

Revisiting the Gali–Monacelli Small Open Economy Model: A Calibrated DSGE Comparison of Pakistan and Canada

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Received: December 11, 2025 | Accepted: September 16, 2026

This study explores the structural factors that differentiate the macroeconomic responses of Pakistan and a developed economy to domestic and global shocks within a Dynamic Stochastic General Equilibrium (DSGE) framework. Using the model put forward in Gali & Monacelli (2005), we calibrated key parameters to reflect Pakistan's economy, allowing for a comparative analysis of impulse response functions (IRFs) generated for output, inflation, interest rate, and exchange rate under (a) the labour productivity and (b) the world demand shock. In comparison with those for Canada – an advanced economy. The estimation of model parameters for Pakistan reveals relatively lower degree of openness, higher sensitivity of inflation to the output gap, lower price stickiness, lower coefficient of relative risk aversion (CRRA), lower disutility of labour supply and lower persistence of productivity shocks. These factors lead to a larger initial, however, less persistent monetary policy response than in Canada, higher inflation volatility, and shorter-lived benefits from productivity gains. Just to contextualise, if only the persistence of the positive productivity shock for Pakistan is equated to that of Canada, the output response more than doubles, highlighting the need for undertaking work on the most probable missing component i.e., the structural reforms for productivity enhancement.

JEL Classifications: E32, E52, F41, O47.

Keywords: Dynamic Stochastic General Equilibrium (DSGE), Small Open Economy (SOE), Productivity Changes, World Demand.

1. INTRODUCTION

Emerging and developed economies frequently respond differently to common domestic and external shocks, such as productivity shock and global demand shock. Understanding such differences and their triggers is essential for designing effective policies that are appropriate for the country's structural characteristics. For this purpose, assessment of outcomes from a consistent/comparable model may be capable of decomposing the underlying causes of such differences, rather than simply describing them. Such models may allow policymakers to identify which structural features amplify or dampen the transmission of shock specifically productivity and demand shocks, and to prioritise reforms accordingly.

To this end, previous studies have successfully applied same DSGE models to examine cross-country economic responses, emphasising the role of parameters like trade openness, sectoral composition, and labour market rigidities in shaping these responses. Christiano, Eichenbaum, and Evans (2005) explore how monetary policy transmission differs across

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An earlier version of this paper was published as State Bank of Pakistan (SBP) Working Paper No. 120, January 2026. The authors are thankful to anonymous reviewers whose comments helped in improving the paper markedly.

economies due to nominal rigidity and openness. Adolfson, et al. (2007) analyses how incomplete exchange rate pass-through influences shock responses in an open economy DSGE model, revealing parameter-driven variations. Smets and Wouters (2003) compare the euro area with other advanced economies, highlighting the role of consumption habits and wage rigidities in shaping model dynamics. Justiniano and Preston (2010) further investigate the responses of small open economies to foreign demand shocks, using Canada and Australia to demonstrate how structural differences influence the transmission of shocks.

With regard to developing countries, like Pakistan, both the comparative analytics and parameters estimation are generally missing from contemporary literature or remain outdated. To address this gap, we selected the DSGE model given in Gali & Monacelli (2005). It is a small open economy framework that provides a suitably generalised system for capturing fundamental economic relationships broadly applicable across different economies in the New Keynesian macroeconomic setup and already has comparable results for an advanced country, Canada. The same framework is widely adapted to analyse different economies. Some researchers used this framework with some targeted modification. For instance, Lubik & Schorfheide (2007) retained the original theoretical structure and only simplified the terms of trade element to be exogenous for tractability. Caldara, et al. (2020) used this model to analyse the impact of trade policy uncertainty on the macro-economy. They modified the firm structure by including heterogeneity, endogenous entry and exit in export markets with sunk cost. More recently, Auclert, et al. (2025) borrowed this model to analyse the macroeconomic transmission of large-scale tariff shocks, such as the US 2025 tariff episode. The reason behind such extensive use of the Gali & Monacelli (2005) is its richer structure features such as provision of incomplete international financial markets, use of imports as an intermediate input in export production, and sticky nominal wages and flexible goods prices. We deliberately retain the original model without structural modification, so that model result differences between Pakistan and Canada can be discussed in terms of extent of the role of parameters of model variables as well as those that determine shock persistence and its variance in determining model outcomes, especially under productivity and global demand shocks. In a data scarce environment, estimating parameters and bringing together latest information on others together on a same platform is rather challenging.

This paper's contribution is multifold. First, to the best of our knowledge, the existing literature applies a unified DSGE framework to compare shock transmission only within developed economies. Such comparison between a developing and a developed economy is rarely undertaken. This study fills this gap to an extent by applying the original, unmodified Gali & Monacelli (2005) framework to both Pakistan and Canada. We believe that this approach will be followed extensively in recent future given the rising role of Artificial Intelligence and Machine Learning in estimating parameters. Second, we compile and construct a Pakistan-specific calibration of parameters of the Gali & Monacelli (2005) model. We estimated some parameters directly and that way contributed to the literature. Some parameters are adopted from recent literature on Pakistan including few from (Ahmed, et al. 2026; Ahmad, et al. 2018). For each parameter, we reported its data source, sample period, estimation methodology, literature reference and the mapping between the empirical measure and its theoretical counterpart. Third, we compare the resulting impulse responses to positive productivity and world demand shocks against the original Canada calibration. We then systematically identify sources of the differences in impulse response parameter by parameter and by parameter block (preferences, openness and substitution, price rigidity, the policy rule, and shock persistence). These findings provide policymakers with a reasonably clear picture about structural issues that impede performance for Pakistan. Fourth, we undertook extensive

mechanical parameter sensitivity exercises to identify which structural features are most influential in shaping the economic response and play critical role in the divergence.

After calibrating the model parameters for Pakistan, the impact of two exogenous shocks on model variables is analysed for both countries (Pakistan and Canada). Key results under the positive productivity shock include the following: (i) Initially Pakistan depicts a relatively higher increase in output due to the higher sensitivity of potential to productivity changes, however, the impact dissipates quickly due to low persistence of the productivity shock. (ii) There is lower disutility of labour supply due to large population, higher unemployment and lower wages. (iii) Price adjustment is quicker due to lower competitive market structure; hence, inflation rebounds rather quickly.

Under the positive world demand shock, (i) Pakistan depicts a relatively persistent increase in output due to less disutility from supplying labour. (ii) However, appreciation in exchange rate is less due to lower degree of openness. (iii) Since domestic prices have higher sensitivity with regards to the output gap that closes quickly in response to higher global demand, deceleration in CPI inflation is low.

The paper is structured as follows: Section 2 outlines the key features of the adopted DSGE model, and discusses the parameter calibration process, while Section 3 and 4 present the results and the concluding remarks, respectively.

2. MODEL

Gali & Monacelli (2005) presents a DSGE model for a small open economy (SOE) operating in a global environment. The global economy is considered as a continuum of many small open economies, represented by a unit interval $[0, 1]$, where each point i corresponds to a small open economy. Hence, it is possible to focus on the dynamics of a SOE without having a major impact on the global economy.

Important model features include the following:

- Under budget constraints, the representative household within the SOE aims to optimise utility from both imported and domestic consumption goods and leisure.
- The household has access to foreign financial instruments that allow households to optimise their consumption and savings decisions, ensuring intertemporal utility maximisation.
- Firms in the SOE produce differentiated goods by combining labour with technology, with labour supplied by the households.
- The model employs the Calvo price-setting mechanism, where firms stagger their price adjustments.
- The optimal decisions made by both the household and firms, given their respective constraints, jointly determine the equilibrium in the SOE, thus capturing the interactions between consumption, production, and monetary policy under an inflation targeting setup.
- The natural level of output (Potential) is expressed as highlighting the role of productivity (a_t) and world demand (y_t^*) in shifting the potential of the SOE:

$$\bar{y}_t = \Omega + \Gamma a_t + \alpha \Psi y_t^* \quad (1)$$
- In SOE, the domestic output is defined as function of world output and term of trade (s_t):

$$y_t = y_t^* + \frac{1}{\sigma_\alpha} s_t \quad (2)$$

- The deviation of domestic output y_t from its natural level $\bar{y}_t$ is the output gap x_t , which is expressed in term of forward looking IS equation as:

$$x_t = E_t\{x_{t+1}\} - \frac{1}{\sigma_\alpha} (r_t - E_t\{\pi_{H,t+1}\} - \bar{r}\bar{r}_t) \quad (3)$$

- The above equation illustrates how output gap depends on expected future output gap $E_t\{x_{t+1}\}$ and deviation of ex-ante real interest rate $(r_t - E_t\{\pi_{H,t+1}\})$ from natural interest rate $(\bar{r}\bar{r}_t)$.
- Furthermore, the proportionality of real marginal cost with the output gap led to a version of New Keynesian Phillips Curve (NKPC) as:

$$\pi_{H,t} = \beta E_t\{\pi_{H,t+1}\} + \kappa_\alpha x_t \quad (4)$$

- Where domestic inflation is defined as the function of expected future domestic inflation and output gap. This is identical to that of closed economy. The difference occurs only in the slope parameter κ_α , which incorporates the effect of trade openness. While the CPI inflation is expressed in terms of domestic inflation and terms of trade changes:

$$\pi_t = \pi_{H,t} + \alpha(s_t - s_{t-1}) \quad (5)$$

- The nominal exchange rate (e_t) is defined as the domestic currency price of one unit of foreign currency. Therefore, a decline in e_t represents an appreciation of the domestic currency, while an increase represents a depreciation. The exchange rate is determined by the uncovered interest parity (UIP) condition under the assumption of perfect capital mobility and no risk premium:

$$r_t - r_t^* = E_t\Delta e_{t+1} \quad (6)$$

- In order to control inflation, the central bank monetary policy rule is defined on the basis of *stylised Taylor-type rule* as:

$$r_t = \rho + \phi_\pi \pi_t \quad (7)$$

For easier tractability, the monetary policy rule responds to CPI inflation only. The exchange rate does not explicitly enter the policy rule; however, its impact is encompassed within inflation.

- Altogether, this is a small open economy model derived from the structure of a closed economy's sticky-price model used in monetary policy analysis. However, in the open economy model, additional parameters account for the economy's degree of openness and the substitutability between domestic and foreign goods².

2.1. Shocks of Interest

The model is driven by the two types of exogenous shocks: (a) domestic productivity (a_t) and (b) world demand (y_t^*), that are defined as AR (1) process:

$$a_t = \rho_a a_{t-1} + \varepsilon_t^a \quad (8)$$

$$y_t^* = \rho_y y_{t-1}^* + \varepsilon_t^* \quad (9)$$

Here, ρ_a and ρ_y measure the persistence of shocks – the extent to which the effects of a shock last over time. The value closer to one represents that shock has long lasting impact, whereas closer to zero represents the quicker return to steady state. ε_t^a and ε_t^* , are independently and identically distributed stochastic terms, which represents the unexpected changes in labour productivity and world demand.

² Complete log linearised model is given under Annexure A1.

A positive productivity shock ($\varepsilon_t^a > 0$), increases the potential output and reduces the marginal cost, which in turn increases the domestic output and reduces the inflation from steady state. In result, policy rate, which react to overall inflation, also decreases.

Similarly, a positive world demand shock³ ($\varepsilon_t^* > 0$), increases the domestic output due to higher foreign demand, but reduces the imported inflation burden through the favourable terms of trade. As a result, inflation falls to which monetary policy reacts by reducing the policy rate.

2.2. Calibration

There are several ways for calibrating the parameters of DSGE models. The most typical way is to match the model's moments with their corresponding data-driven moments, which is known as moment matching calibration. Another method is to directly calibrate parameters using data, existing structural estimations, or well-established standards from the literature, known as direct calibration. Furthermore, Bayesian estimation uses prior knowledge and observed data to estimate structural parameters (Canova, 2011).

Using the direct calibration approach, we calibrated the SOE DSGE model for the Pakistan economy using the most appropriate source of information for their economic interpretation and data availability. We estimated various parameters, such as import share in domestic consumption, disutility from labour supply, optimal markup on MC, and domestic labour productivity persistence, using historical macroeconomic data and econometric methodologies that were compatible with their theoretical specification. In the absence of direct empirical parallels, institutional proxies are used to calibrate a parameter such as employment subsidies (Table 1). Furthermore, some parameters from latest DSGE research are adopted, such as time preferences, CRRA, substitutability between domestic and international commodities, monetary policy response to inflation, and elasticity of substitution between differentiated goods (Table 2). While parameters such as the elasticity of substitution between items produced in a foreign economy and the persistence of a global output shock are kept from Gali & Monacelli (2005), as they remain identical across economies (Table 3). However, for Canada, we adopted the original calibration provided in Gali & Monacelli's (2005) work.

2.2.1. Parameter Calibration for Pakistan and Canada

- The discount factor (β) and CRRA (σ): β (representing the preference of future consumption over current consumption) and σ (showing households' willingness to substitute consumption intertemporal) are taken from the latest study of Ahmed, et al. (2026). For the estimation, they used Generalized Method of Moments (GMM) technology. The estimation was based on annual and quarterly data on per capita real private consumption, real interest rate, and natural real interest rate from 1978 to 2024. To ensure robustness, the parameters were calculated using various data frequencies, sample durations, and utility function specifications. In this study, they used average values that came from different utility function specifications and different data frequencies⁴. However, for Canada, these parameters are assumed from a benchmark for developed economies. If we compare the values of both parameters, the discount factor is slightly lower, while CRRA is significantly lower in Pakistan, relatively. This suggests that households in Pakistan are somewhat adaptable to

³ Throughout this paper, a world demand shock refers to an exogenous shock to world output, proxied by USA GDP.

⁴ For more details, please see Ahmed, et al. (2026), *SBP Working Paper No. 121*.

economic uncertainty, likely due to limited access to long-term financial products, low savings, and low financial literacy.

- Degree of openness (α): This parameter is calibrated based on the information from the Consumer Price Index (CPI) basket (base year: 2015-16) and the ratio of imports to nominal GDP. The CPI basket indicates that imported goods account for 15 percent of the consumption basket, while the average ratio of import to nominal GDP from FY12 to FY24 is 14.2 percent. These values are closely aligned, suggesting consistency between consumption and production-side measures of openness. Since α represents the share of imported goods in the CPI basket, we use the CPI-derived value of 0.15 in our calibration. This parameter is relatively lower for Pakistan, reflecting its limited integration with world economy.
- Disutility from supplying labour (φ): To calibrate the elasticity of disutility from labour supply (φ), we estimated log-linearised equation $C_t^\sigma N_t^\varphi = \frac{W_t}{P_t}$, following Gali & Monacelli (2005). By transforming this into $\Delta \ln \left(\frac{W_t}{P_t} \right) = \sigma \Delta \ln(C_t) + \varphi \Delta \ln(N_t)$, we regress the growth rate of real wages on the changes in per capita consumption (C_t) and labour supply (N_t). Our estimation yields a φ value of 0.70, suggesting a somewhat elastic labour supply, where individuals experience growing costs in terms of utility but still respond to incentives like wage increases. Such a value aligns with the economic structure of developing economies like Pakistan, where labour markets exhibit moderate flexibility, and workers are sensitive to shifts in real wages.
- Optimal markup on marginal cost (μ): The parameter μ models firm's pricing strategy. For Canada, this parameter is derived from elasticity of substitution (ε), such as $\mu = \frac{\varepsilon}{\varepsilon-1}$. However, in Pakistan, it is calculated directly from enterprises' financial data, providing a more accurate assessment. We computed it using the sales-to-cost ratio as a proxy for the markup. We also derived this parameter from the elasticity of substitution (ε), and the results are consistent with the value obtained using financial data. The value of this parameter is slightly low in Pakistan relatively.
- Persistence of Domestic Productivity Shock (ρ_a): For Canada, Gali & Monacelli (2005) calibrated this parameter by fitting an AR (1) model to Canada's log labour productivity quarterly Hodrick-Prescott (HP) filtered data. To calibrate this parameter for Pakistan, we used the same methodology. We estimated an AR (1) process using HP-filtered, seasonally adjusted labour productivity data (1978Q1–2021Q4) on Pakistan. In Pakistan, the labour productivity shock is found to be comparatively less persistent.
- Employment subsidy parameter (τ): In Gali & Monacelli's model, this parameter represents the government subsidy provided to firms that lowers the effective marginal cost of labour. As in the context of Pakistan, we did not find direct data on employment subsidy, therefore, we proxied it by the business subsidies. Although this proxy does not represent employment subsidies in the strict theoretical sense, it closely reflects government support that reduces firms' production costs, consistent with the economic role of the employment subsidy in the model.
- Elasticity of substitution between domestic and foreign good (η): For Pakistan, this parameter is taken from Ahmad, et al. (2018), where it is derived from Bayesian estimation using actual data. However, for Canada, the value is assumed based on

benchmark, the value of this parameter is relatively lower for Pakistan, indicating a lower scope for substitution.

- Calvo price stickiness parameter (θ): For Pakistan, this parameter is taken from Ahmad, et al. (2018), who estimated this parameter using Bayesian DSGE model, by setting the prior equal to the estimates provided by Choudhary, et al. (2011, 2016) from survey data on price setting behaviour of firms. However, for Canada, this parameter is assumed based on the conventional calibration of an average period of one year between price adjustment. The value of this parameter shows that prices in Pakistan adjust relatively more quickly.
- Response of monetary policy rule to inflation (ϕ_π): For Pakistan, this parameter is taken from Ahmad, et al. (2018), while for Canada, the value of parameter is set following the standard Taylor rule. This parameter is slightly higher for Pakistan, relatively.
- Elasticity of Substitution Between Goods produced in Foreign Economies(γ): it is assumed that this parameter remains uniform across small open economies regardless of domestic characteristics.
- Persistence of World Demand Shock (ρ_y): Global business cycle shocks are assumed to have similar persistence for small open economy such as Pakistan and Canada; thus, the value of parameter is identical.

Based on the calibrated primitive parameters described above, the relevant composite parameters are derived using the model's theoretical relationships. The values obtained for Pakistan and Canada are listed in Table 4.

Table 1
Parameters Estimated Using Pakistan Data or Structural Estimates

Parameter	Definition	Canada	Pakistan	Reference/Remarks
Alpha (α)	Degree of openness (Share of imported goods in domestic consumption)	0.40	0.15	Estimated using the latest data from Consumer Price Index (CPI) basket (base year: 2015-16)
Phi (φ)	Disutility from supplying labour	3.00	0.70	Estimated by regressing the growth rate of real wages on the changes in per capita consumption (C_t) and labour supply (N_t) ⁵
Mu (μ)	Optimal markup over marginal cost	1.20	1.16	Estimated by using financial data of firms listed on the Pakistan Stock Exchange (PSX) between 2005 to 2019
Rhoa (ρ_a)	Persistence of domestic productivity shock	0.66	0.23	Estimated using HP-filtered, seasonally adjusted labour productivity data (1978Q1–2021Q4). Calculated as a six-year average (FY18-FY24) of proportion of total subsidies allocated to business, based on budget estimates.
Tau (τ)	Employment subsidy	0.76	0.70	

⁵ The data is sourced from SBP and Asian Productivity Organization (APO) from 1970 to 2021.

Table 2
Parameters Adopted from Previous DSGE Studies

Parameter	Definition	Canada	Pakistan	Reference/Remarks
Beta (β)	Time preference (Discount Factor)	0.99	0.98	Ahmed, et al. (2026)
Sigma (σ)	Coefficient of Relative Risk Aversion (CRRA)	1.00	0.31	Ahmed, et al. (2026)
Eta (η)	Elasticity of substitution between domestic and foreign goods	1.00	0.78	Ahmad, et al. (2018)
Theta (θ)	Calvo price stickiness parameter	0.75	0.49	Ahmad, et al. (2018)
Phi (ϕ_π)	Monetary policy response to inflation	1.50	1.55	Ahmad, et al. (2018)
Epsilon (ϵ)	Elasticity of substitution among differentiated goods	6.00	7.20	Sharma and Behera (2022)

Table 3
Benchmark Parameters Retained from Gali & Monacelli (2005)

Parameter	Definition	Canada	Pakistan	Reference/Remarks
Gamma (γ)	Elasticity of substitution between foreign-produced goods	1.00	1.00	Gali & Monacelli (2005)
Rho (ρ_y)	Persistence of world output shock	0.86	0.86	Gali & Monacelli (2005)

Table 4
Derived Model Parameters⁶

Parameter	Definition	Canada	Pakistan	Formula
Sigma_a (σ_a)	Sensitivity of domestic output to terms of trade	1.00	0.44	$\sigma_a = \frac{\sigma}{(1-\alpha) + \alpha\omega}$ Where; $\omega = \sigma\gamma + (1-\alpha)(\sigma\eta - 1)$
Rho (ρ)	Discount rate (Log of discount factor)	0.01	0.02	$\rho = \beta^{-1} - 1$
Tau_n (Γ)	Sensitivity of natural level of domestic output to productivity	1.00	1.49	$\Gamma = \frac{1 + \varphi}{\sigma_a + \varphi}$
Theta_n (θ)	Part of sensitivity of natural interest rate to expected change in world output	0.00	-1.25	$\theta = (\sigma\gamma - 1) + (1-\alpha)(\sigma\eta - 1) = \omega - 1$
Xi_n (Ψ)	Sensitivity of natural level of domestic output to world output	0.00	1.79	$\Psi = -\frac{\theta\sigma_a}{\sigma_a + \varphi}$
Kappa_a (κ_a)	Sensitivity of inflation to output gap in Philips curve	0.34	0.62	$\kappa_a = \lambda(\sigma_a + \varphi)$ Where $\lambda = \frac{(1-\beta\theta)(1-\theta)}{v - \mu}$
Omega_n (Ω)	Constant representing the natural level of output	-0.13	-0.17	$\Omega = \frac{v - \mu}{\sigma_a + \varphi}$ Where $v = -\log(1 - \tau)$ and $\mu = \frac{\epsilon}{\epsilon-1}$

⁶ These parameters are the functional transformations of the baseline parameters provided above in the Table 1, 2 and 3.

3. RESULTS

The Impulse Response Functions (IRFs) of key macroeconomic variables are computed using parameters in Table 1 to 4 for Pakistan and Canada. The magnitude of shocks applied to both countries correspond precisely to those used in the original study, i.e. one standard deviation of labour productivity and world demand shocks⁷.

3.1. Domestic Labour Productivity Shock

In the simulation, the one standard deviation shock⁸ is applied to the domestic labour productivity, and its dynamic impact on output, inflation, interest rate and exchange rate are analysed in Fig. 1 as given below:

Fig. 1. Response of Key Macroeconomic Variables to Domestic Labour Productivity Shock

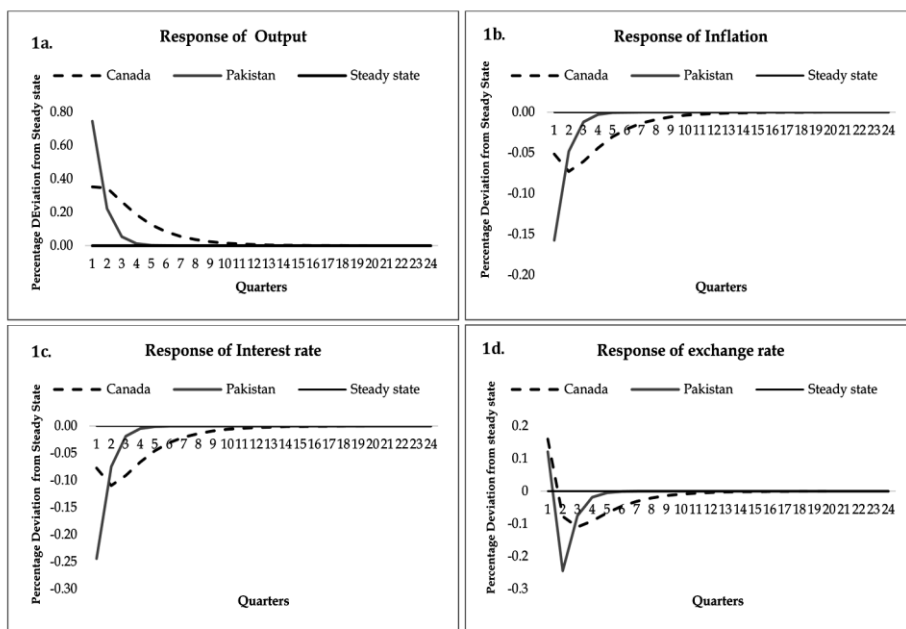


Figure 1 shows different IRFs paths in response to the productivity shock arises from differences in parameters. Particularly, Figure 1a describes the response of output to the shock. Here we can clearly see that initial Pakistan output response is much sharper than Canada. The difference can be explained by the larger response of potential output to productivity changes. The productivity transmission coefficient, $\Gamma = (1 + \varphi)/(\sigma_a +$

⁷ In this study, our objective is to compare the propagation mechanism rather than the effects of differences in shock volatility. Accordingly, the IRFs are based on equal normalised structural shocks. Using country-specific shock standard deviations would only rescale the magnitude of the responses; it would not change the qualitative pattern, direction, or transmission mechanism of the IRFs in this linear model.

⁸ We retain the original calibration of the exogenous shocks. The standard deviation of productivity shock is set to 0.0071 as given in Gali & Monacelli (2005).

φ) is determined by the interaction of household preferences, labour supply, trade openness, and trade elasticities. For Pakistan, numeric values of both parameters are less than Canada. However, the denominator value due to σ_a , dominates the overall results, making Pakistan output more sensitive to the productivity changes. Pakistan's calibration generates a significantly lower value of σ_a , mainly due to its lower coefficient of relative risk aversion and lower degree of openness. The degree of openness in Pakistan shows that household consume more domestically produced goods. Following a positive productivity shock, higher productivity raises real income and consumption, which in turn increases aggregate demand of domestic produce goods, resulting in a stronger response of domestic output. This impact is further amplified by household less risk averse behaviour towards changes in consumption pattern in Pakistan.

However, Pakistan has a short-lived response, as output returns to the steady-state within five quarters, while for Canada it is initially smaller but much more durable, converging back to the steady-state in twelve quarters. The lower persistence parameter explains these dynamics. The model results highlight the importance of persistence in this regard. The lower persistence could be due to various structural issues in Pakistan like inadequate capital, weaker technological absorption, and lower financial inclusion. Identifying the relative importance of these factors is beyond the scope of the present study and represents a useful avenue for future research.

Inflation declines in both economies due to the excess supply generated by productivity shocks; however, the magnitude and convergence differ (Figure 1b). Pakistan has seen a more significant drop in inflation, which can be attributed to the higher speed of adjustment price in Pakistan than Canada as reflected by price stickiness parameter. When combined with the lower persistence of shock, it results in a short-lived response of inflation, as it converges to steady state within six quarters. The similar pattern is followed by interest rate (Figure 1c). To bring the supply and demand equal, interest rates must be adjusted to boost consumption and aggregate demand while accounting for the production and inflation dynamics. Both Pakistan and Canada, experienced the adjustment in interest rate to bring the inflation back to its steady state. However, the adjustment of interest rate in Pakistan is larger and short lived.

In contrast, Canada's response is more gradual, a stronger interest rate adjustment initially, but inflation and output return to their steady-state levels at a slower pace. This gradual response is indicative of the more resilient economic framework in Canada, where inflationary pressures are absorbed over time, allowing for a smoother transition back to equilibrium. Thus, the difference in the speed and scale of response between two countries reflects differences in monetary transmission mechanism and structural characteristics.

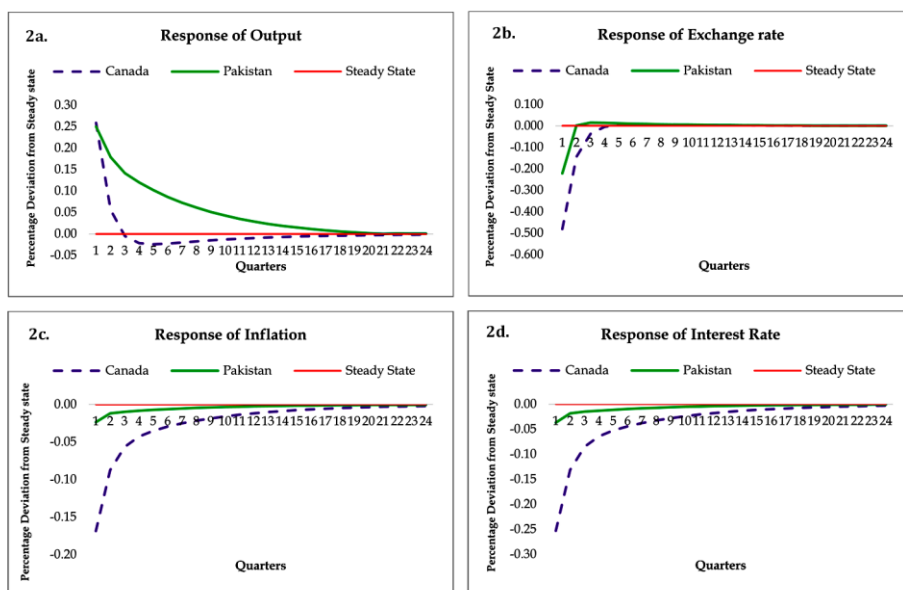
These dynamics also interact with exchange rate movements, particularly in response to labour productivity shocks (Figure 1d). In such cases, the exchange rate initially depreciates before eventually appreciating. The behaviour can be understood through the lens of Uncovered Interest Parity (UIP) condition. Assuming global interest rate remain stable, a reduction in domestic interest rates relative to global rates makes foreign assets more attractive, leading to capital outflows and a depreciation of the domestic currency. However, as inflation declines, domestic goods become more competitive in international markets, increasing demand for the local currency and driving their appreciation in the future. This interplay between interest rate differentials and inflation dynamics explains the eventual reversal of the initial depreciation.

3.2. World Demand Shock

A one standard deviation shock⁹ is introduced to world demand in the simulation, and the subsequent responses of output, inflation, interest rate, and exchange rate are depicted in Figure 2, as given below:

Figure 2a displays impulse responses of Canada and Pakistan to a positive world demand shock. Although the initial responses are broadly similar, Pakistan's output takes longer to return to its steady state than Canada's. The difference is primarily driven by two parameters, disutility of supplying labour and lower CRRA¹⁰. Households' greater willingness to increase labour supply in response to higher demand, and higher consumption response to changes in income encourage a more sustained expansion in economic activity. Lower CRRA affects derived parameter σ_a , making it much smaller than Canada. A larger coefficient $1/\sigma_a$, makes aggregate demand more responsive to changes in the gap in real and natural real interest rate. Since monetary policy adjusts only gradually, the actual real interest rate remains temporarily below its natural level, which in turn keeps stimulating aggregate demand through the IS curve, hence, resulting in a more persistent output response.

Fig. 2. Response of Key Macroeconomic Variables to World Demand Shock



As increase in world demand boosts export, leading both Pakistan and Canada experience an appreciation in exchange rate, however, with different magnitude and persistence (Figure 2b). Pakistan exhibits a smaller and short-lived response due the calibrated

⁹ The world demand shock is set to 0.0078 following the Gali & Monacelli (2005).

¹⁰ The lower coefficient of relative risk aversion (CRRA) implies that household are highly willing to substitute consumption across period, hence increasing the sensitivity of aggregate demand and affecting the slope of IS curve. As the export led income rises during the shock, the households increase their domestic consumption rather than smoothing it over time, which keeps the domestic aggregate demand high along with foreign demand.

structural parameters governing household preferences and consumption. Particularly, the low CRRA implies that extra income generated through external demand shock is quickly directed into consumption, absorbing the shock and shortening the appreciation of exchange rate.

Following the exchange rate appreciation, both countries see a decline in inflation due to lower cost of imported goods (Figure 2c). However, Pakistan's disinflationary impact is weaker than Canada. This is due to interplay of the parameters. The first parameter is the degree of openness, which in this model is defined as the share of imported goods in the consumption basket. Pakistan has a lower degree of openness; therefore, the exchange rate appreciation has a weaker disinflationary impact on Pakistan's CPI inflation. The second parameter is the coefficient of relative risk aversion (CRRA), which has a lower numerical value in Pakistan. A positive global demand shock increases the income of domestic households, which are less risk averse in Pakistan. Consequently, they spend more of their additional income on consumption, increasing domestic demand which creates a larger output gap. Through the Phillips curve, combined with lower price stickiness, this raises domestic inflation which partially offsets the disinflation coming from cheaper imports.

The implication of these dynamics is evident in the response of interest rate depicted in (Figure 2d), where both Pakistan and Canada cut their interest rate. However, Pakistan shows a cautious approach to inflation which results in slower response. The interplay of higher domestic inflation in response to higher demand and decline in imported inflation amidst appreciation, as discussed above, the central bank perceives less inflationary pressure and adjust interest rates gradually. However, it may prolong economic vulnerability such as prolonging output gap by delaying economy's return to equilibrium. Canada, on the other hand, moves quickly to stabilise inflation and output with decisive interest rate adjustments. A substantial and sustained appreciation of the exchange rate in Canada helps stabilise inflation, allowing for more focused and effective interest rate adjustments. This aids Canada's ability to anticipate and respond to shocks effectively.

3.3. Sensitivity Analysis

We conducted parameter simulation exercises to analyse the sensitivity of IRF to the parameters for both shocks. Initially, we kept all other parameters identical to Canadian benchmark values and replaced only one parameter at a time with its Pakistan-specific estimates. Second, we changed the parameter in sequence, starting with the Canadian calibration and gradually adding the Pakistan-specific parameter. Each consecutive simulation keeps all previously substituted parameters while adding one more Pakistan-specific parameter, with the final specification reflecting the whole Pakistan calibration. For brevity, we report only the response of output to the domestic labour productivity shock. The results are reported in annexures A2 and A3. However, the same simulation exercises were carried out for other variables such as inflation, exchange rate and interest rate under both domestic labour productivity and global demand shocks¹¹.

The results of the simulation exercises validate the findings reported in Section 3.1 and 3.2 by confirming that the difference in the responses of Pakistan compared to those of Canada are primarily driven by coefficient of relative risk aversion, trade openness, price stickiness, disutility for labour supply, and persistence of productivity shock. In

¹¹ Results for the remaining variables under both shocks are qualitatively similar and are available from the authors upon request.

contrast, the parameters pertaining to the discount factor, employment subsidy, and response of monetary policy to inflation have little relative impact under both simulation exercises.

3.4. Importance of Increasing Productivity for Pakistan

According to the analysis above, the country's ability to react to shocks is influenced by underlying structural parameters such as persistence of productivity shock, CRRA, price stickiness, disutility from supplying labour etc. However, even when several parameters are important at the same time, altering just one – persistence of productivity – can change the macroeconomic picture as a whole. In Pakistan, Persistence of productivity shock is relatively low, and the mechanical increase in this parameter leads to significantly large cumulative macroeconomic effects.

This exercise emphasises productivity persistence as a significant structural parameter in the model, but it does not specify how such an increase may be accomplished in practice. From a policy standpoint, changes aimed at developing human capital, promoting technological adoption and innovation, strengthening institutions, and upgrading infrastructure are frequently viewed as measures that can enable more sustained productivity gains.

Table compares cumulative responses over 12 quarters under two scenarios for Pakistan: one with lower persistence at $\rho_a = 0.23$, which represents Pakistan's own estimate, and another with higher persistence equivalent to the level seen in Canada $\rho_a = 0.66$.

Table 5
Cumulative Response to Labour Productivity Shock (12 Quarters)

Variables	$\rho_a = 0.23$	$\rho_a = 0.66^{12}$
Output	1.04	2.80
Inflation	-0.22	-0.39
Interest rate	-0.34	-0.60
Exchange rate	-0.24	-0.39

The results in Table 5 reveal several important insights:

- Output: With lower persistence, the cumulative output gain is only 1.04 percent above steady state over twelve quarters (three years). In contrast, with higher persistence, the cumulative output gain would be more than double – 2.80 percent above steady state, highlighting the importance of structural reforms required to sustained productivity shock.
- Inflation: Under low persistence, inflation falls by cumulatively 0.22 percent below the steady state over twelve quarters, whereas under higher persistence, the decline is larger – 0.39 percent, allowing the economy to experience both higher output and lower inflation simultaneously.
- Interest rate: Similar pattern is followed by interest rate. It declines more sharply (0.34 versus 0.60, percent below steady state), when moving from lower to higher persistence, indicating the greater monetary space to sustain investment and consumption.

¹² Equivalent to Canada's value given in Gali & Monacelli (2005).

- Exchange rate: Cumulative appreciation in exchange rate will be increased by 0.15 percent, in the higher persistence scenario, underscoring the importance of productivity persistency in improving the country's external competitiveness and attractiveness for capital inflows.

4. CONCLUSION

The analysis of this study reveals that Pakistan's economy has higher sensitivity of potential to productivity changes, higher sensitivity of inflation output gap, lower price stickiness, lower degree of openness, lower disutility from supplying labour, lower CRRA, and lower persistence of productivity shocks. These findings carry direct implications for policymakers.

The results suggest that if Pakistan could address the structural issue relating to persistence of productivity shock, the gain in output would more than double over the twelve quarters, while also allow the economy to simultaneously experience the lower inflation, greater monetary space and higher appreciation in exchange rate. To achieve such higher persistence, it is essential to focus on reforms such as consistent investment in human and physical capital, technology adoption, and building institutional capacity, so that the benefits of increased productivity are not short-lived.

In Pakistan, prices are less sticky than in Canada. This implies that firms adjust their prices more frequently in response to changes in economic conditions of Pakistan. Consequently, domestic prices respond more rapidly to demand and supply shocks, leading to a stronger short-run inflation response through the Phillips curve. While the model does not explicitly analyse inflation expectations or central bank credibility, the greater responsiveness of inflation highlights the importance of maintaining well-anchored inflation expectations through a credible monetary policy framework.

In addition, limited openness and low value-added exports highlight the need for diversification to better capture benefits from global demand shocks. Another important finding is that the households in Pakistan are highly willing to substitute consumption across the periods in response to changes in real interest rates, thereby emphasising the importance of promoting financial literacy and safe investment avenues, so that household could smooth their consumption efficiently over time.

ANNEXURE

A1

Complete Log-Linearised Model

All variables below are log-deviations from steady following Galí and Monacelli (2005). Composite (Derived) model parameters (Greek capitals and subscripted lower-case Greek letters other than the primitives listed in Table-1) are defined in the subsequent section.

New IS Curve of SOE: $x_t = E_t\{x_{t+1}\} - \frac{1}{\sigma_\alpha} (r_t - E_t\{\pi_{H,t+1}\} - \bar{r}_t)$

Definition of natural rate of interest in SOE: $\bar{r}_t = \rho - \sigma_\alpha \Gamma(1 - \rho_\alpha) a_t + \alpha \sigma_\alpha (\theta + \Psi) E_t\{\Delta y_{t+1}^*\}$

Phillips Curve of the SOE: $\pi_{H,t} = \beta E_t\{\pi_{H,t+1}\} + \kappa_\alpha x_t$

Definition of Natural Level of Output of SOE: $\bar{y}_t = \Omega + \Gamma a_t + \alpha \Psi y_t^*$

Monetary Policy Rule: $r_t = \rho + \phi_\pi \pi_t$

Wedge between domestic and world output: $y_t = y_t^* + \frac{1}{\sigma_\alpha} s_t$

Wedge between domestic and CPI inflation: $\pi_t = \pi_{H,t} + \alpha(s_t - s_{t-1})$

Definition of CPI inflation: $\pi_t = p_t - p_{t-1}$

Definition of domestic inflation: $\pi_{H,t} = p_{H,t} - p_{H,t-1}$

Definition of terms of trade: $s_t = e_t + p_t^* - p_{H,t}$

Foreign inflation is set to be zero: $\pi_t^* = 0$

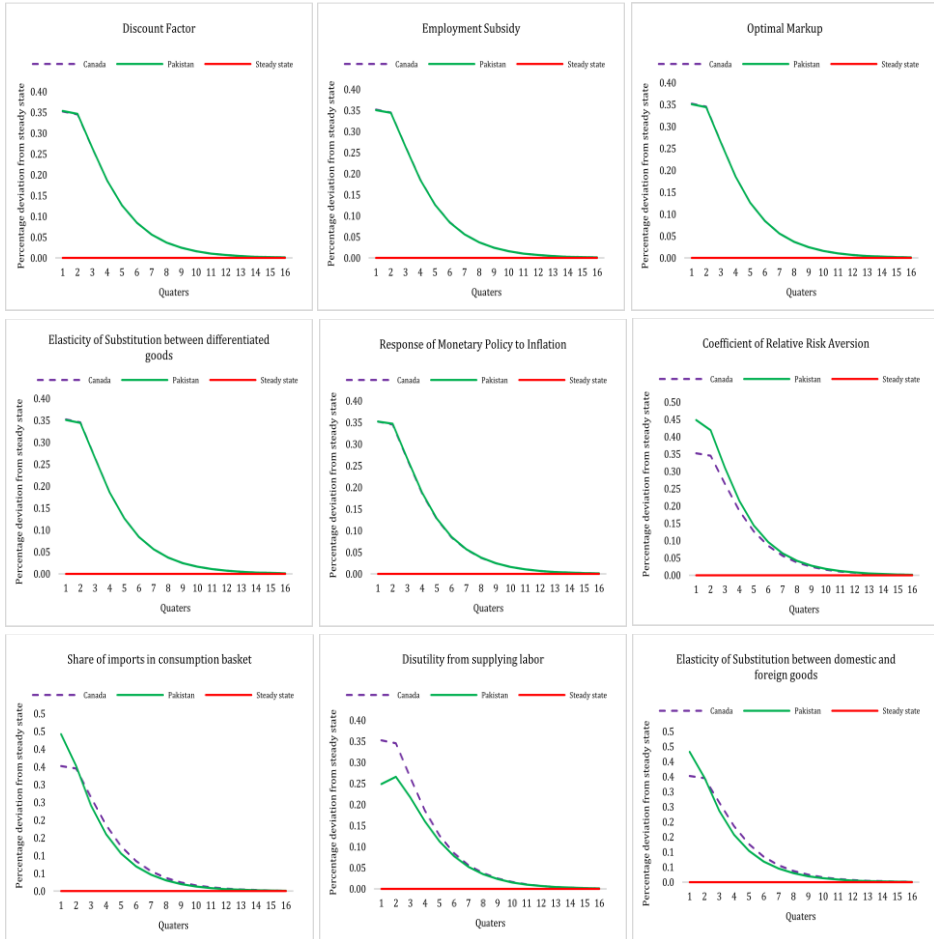
Uncovered Interest rate Parity, set world interest rate to zero: $r_t - r_t^* = E_t\{\Delta e_{t+1}\}$

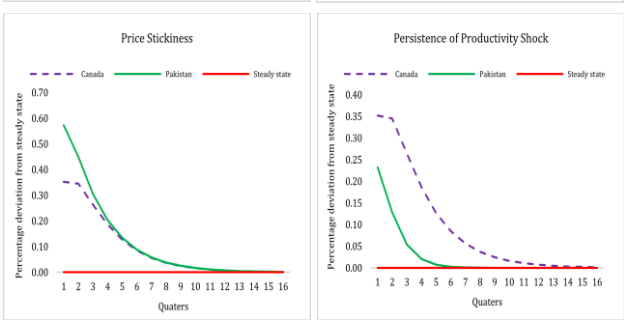
Exogenous Process of Productivity in SOE: $a_t = \rho_a a_{t-1} + \varepsilon_t^a$

Exogenous Process of World Output: $y_t^* = \rho_y y_{t-1}^* + \varepsilon_t^*$

A2

Individual Parameter Sensitivity Analysis: Response of output to domestic labour productivity shock





A3

Cumulative Parameter Sensitivity Analysis: Response of output to Domestic labour Productivity shock



A4

Matlab/Dynare Code for Generating IRFs:

```

// Model: NK_GM05
// Further references:
// Galí, Jordi, and Tommaso Monacelli (2005) “Monetary Policy and Exchange Rate
// Volatility in a Small Open Economy” Review of Economic Studies 72, 707-734.
// Created: 2010/02/07 by Likun Wang
// Policy regime: CITR
//for IRF figures, the following parameter setting should be used:
//rhoa = 0.9; //parameter of AR (1) for a,
//rhoy = 0.9; //parameter of AR (1) for y_star
//var a_ = 1^2; //the SD of productivity in SOE, it is 1 here, coz IRF in the paper is shocked
by 1 (other than a Standard Deviation)

//var ystar_ = 1^2; //the SD of world output, it is 1 here,
//for the SD in table 1, the following parameter setting should be used:(as in this code)
//rhoa = 0.66; //parameter of AR (1) for a,
//rhoy = 0.86; //parameter of AR (1) for y_star
//var a_ = 0.0071^2; //the SD of productivity in SOE, it is 1 here, coz IRF in the paper is
shocked by 1 (other than a Standard Deviation)

//var ystar_ = 0.0078^2; //the SD of world output, it is 1 here,
//world economy exogenous (output is exogenous, and world monetary policy is setting
world interest rate to 0,)

//but in the Gali (2002) NBER working paper, they also modeled the dynamics of world
economy, i.e.

//looking into the world IS curve, world Phillips curve, and exogenous dynamics of world
productivity

//this model includes (1) Philips Curve of SOE (2) def. of nature level of output of SOE
// (3) New IS Curve of SOE (4) def. of nature rate of interest rate of SOE
// (5) def. of outout gap of SOE (6) monetary policy rule in SOE, (only DITR is possible
here, coz CITR need CPI inflation, PEG need nominal exchange rate

// (7) exogenous process of productivity (8) exogenous process of world output
// above equations are all the same with my first try, treat it as the counterparts of closed
economy

// (9) wedge between domestic and world output (10) wedge (gap) between domestic and
CPI inflation

// (11) def. of CPI inflation (12) def. of domestic inflation (PPI)
// (13) def. of Terms of Trade (14) Uncovered Interest Rate Parity
// (15) foreign inflation
var pih x y ynat rnat r s pi p ph e ystar a pistar;

// endogenous variables,
// r = interest rate / policy rule (DITR / CITR / PEG)
// pih = domestic inflation in SOE, x = output gap, y = output,
// ynat = natural level of output in SOE, rnat = natural rate of interest rate in SOE,

```

```

// s = term of trade (TOT) in SOE e = nominal exchange rate for home country
// pi = CPI inflation p = price level in SOE
// ph = domestic price level (PPI) rstar = world interest rate
// ystar = world output, a = productivity in SOE
// pi_stsr= world inflation,
varexo ystar_ a; // exogenous variables (innovations)

// a_ = shocks in productivity in SOE
// ystar_ = shocks in world output
parameters sigma rho tau alpha theta xi beta kappa omega phipi rhoa rhoy;

sigma = 1;
rho = 0.0101;
tau = 1;
alpha = 0.4;
theta = 0;
beta = 0.99;
kappa = 0.3433;
omega = -0.1277;
xi = 0;
phipi = 1.5;
rhoa = 0.66; //parameter of AR (1) for a,
rhoy = 0.86; //parameter of AR (1) for y_star

model(linear);
x = x(+1) - sigma^(-1)*( r - pih(+1) - rnat) ; //1 New IS Curve of SOE, equ. (37) in the
paper

rnat = -sigma*tau*(1-rhoa)*a + alpha*sigma*(theta+xi)*(rhoy-1)*ystar; //2 def. of
nature rate of interest rate of SOE, the last term of plugged  $E[d\_ystar(t+1)]=(rhoy-1)*ystar$ 
in the equ below (37)
pih = beta * pih(+1)+ kappa*x; //3 Philips Curve of the SOE, equ. (36) in the paper
ynat = tau*a + alpha*xi*ystar; //4 def. of nature level of output of SOE, equ. (35) in the
paper

x = y - ynat; //5 def. of outout gap of SOE
//pih = 0; //DIT optimal rule
//r = phipi*pih; //DITR //6* monetary policy rule in SOE, (DITR / CITR / PEG) r = phipi*pi;
//CITR
//e = 0; //PEG
//pi = 0; //CIR in NBER 2002 paper

y = ystar + sigma^(-1)*s; //9 wedge between deomestic and world output, equ (29)
pi = pih + alpha*(s-s(-1)); //10 wedge (gap) between demestic and CPI inflation, equ (14)
pi = p - p(-1); //11 def. of CPI inflation
pih = ph - ph(-1); //12 def. of domestic inflation (PPI)
s = s(-1) + e - e(-1) + pistar - pih; //13 from def. of TOT, first difference of equ (15),
pi_star=0
pistar = 0; //15 foreign inflation is set to be zero
//r = e(+1) - e; //14? Uncovered Interest Rate Parity, set world interest rate to zero(see
p724), equ (19)

a = rhoa*a(-1) + a_; //7 exogenous process of productivity in SOE,

```

```

ystar= rho*y*ystar(-1) + ystar_ ; //8 exogenous process of world output,
end;
shocks;
var a_ = 0.0071^2; //the SD of productivity
var ystar_ = 0.0078^2; //the SD of world output
var a_, ystar_ = 0.3*0.0071*0.0078;
end;
stoch_simul(noprint, nograph) y pi r e;

```

Funding: The authors affirm that the study was completed without financial sponsorships that might compromise, or appear to compromise, the impartiality of the research reported in this article.

Declarations

Conflict of Interest: The authors state that they have no financial, professional, or personal affiliations or relationships that might compromise, or appear to compromise, the impartiality of the research reported in this article.

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