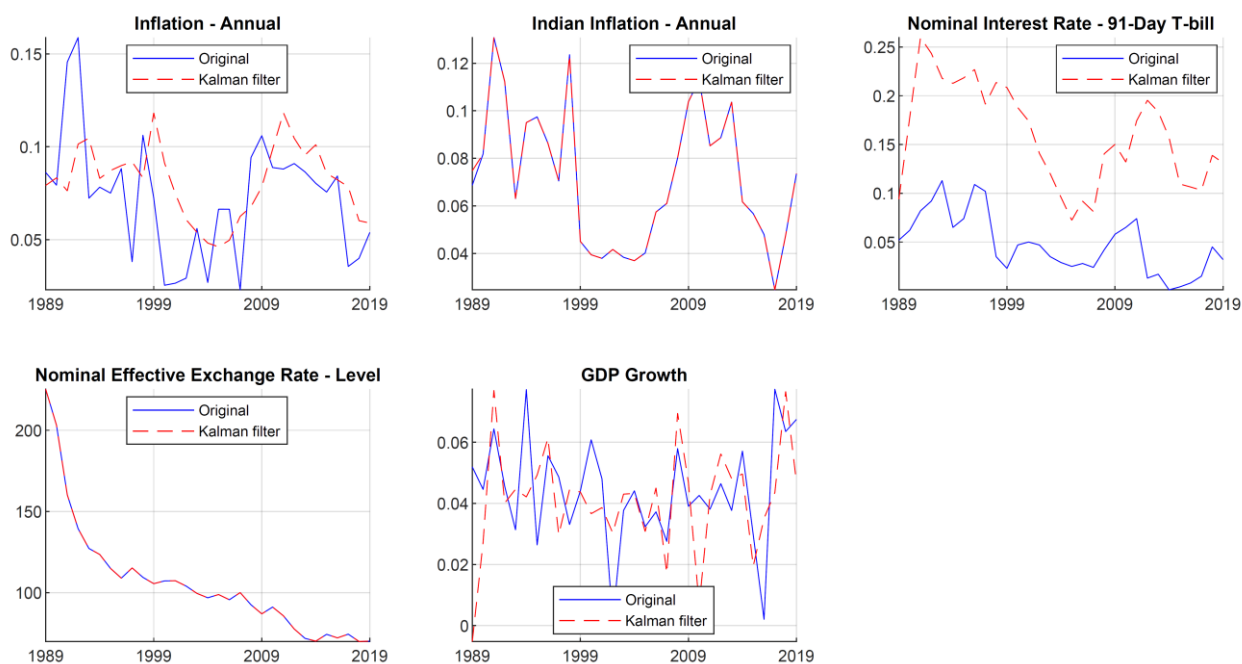

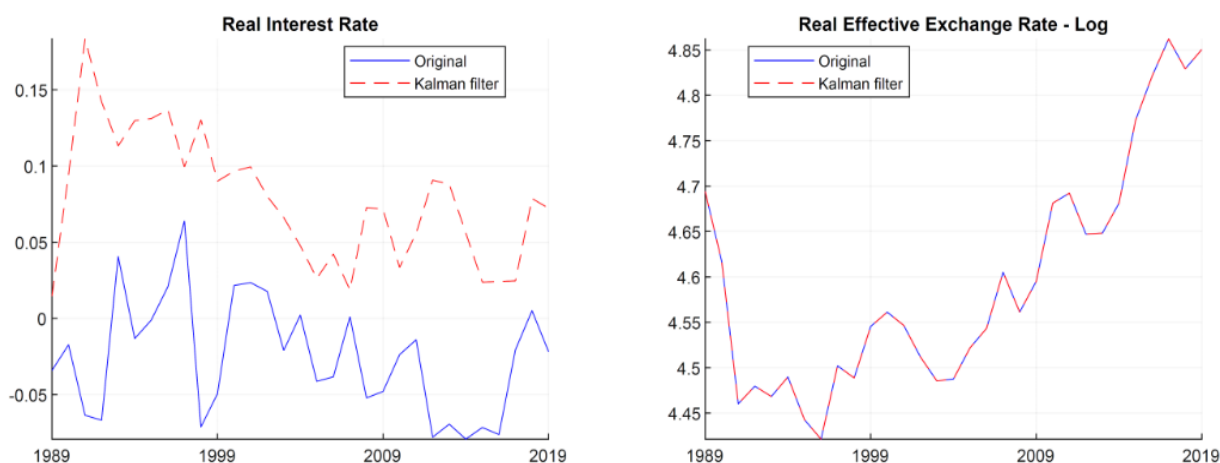**Figure 7.** Simulation result: c1 being 0.5 | Nominal variables.

Figure 8. Simulation result: c1 being 0.5 | Real variables/trends.

5.2.3. When c_i is 0.1

When $c_i \rightarrow 0$, it indicates that domestic monetary policy is entirely dependent on foreign monetary policy, with a negligible effect from domestic economic conditions. We continued to reduce the value of c_i from 0.5 to the lowest possible level while simulating the model (0.1).
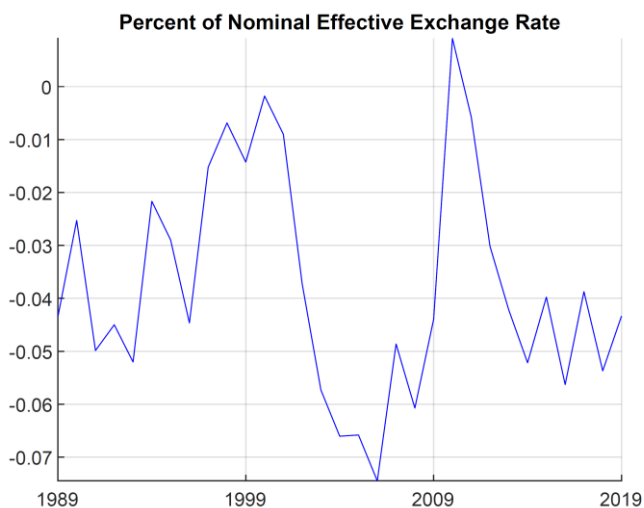
Percent of Nominal Effective Exchange Rate

Figure 9. Simulation result: c1 being 0.5 | Risk premium.

When the value of c_i is 0.1, we obtained the observed and simulated interest rates in a similar trend and nearing each other. The calibrated value of inflation and economic growth remains the same. In Figure 10, the calibrated interest rate data closely follows the observed interest rate. The real interest rate calibration by the Kalman filter is indeed a perfect fit (see Figure 11). The risk premium calibration in Figure 12 also shows that the Kalman filter's risk premium simulation is closer to the risk premium simulated by Bhatta et al. (2021). This provides stronger evidence that we should not reject the null hypothesis that Nepal's monetary policy is not independent. The results show that price stability is imported in Nepal by fixing the exchange rate at the cost of foregone interest rate settings.
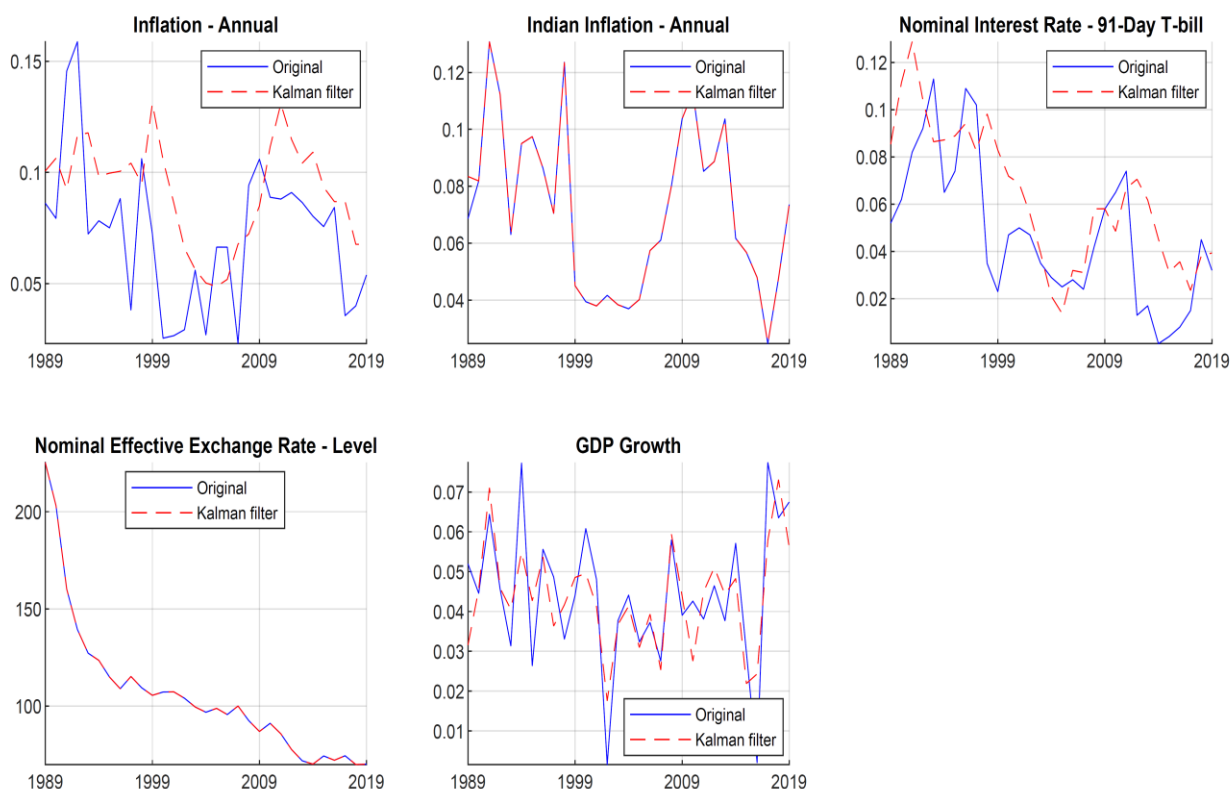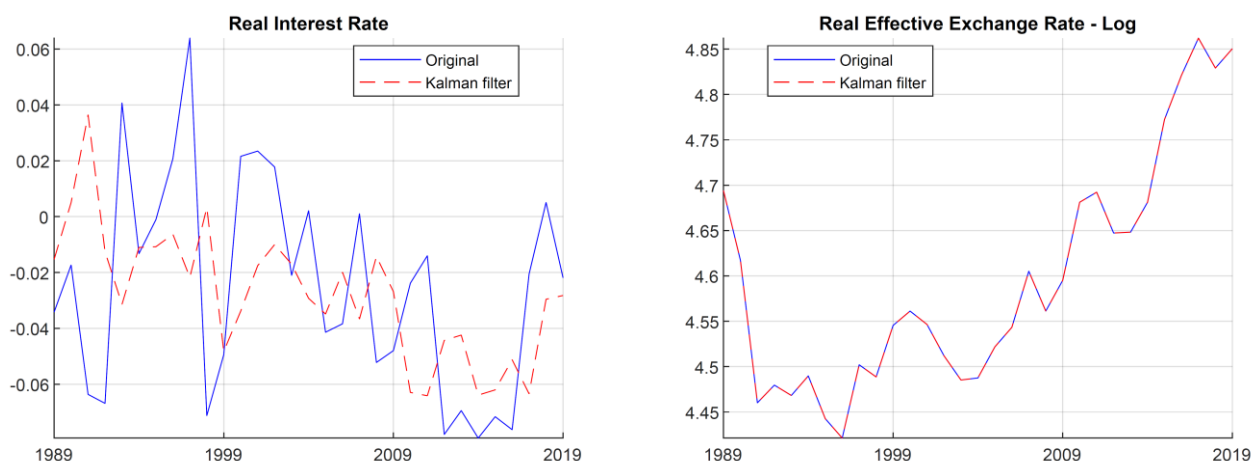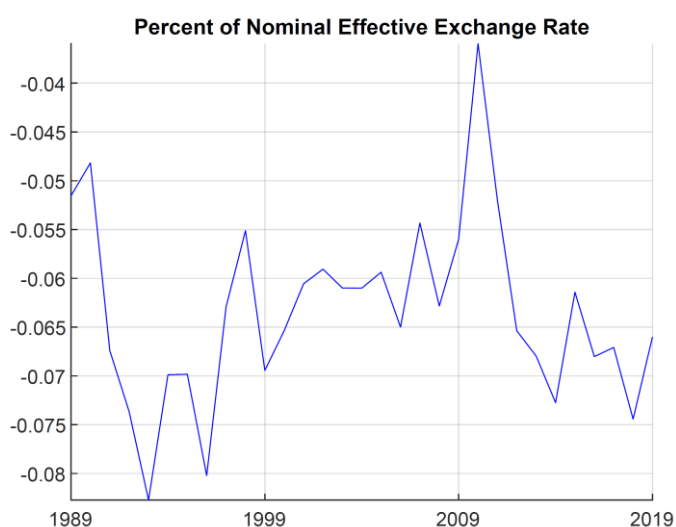

Figure 10. Simulation result: c1 being 0.1 | Nominal variables.

215

Figure 11. Simulation result: c1 being 0.1 | Real variables/trends.

Figure 12. Simulation result: c1 being 0.1 | Risk premium.

These findings suggest 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, questions about the efficacy and rationale of policy choices that Nepal has been implementing can be raised even when Nepal fixes the exchange rate and closes the capital account.

5.3. Discussion

Based on the findings presented in the previous section, we confirm that Nepal is not confined to the policy trilemma condition. The policy mix that has been adopted for a long period of time in Nepal raises serious questions about its 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 is still strong among the central bank, policymakers, and international advisors, including the IMF (IMF, 2010; IMF, 2012; IMF, 2017a; Yelten, 2004). Furthermore, as the fixed exchange rate is rather explicit and relatively easier to enforce, policy concerns have been raised about the capital account policy Nepal has been adopting. The failure of the policy trilemma hypothesis in Nepal is not surprising, but the quadrilemma argument of Aizenman (2019) and dilemma argument of Rey (2015) are not valid for Nepal due to the following factors, which are discussed in more detail below: i) a higher volume of illicit capital and financial flows; ii) upsurging remittance inflows, and iii) the dominance of a larger economy's policy relative to that of a smaller economy.

When the current account is fully convertible, illicit capital flows can occur through this window (Ajayi, 2014; Nitsch, 2012). Nepal has sizeable informal transactions in remittances, trade, and investment. For instance, Taneja, Sarvananthan, Karmacharya, and Pohit (2004) estimated that informal trade from Nepal to India accounts for about 38% of total formal trade, while informal trade from India to Nepal accounts for more than formal trade. Likewise, illicit financial flows from Nepal to India accounts for about 32% of total trade (Global Financial Integrity, 2019). Illicit financial and trade flows make up 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.

The impossible trinity may also have further deteriorated, arising from a rapid expansion in Nepal's remittances.[19] Remittances have been a substantial source of foreign exchange reserves in Nepal and is the seventh-largest economy in the world in terms of the remittance-to-GDP ratio in 2020 (see theglobaleconomy.com). Furthermore, informal remittance flows are also estimated to be substantial for Nepal,[20] which is further exacerbated by the unmonitored and open border with India. Monetary policy and remittance relationships become more complex in the presence of informal and volatile remittances (Vacaflores, 2012). Such informal remittances affect the sterilization of the foreign currency market and money supply projections (Vacaflores, 2012).

Evidence shows that Nepal's REER has appreciated due to the exchange rate peg, while rapidly rising remittances put upward pressure on domestic prices (Paudel & Burke, 2015). Remittance flows can also cause Dutch disease effects,[21] thereby deteriorating the external sector's competitiveness (Barajas, Chami, Ebeke, & Oeking, 2018; Bourdet & Falck, 2006; Hassan & Holmes, 2013; Lartey, Mandelman, & Acosta, 2012; Makhlouf & Mughal, 2013; Rabbi, Chowdhury, & Hasan, 2013). Furthermore, remittances inject relatively easy liquidity into the financial system that can substantially lower the short-term interest rate (Bayangos, 2012; Machasio, Tillmann, & Göcke, 2018; Tenreyro & Thwaites, 2016). Vacaflores (2012) showed that a positive remittance shock could improve aggregate consumption and lower the interest rate, supporting our discussion. A study by Barajas et al. (2018) concluded that higher remittance inflow leads to a loss of monetary policy independence, even if the exchange rate is fixed and capital flow is restricted. This finding is also consistent with the evidence of Singer (2010), who argued that countries with a higher level of remittance tend to fix their exchange rate. The conclusions reached by Barajas et al. (2018) and Singer (2010) are that remittance income has a similar impact to that of capital flows in the impossible trinity diagram and in the case of Nepal. We did not include both REER and remittance in our analytical model, since evidence has shown that remittance causes REER to appreciate (Barajas et al., 2018; Bourdet & Falck, 2006; Hassan & Holmes, 2013; Lartey et al., 2012; Makhlouf & Mughal, 2013; Rabbi et al., 2013).

Finally, the influence of Indian monetary policy may be dominant in Nepal. As Bhatta (2018) demonstrated, liberalization of the Nepalese economy benefits India when the financial development level is not synchronized. Furthermore, Bhattarai, Mallick, and Yang (2021) showed that monetary policy shocks are competitive between the US and India, but technology shocks are complementary. Indian monetary policy may be competitive with Nepal's, resulting in a loss of control over the domestic interest rate. Velickovski (2013) reported that both demand and supply shocks do not synchronize between the Western Balkan countries and the Euro area, suggesting that loss of independent monetary policy carries a high cost. Furthermore, a divergence in shock is valid when a small, open, economy such as Nepal is unable to influence India's interest rate and exchange rate, as evidenced by Cover and Mallick (2012) for the case of the United Kingdom. Similar evidence is also provided by Goczek and Partyka (2019), that non-Euro members are 'too small to be independent' of the ECB.

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[19] Remittance flows from immigrants to families back home have emerged as a major source of foreign exchange in recent years for Nepal. They have been steadily increasing since 2010–11, peaking at Rs. 961 billion in July 2021, equivalent to 22.5% of Nepal's GDP.

[20] It has been estimated that informal remittance flows account for between 35% and 75% of formal flows in developing countries (Freund & Spatafora, 2005).

[21] The Dutch disease is a problem in the performance of the manufacturing/industrial sectors due to the continuous appreciation in the real exchange rate; this term now is being used for higher foreign currency inflow, causing the domestic real exchange rate to appreciate. For further information, refer to Corden (1984).

While the primary objective of the NRB is to '*formulate monetary and foreign exchange policies and manage them to maintain price and balance of payments stability…*' (Government of Nepal, 1955), the exchange rate policy reforms are a priority of both the central bank and the government. The strategy and the actions of the Fifteenth Development Plan Approach Paper (2019/20–2023/24) emphasize the need for scientific study to review the laws and systems related to financial and foreign exchange sectors to enhance the effectiveness of the monetary and financial sector policies (National Planning Commission of Nepal, 2019). The major findings from this study have a direct implication for reviewing the 'laws and systems' mentioned in the periodic plan document. Nepal may consider that it is appropriate to exercise capital controls and aim for moderate exchange rate flexibility to achieve monetary autonomy, as discussed by Klein and Shambaugh (2015). A further opening of the capital account from 'closed' to 'controlled' and a short-term strategy of devaluing the currency according to the risk premium's size may help to achieve both monetary policy independence and a correction in the REER appreciation. In the longer run, both exchange rate policy and capital account management should go side by side as part of a broader financial sector reform.

6. CONCLUSION AND POLICY IMPLICATIONS

Continuous financial liberalization has increased the need for dynamic reforms in the conduct of a macroeconomic policy mix that relies on an effective monetary policy. Against this backdrop, we studied whether the traditional policy trilemma of the Mundell–Fleming model still holds in a small, open, landlocked, developing (SOLD) economy, citing Nepal as a specific case for the 1989–2019 period. Nepal is a heavily trade-dependent, landlocked, South Asian country that historically fixes its exchange rate with India and keeps the border open. Both economies initiated monetary policy liberalization in 1989, and reforms are ongoing to the present date. We modified the traditional Taylor rule-based monetary policy reaction function to represent the local economic characteristics. We applied the Kalman filter analysis in a state–space modelling framework and a mixture of backward-looking and forward-looking strategies, incorporating a fixed exchange rate to simulate the short-term interest rate, inflation rate, and economic growth, and compared the simulated data with the observed data.

The model calibration results provide strong evidence of the policy trilemma's failure. A better match of the simulated short-term interest rate with the observed data was found when the parameter value of the domestic condition is closer to zero. The model is more able to predict the real interest rate while keeping inflation and economic growth stagnant in the initial condition of the model and recalibrating the interest rate. The calibration of the risk premium is also consistent with an earlier study by Bhatta et al. (2021). The predictability of the model's calibration results for the interest rate, inflation rate, and economic growth, as well as the response of the model to the shocks, confirm the validity and reliability of the calibrated model.

Failure of the policy trilemma indicates the compromise on monetary policy independence, raising policy issues for the Nepalese economy. Even though the recent empirical evidence suggests that the policy trilemma's failure is due to the dilemma (Rey, 2015; Rey, 2016) or quadrilemma (Aizenman, 2019), both arguments are rejected for Nepal due to the economy's poor financial market integration. Beyond the dilemma or quadrilemma, some domestic economic conditions, as discussed below, may have caused the policy trilemma failure. The primary cause may be upsurging remittance inflows and illicit financial flows, which inhibit the official restrictions on cross-border capital flows. Remittance inflows appear to appreciate the REER through the Dutch disease effect (Barajas et al., 2018; Bourdet & Falck, 2006; Hassan & Holmes, 2013; Lartey et al., 2012; Makhlouf & Mughal, 2013; Rabbi et al., 2013), while it also injects external liquidity into the domestic economy (Bayangos, 2012; Machasio et al., 2018; Tenreyro & Thwaites, 2016), further deteriorating the role of the central bank. Therefore, Nepal should consider the findings of Klein and Shambaugh (2015) by introducing capital controls (not restrictions) and moderating the exchange rate flexibility to achieve monetary autonomy. To realize this, Nepal should take into consideration an alternative exchange rate policy while further opening its closed capital account and introducing a 'controlled capital account' regime. As for exchange rate adjustments, Nepal might consider retaining the status quo of fixed exchange rate policy

in the short term but allow some adjustment in the parity level by devaluing the currency to neutralize the adverse effects of the negative risk premium and ameliorate the REER appreciation.

This study's findings agree with Klein and Shambaugh (2010), that losing monetary independence is not detrimental to the economy of Nepal if it can import India's price stability and policy credibility, which might, in the process, enhance welfare. However, strengthening international competitiveness and formulating a sound monetary policy to address local economic conditions are equally important to stabilize the economy. The monetary policy reform agenda may not be a priority of Nepal's central bank, when it focuses on managing the interest rate spreads but not on addressing the core concern of the structural factors of the financial sector policies. Nepal's monetary policy framework sets a fixed exchange rate as a nominal anchor and restricts the capital flows, which might result in a higher interest rate spread. Anguyo, Gupta, and Kotzé (2020) in Uganda showed that even if capital and financial markets are at a nascent stage, the monetary policy is focused on managing the interest rate spread, which further worsens the financial frictions. The calibrated negative risk premium provided a couple of policy implications, as discussed in the study by Bhatta et al. (2021). These include the motivation of domestic investors to hold foreign assets, thereby impeding local bond market development and as an indication of future currency devaluation. Altogether, constraining global financial flows may further restrain the Nepalese economy and hinder the promotion of broader financial sector reform. Optimal policy options for the central bank in the short term are managing both capital flows and the exchange rate, with a stricter and more selective strategy for the former. Future research can include investigating the possible factors explaining Nepal's short-term interest rate and further exploring the optimal policy choices for reforming the existing exchange rate policy, including the devaluation strategy and introducing a managed float.

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Appendix A. Modeling Framework.

A1. 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 (2012) 'Real effective exchange rates for 178 countries: A new database', *Working Paper* 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 T-bill rate	Nepal Rastra Bank's 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 authors average the daily cut-off rate of every transaction in each Month to calculate the average monthly T-bill rate.
GDP	Gross Domestic Product – Producer's Price	World Development Indicators, The World Bank.
GDP_STAR		

A2. Model Variable Names and Definitions

Variable Name	Variable Definition
cpi	average price level, all goods
ni	nominal interest rate
ri	real interest rate
ni_neutral	policy neutral rate
lnx	log of nominal effective exchange rate
lrx	log of real effective exchange rate
_gap	cyclical deviation from a trend of the respective variable
_eq	trend (equilibrium) of the respective variable
ss_	steady-state value of the respective variable
dot_	month-on-month change
dot12_	year-on-year change
_star	foreign (Indian) variable
e_	equation residual
ms_	measurement shock
gdp	gross domestic product
cr_prem	credit premium
rmc	real marginal cost
mci	monetary conditions index

A3. Measurement Variables

LGDP	LNX	LRX	DOT_CPI	LCPI_STAR
NI_STAR	LRX_EQ	LGDP_STAR		

A4. Transition Variables

List of transition variables used					
lcpi	dot_nx	prem	shock_prem	ni	
ri	ri_eq	ri_gap	ni_neutral	cr_prem	
rmc	dot_rx	lrx_gap	lrx_eq	dot_rx_eq	
nx_tar	dot_nx_tar	ri_star	ri_star_gap	ri_star_eq	mci
dot_cpi_star		lgdp_eq,	lgdp_gap,		target
dot_gdp,	dot_gdp_eq,	lgdp_star_gap	shock_prem		cpi_star

A5. Parameter Values

Parameter	Final Value	Variable and Assumptions
a1	0.3	Output persistence, noting smaller value with flexibility and more persistence
a2	0.2	Impact of monetary policy on real economy, also known as policy passthrough. Based on the discussed evidence, a low impact is presumed
a3	0.1	External demand impact
a4	0.45	Weight between Nepal's and India's inflation. Nepal's inflation is assumed to be explained about 45% by India, based on the empirical evidence
a5	0.8	Weight of real interest rate and real exchange rate in monetary conditions, assumed a greater influence of real interest rate
a6	0.5	Persistence in credit premium
b1	0.7	(1-b1) is a ratio of imported goods in firms' marginal costs
b2	0.5	Weight of real marginal cost in the domestic price level
c1	0.6	Exchange rate persistency in the UIP model, with a higher value indicating a backward-looking strategy with higher persistency
f1	0.1- 0.9	Key simulation variable. It captures the backward-looking vs forward looking monetary policy, higher value of f1 indicates monetary policy independence
f2	0.8	Persistence in monetary policy setting, higher value indicates a wait and see monetary policy while 0 means no persistence
f3	9	Based on the Taylor principle, policy reactiveness over inflation gap by policy makers
f4	6	Policy reactiveness over output gap by policy makers
h0	0.7	Shock persistence to risk premium, weight over past value
h1	0.3	Persistence in the convergence of trend variables to their steady-state levels for real interest rate, real exchange rate, and the GDP
h2	0.2	Persistence in the foreign GDP gap, higher value means higher persistence
h3	0.5	Persistence in foreign interest rates, higher value means higher persistence
h4	0.5	Persistence in foreign inflation; higher value means higher persistence
t1	0.9	Speed of inflation target adjustment to the medium-term target (higher values mean slower adjustment
target_ss	0.07	Domestic inflation target, which is consistent with inflation target of the NRB
ss_ri_eq	0.003	Trend level of domestic real interest rate, most of the time it is negative, so trend set as close to zero
ss_dot_rx_eq	0.02	Trend changes in the real effective exchange rate
ss_dot_cpi_star	0.05	Equilibrium/trend of foreign inflation (i.e., India)
ss_ri_star_eq	0.02	Equilibrium/trend of foreign real interest rate (i.e., India)
ss_dot_gdp_eq	0.04	Equilibrium/trend growth of potential output based on historical average GDP growth