

Structural Shocks in Peru's Macroeconomic Aggregates across 1990s Reforms: A Bayesian State-Space Analysis

Cesar Sobrino

sobrinoc1@uagm.edu

UAGM: Universidad Ana G Mendez <https://orcid.org/0009-0000-9736-3139>

Research Article

Keywords: Time Series Models, Forecasting, Cycles, Economic Reforms

Posted Date: October 6th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11252309/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: The authors declare no competing interests.

Structural Shocks in Peru's Macroeconomic Aggregates across 1990s Reforms: A Bayesian State-Space Analysis

César R. Sobrino ^{*1}

¹*School of Business, Tourism & Entrepreneurship at UAGM, Gurabo, PR 00778*

October 3, 2026

Abstract

This study analyzes permanent and temporary shocks in Peru's macroeconomic time series, focusing on changes before and after the 1990s economic reforms. Using a Bayesian state-space framework with quarterly per capita GDP data (1980–1992 and 1993–2019), it compares a Local Level Model (LLM) and Local Linear Trend (LLT). The LLM is preferred based on Expected Log Predictive Density. Results show permanent shocks dominate output fluctuations in both periods, but their relative importance decreases post-reforms as the trend stabilizes. Temporary shocks become more persistent afterward, with meaningful effects lasting up to ten quarters. A key structural change occurs in shock correlations: positive and significant pre-reforms, but significantly negative for per capita GDP post-reforms. These findings support the Cycle-is-the-Trend hypothesis before the reforms but offer limited support in the post-reform era, highlighting greater trend stability after liberalization.

Keywords: *Time Series Models, Forecasting, Cycles, Economic Reforms*

JEL Classification: *C32; E37; E32; E65*

^{*}Email: sobrinoc1@uagm.edu; ORCID: 0009-0000-9736-3139; corresponding author

1. Introduction

Peru's economic trajectory during the late 20th century illustrates the profound impact of structural reforms on macroeconomic stability and growth. Following a period of severe macroeconomic disarray in the 1980s, characterized by hyperinflation and fiscal collapse, the early 1990s reforms—encompassing fiscal and monetary stabilization, trade liberalization, privatization, central bank independence, and financial reinsertion—marked a turning point (Parodi, Carlos (2022); Lago, Ricardo (2022); Perea, Hugo (2022)). These reforms led to sustained growth, single-digit inflation, and reduced volatility (Rossini, Renzo and Alejandro Santos (2015); Ortiz and Winkelried (2022)). More recent analyses document the milestones of this process, emphasizing institutional strengthening and resilience to external shocks (e.g., Végh (2022), on regional stabilization programs; Valderrama, José (2022), on fiscal institutions). The monetary and fiscal history of Peru between 1960 and 2010 further reveals radical policy experiments that shaped long-run dynamics (Martinelli, César and Marco Vega (2018)). Situating our analysis within this historical context underscores the relevance of examining how these reforms altered the relative importance and persistence of structural shocks in key macroeconomic aggregates.

Understanding the relative contributions and persistence of permanent versus temporary shocks is crucial for policy design: temporary shocks call for countercyclical stabilization tools, while permanent shocks require structural responses. However, conventional decomposition methods based on the co-movements approach (Johansen, Søren (1991); Engle, Robert F. and Sharon Kozicki (1993); Vahid, Farshid and Robert F Engle (1993)) cannot accommodate the structural breaks that characterize Peru's reform experience. Even extensions of cointegration methods such as Gregory, Allan W. and Bruce E. Hansen (1996), Hatemi-J, Abdulnasser (2008), and Maki, Daiki (2012) allow for structural breaks, but typically treat them as discrete, exogenous shifts and do not provide a flexible framework for modeling time-varying trend dynamics.

This study examines these shock dynamics by comparing their absolute and relative volatilities and persistence across macroeconomic aggregates before and after the 1990s economic reforms. We employ a Bayesian state-space model to

estimate the variances of permanent and temporary shocks in per capita output, consumption, investment, fiscal spending, exports, and imports. Previous studies using this approach include [Grant, Angelia L. and Joshua Chan \(2017\)](#) and [Kim, Chang-Jin and Jaeho Kim \(2022\)](#), which offers advantages including the capacity to accommodate broken trends (particularly relevant for Peru's 1980s structural breaks) and avoid biased estimates that can arise in maximum likelihood estimation due to the 'pile-up problem'.

Specifically, we contrast the Local Level Model (LLM) against the Local Linear Trend (LLT). The first approach assumes the trend is a random walk, and the second one adds a stochastic slope term so the trend can drift upward or downward. The main contributions are to assess absolute and relative volatility before and after the 1990s reforms—where a smoother stochastic trend signals successful stabilization—and to evaluate the persistence of short-term shocks, which provides valuable insights for short-term policymaking.

Using quarterly data divided into two sub-periods—1980:Q1 to 1992:Q4 and 1993:Q1 to 2019:Q4—model comparison based on Expected Log Predictive Density (ELPD) indicates that the Local Level Model (LLM) consistently outperforms the Local Linear Trend (LLT) across all aggregates and sub-samples. Under the preferred LLM specification, permanent shocks account for the majority of output fluctuations in both periods, consistent with [Mitra, Sinchan and Tara M. Sinclair \(2010\)](#) for emerging markets, although their relative dominance declines in the post-reform era as the long-term trend becomes more stable. Under the LLT specification, permanent shocks also play the dominant role for all series, with the exception of per capita output in the pre-reform subsample, and their relative importance similarly declines after the reforms. In both model specifications, transitory shocks become more persistent in the post-reform period, remaining economically meaningful for up to ten quarters. Taken together, these results are consistent with a smoother long-term trend following the reforms, which reduced the relative importance of permanent shocks. Likewise, post-reform cyclical volatility declines, in line with [Castillo, Paul et al. \(2006\)](#)'s documented stabilization of output and consumption.

Crucially, we identify a structural shift in shock correlations (ρ): under the

preferred LLM specification, pre-reform correlations were uniformly positive and significant, whereas the post-reform period is characterized by a significant negative correlation in per capita GDP. This shift in correlation points to a change in the nature of macroeconomic adjustment, with cyclical fluctuations increasingly reflecting short-run adjustment dynamics rather than independent sources of long-run volatility.

For the first sub-sample, the dominance of permanent over transitory shocks and the limited persistence of temporary disturbances are consistent with the Cycle-is-the-Trend Hypothesis (CTH) proposed by [Aguilar, Mark and Gita Gopinath \(2007\)](#). Under this hypothesis, output fluctuations reflect shocks with lasting level effects rather than transitory deviations around a stable trend. Such dynamics have often been associated with economies subject to frequent policy shifts, fiscal instability, and sudden stops in capital flows. Consistent with this view, [Bluedorn, John C. and Daniel Leigh \(2018\)](#) document that professional forecasters expect output shocks to have largely permanent effects across 19 emerging market economies, including Peru.

Conversely, the emergence of a significant negative correlation ($\rho = -0.59$) in the post-reform period (*S2*) suggests a shift in the nature of macroeconomic adjustment. In line with the unobserved-components evidence of [Mitra, Sinchan and Tara M. Sinclair \(2010\)](#), cyclical fluctuations increasingly reflect short-run adjustment dynamics in response to permanent shocks. Following the adoption of inflation targeting and strengthened fiscal frameworks, the business cycle appears to function as a stabilization margin, cushioning the short-term adjustment process while allowing the economy to converge to a new long-run path. This pattern resembles the adjustment dynamics observed in developed small open economies and is consistent with improved macroeconomic stabilization, though not with the complete insulation of long-run output from permanent disturbances.

The remainder of the study is organized as follows: Section 2 discusses the relevant literature, Section 3 presents the methodology and data, Section 4 presents the outcomes, Section 5 provides a discussion, and Section 6 concludes.

2. Literature Review

A standard approach to identifying the sources of macroeconomic fluctuations is to impose long- and short-run restrictions in a VECM framework to perform trend–cycle decomposition. Seminal contributions such as [King, Robert G. et al. \(1991\)](#) and [Issler, Joao Victor and Farshid Vahid \(2001\)](#) show that, under Real Business Cycle (RBC) predictions,¹ temporary shocks play an important role in explaining short-run fluctuations, particularly in investment dynamics. This framework relies on multiple time series to identify common trends and cycles, often implemented through the Beveridge–Nelson decomposition [Beveridge, Stephen and Charles R. Nelson \(1981\)](#).

2

However, these approaches depend on cointegration and common cycle tests (e.g., [Johansen, Søren \(1991\)](#); [Vahid, Farshid and Robert F Engle \(1993\)](#)), which are less flexible in accommodating structural breaks. This limitation is particularly relevant for economies such as Peru, which experienced major structural reforms in the early 1990s, including stabilization policies, trade liberalization, and market-oriented reforms that significantly altered macroeconomic dynamics. Even extensions of cointegration methods such as [Gregory, Allan W. and Bruce E. Hansen \(1996\)](#), [Hatemi-J, Abdunasser \(2008\)](#), and [Maki, Daiki \(2012\)](#) allow for structural breaks, but typically treat them as discrete, exogenous shifts and do not provide a flexible framework for modeling time-varying trend dynamics.

A large body of literature has applied trend–cycle decomposition methods to the Peruvian economy (e.g., [Guillén, Ángel and Gabriel Rodríguez \(2014\)](#), [Martinez, Martín and David Florián \(2019\)](#), [Pérez-Forero \(2021\)](#)). These studies generally focus on output dynamics and, in some cases, incorporate structural breaks or Bayesian state-space methods. In particular, [Martinez, Martín and David Florián \(2019\)](#) adopts a Bayesian framework, while [Guillén, Ángel and Gabriel Rodríguez \(2014\)](#) allows for broken trends using modern econometric techniques. These studies also show that incorporating stochastic volatility in trend and cycle components improves model fit

¹See [King, Robert G. et al. \(1988\)](#).

²Similar methodologies have been applied internationally: [Narayan, Paresh K. \(2008b\)](#) (UK), [Narayan, Paresh K. \(2008a\)](#) (Australia), [Narayan, Paresh K. \(2011\)](#) (Indonesia), and [Sobrino, Cesar R \(2021\)](#) (Peru post-1990s reforms).

and helps capture the decline in macroeconomic volatility observed after the 1990s. However, most of this literature focuses on individual series—primarily output—and does not jointly examine multiple macroeconomic aggregates.³

More recent contributions emphasize the advantages of Bayesian state-space models for trend–cycle decomposition, particularly their flexibility in handling structural change and model uncertainty. For instance, [Grant, Angelia L. and Joshua Chan \(2017\)](#) highlights the benefits of Bayesian model comparison, while [Kim, Chang-Jin and Jaeho Kim \(2022\)](#) revisits business cycle measurement using both classical and Bayesian approaches.

Despite these advances, there remains limited evidence on how the relative importance of permanent and transitory shocks across multiple macroeconomic aggregates has evolved following Peru’s structural reforms. This paper contributes by jointly analyzing multiple per capita macroeconomic aggregates within a unified Bayesian state-space framework, focusing on the decomposition of fluctuations into permanent and transitory shocks and their evolution across reform regimes.

3. Methodology

3.1. Research Design and Model Specification

This paper employs a Bayesian unobserved components model (state-space) to decompose key Peruvian macroeconomic series into trend and cycle. This approach is chosen to address the structural breaks present in Peruvian data, a key limitation of traditional methods such as the Hodrick-Prescott filter and standard cointegration tests.⁴

3.1.1 Local Level Model (LLM)

The observed output Y_t is modeled as:

$$Y_t = T_t + C_t + \varepsilon_t, \quad (1)$$

³Abundant literature exists on trend-cycle decomposition and output gap estimation for Peru, including [Díaz González, Joaquín and Khertd Palermo \(2022\)](#), [Pérez-Forero \(2021\)](#), [Martinez, Martín and David Florián \(2019\)](#), [Guillén, Ángel and Gabriel Rodríguez \(2014\)](#), [Terrones, Marco and César Calderón \(1993\)](#), and [Seminario, Bruno and César Bouillón \(1992\)](#).

⁴While [Perron, Pierre and Tatsuma Wada \(2009\)](#) offers another way to address these breaks using a random-driven drift to capture trend shifts, we adopt the framework of Grant and Chan.

where T_t is the stochastic trend, C_t is the cyclical component modeled as an AR(2) process, and ε_t is the irregular component representing measurement error, assumed to be normally distributed with mean zero and variance σ_ε^2 .

The state equations are defined as follows:

$$T_t = T_{t-1} + \mu_t^P, \quad (2)$$

where μ_t^P is the trend-level shock.

$$C_t = \phi_1 C_{t-1} + \phi_2 C_{t-2} + \mu_t^T, \quad (3)$$

where ϕ_1 and ϕ_2 are the coefficients of the AR(2) process, and μ_t^T is the temporary shock driving cyclical fluctuations. Stationarity requires $\phi_1 + \phi_2 < 1$ and $|\phi_2| < 1$.

In matrix form, the system is represented as:

$$\begin{bmatrix} T_t \\ C_t \\ C_{t-1} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \phi_1 & \phi_2 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} T_{t-1} \\ C_{t-1} \\ C_{t-2} \end{bmatrix} + \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \mu_t^P \\ \mu_t^T \end{bmatrix}. \quad (4)$$

The variance-covariance matrix of the shocks is:

$$\text{Var} \begin{bmatrix} \mu_t^P \\ \mu_t^T \end{bmatrix} = \begin{bmatrix} \sigma_{\mu^P}^2 & \rho \sigma_{\mu^P} \sigma_{\mu^T} \\ \rho \sigma_{\mu^P} \sigma_{\mu^T} & \sigma_{\mu^T}^2 \end{bmatrix}, \quad (5)$$

where $\sigma_{\mu^P}^2$ and $\sigma_{\mu^T}^2$ are the variances of the trend and cyclical shocks, respectively, and ρ is their correlation coefficient.

Traditional unobserved components models impose restrictions on shock correlations, but recent literature ([Perron, Pierre and Tatsuma Wada, 2009](#); [Grant, Angelia L. and Joshua Chan, 2017](#)) shows that unrestricted correlation improves model fit and better reflects the relative importance of short-term and long-term shocks.

3.1.2 Alternative Specification: Local Linear Trend (LLT)

While LLM assumes the trend is a random walk, LLT adds a stochastic slope term so the trend can drift upward or downward. Then, the stochastic trend in first differences

is

$$\Delta T_t = \Delta T_{t-1} + \Delta \mu_t^P, \quad (6)$$

This specification allows us to test whether reforms affected trend growth rates in addition to levels.

In matrix form, the system is represented as:

$$\begin{bmatrix} T_t \\ T_{t-1} \\ C_t \\ C_{t-1} \end{bmatrix} = \begin{bmatrix} 2 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & \phi_1 & \phi_2 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} T_{t-1} \\ T_{t-2} \\ C_{t-1} \\ C_{t-2} \end{bmatrix} + \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \Delta \mu_t^P \\ \mu_t^T \end{bmatrix}. \quad (7)$$

The variance-covariance matrix of the shocks is:

$$\text{Var} \begin{bmatrix} \Delta \mu_t^P \\ \mu_t^T \end{bmatrix} = \begin{bmatrix} \sigma_{\Delta \mu^P}^2 & \rho \sigma_{\Delta \mu^P} \sigma_{\mu^T} \\ \rho \sigma_{\Delta \mu^P} \sigma_{\mu^T} & \sigma_{\mu^T}^2 \end{bmatrix}, \quad (8)$$

where $\sigma_{\Delta \mu^P}^2$ and $\sigma_{\mu^T}^2$ are the variances of the trend and cyclical shocks, respectively, and ρ is their correlation coefficient.

3.2 Data

From 1980:Q1 to 2019:Q4, the Central Bank of Peru provides quarterly data on GDP, private consumption, gross fixed capital formation, fiscal spending, net exports, and population. All macroeconomic time series are expressed in 2007 constant Nuevos Soles and are seasonally adjusted.

Using these data, per capita variables are constructed as follows: per capita output is real GDP divided by population; per capita consumption is private consumption divided by population; per capita investment is gross fixed capital formation divided by population; per capita fiscal spending is fiscal spending divided by population; per capita exports are exports divided by population; and per capita imports are imports divided by population. All series are transformed into logarithms and multiplied by 100, a common practice to approximate percentage changes in the context of trend-cycle decompositions. The logarithmic scaling by 100 allows the standard deviation

of the cyclical fluctuations to be interpreted as approximate percentage deviations (e.g., a value of 5 represents about a 5% change). This approach is consistent with economic time-series analysis for assessing volatility.

Table 1 reports the descriptive statistics for all variables. Investment and imports exhibit the highest dispersion, suggesting greater volatility, while consumption shows the lowest dispersion. In addition, Table 2 provides the Elliott, Graham et al. (1996)'s unit root test (ERS) outcomes. The test indicates that most series are stationary in first differences.

Table 1: Descriptive Statistics

in per capita terms	mean	SD
output	782.50	28.16
consumption	739.32	25.76
investment	586.50	54.14
fiscal spending	600.65	34.14
exports	634.15	46.07
imports	613.85	54.12
SD: standard deviation		

Table 2: ERS Unit Root Test

in per capita terms	1-lag	3-lag	5-lag
At levels			
output	0.09	0.44	0.21
consumption	0.39	0.62	0.75
investment	-0.37	-0.56	-0.33
fiscal spending	-0.83	-0.70	-0.54
exports	0.44	0.75	0.98
imports	0.00	-0.11	0.35
In first differences			
output	-7.23***	-5.51***	-3.38***
consumption	-4.20***	-2.99***	-1.47
investment	-2.21**	-1.42	-0.87
fiscal spending	-4.76***	-2.35**	-1.46
exports	-5.05***	-2.60***	-1.37
imports	-4.29***	-2.68***	-1.33
Critical values	1% (***) -2.58	5% (**) -1.95	10% (*) -1.62

The analysis uses two sub-samples: 1980:Q1–1992:Q4 (pre-reform) and 1993:Q1–2019:Q4

(post-reform). The cutoff corresponds to Peru’s major economic reforms period and facilitates comparison with [Sobrino, Cesar R \(2021\)](#).⁵ [Castillo, Paul et al. \(2006\)](#) also used a similar cutoff analyzing 1979-1993 and 1994-2005.

We employ Markov Chain Monte Carlo (MCMC) methods for Bayesian estimation. For the Local Level Model (LLM), informative priors are specified as: $\sigma_{\mu^P} \sim N(0.07, 0.01)$, $\sigma_{\mu^T} \sim N(0.03, 0.005)$, $\rho \sim N(0, 0.2)$ with bounds $[-0.8, 0.8]$, $\phi_1 \sim N(1.03, 0.05)$ with bounds $[0.8, 1.4]$, $\phi_2 \sim N(-0.6, 0.05)$ with bounds $[-0.8, -0.4]$, and $\sigma_\varepsilon \sim N(0.01, 0.002)$. Initial states: trend $\sim N(Y_0, 0.1)$ and cycle $\sim N(0, 0.1)$ where Y_0 is the first observation of the process. For the Local Linear Trend model (LLT), informative priors remain identical except for $\sigma_{\Delta\mu^P} \sim N(0.01, 0.005)$, which is much tighter to reflect shocks to the trend growth rate rather than the trend level. Initial states for LLT are: $T_0 \sim N(Y_0, 0.1)$, $\Delta T_0 \sim N(0, 0.01)$, and $C_0 \sim N(0, 0.1)$.

Once posterior distributions are estimated, we compute forecast error variance decomposition to assess the relative contributions of permanent and temporary shocks. When ρ is significant, we orthogonalize shocks to ensure independent variance contribution.⁶

4. Outcomes

4.1 Posterior estimates

Tables 3 and 4 report the posterior estimates of σ_{μ^P} , σ_{μ^T} , ρ , ϕ_1 and ϕ_2 for the pre-reform (1980–1992) and post-reform (1993–2019) periods using the local level model and the local linear trend model, respectively. All parameters are precisely estimated, with 90% credible intervals excluding zero for most coefficients. The AR(2) coefficients indicate stationary cycles ($\phi_1 + \phi_2 < 1$ and $|\phi_2| < 1$) across all specifications.

For the first specification, the post-reform period shows a dramatic transformation: the standard deviation of both permanent and temporary shock decreased substantially across all aggregates. The volatility of the permanent shock for output fell by 52.01%,

⁵This study employed a log-likelihood ratio test in a three-VAR setup and found five structural breaks between 1980 and 2019. Its analysis period starts in the last structural break.

⁶You may see this procedure in [Issler, Joao Victor and Farshid Vahid \(2001\)](#) among other studies.

consumption by 51.7%, investment by 45.98%, fiscal spending by 39.41%, exports by 45.19%, and imports by 45.67%. Additionally, the volatility of the temporary shocks for output fell by 37.36%, consumption by 49.90%, investment by 39.56%, fiscal spending by 36.14%, exports by 44.75%, and imports by 40%. It is clear that absolute volatility has decreased across sub-samples.

Notably, per capita exports exhibit the highest volatility in terms of permanent shocks, reflecting Peru's commodity-dependent economy across sub-samples. Regarding temporary shocks, while per capita exports show the highest volatility in the first sub-period, fiscal spending shows the highest volatility in the second sub-period. Interestingly, despite Peru remaining an open economy, exports and imports do not exhibit the highest volatility post-reform, indicating reduced vulnerability to external shocks.

A key pre-reform finding is the significantly positive shock correlations across all aggregates, consistent with the absence of systematic countercyclical policies during the 1980s—a period characterized by fiscal dominance and central bank financing of public deficits. Most strikingly, only output exhibits a significant negative shock correlation ($\rho = -0.57$), while other aggregates show orthogonal shocks. This pattern suggests effective countercyclical monetary policy in stabilizing output, while fiscal policy demonstrates less systematic stabilization across other macroeconomic aggregates.

Likewise, for the second specification, the post-reform period also shows a dramatic transformation: the standard deviation of both permanent and temporary shocks decreased markedly across all aggregates. The volatility of the permanent shock for output fell by 75%, consumption by 75%, investment by 61.76%, fiscal spending by 53.06%, exports by 57.14%, and imports by 61.29%, indicating more stable trend swings. Additionally, the volatility of the temporary shocks for output fell by 57.50%, consumption by 53.68%, investment by 49.09%, fiscal spending by 39.13%, exports by 45.90%, and imports by 47.66%. Similar to the first specification, absolute volatility decreased across sub-samples.

In this second approach, per capita investment exhibits the highest volatility in terms of permanent shocks across reforms. However, in the second sub-sample, the

Table 3: Posterior Estimates of Trend-Cycle Decomposition for Peruvian Per Capita Macroeconomic Series - Pre- vs Post-Reforms (Local Level Model)

Variable	Pre-Reforms				Post-Reforms			
	mean	SD	Q5	Q95	mean	SD	Q5	Q95
Per Capita Output								
σ_{μ^P}	0.134	0.007	0.123	0.145	0.064	0.005	0.057	0.072
σ_{μ^T}	0.044	0.005	0.036	0.052	0.028	0.005	0.020	0.035
ρ	0.580	0.130	0.350	0.770	-0.570	0.150	-0.770	-0.290
ϕ_1	1.050	0.045	0.973	1.120	1.040	0.049	0.960	1.120
ϕ_2	-0.640	0.050	-0.720	-0.550	-0.566	0.047	-0.642	-0.488
σ_{ε}	0.010	0.002	0.007	0.013	0.009	0.002	0.006	0.012
Per Capita Consumption								
σ_{μ^P}	0.159	0.007	0.148	0.170	0.077	0.005	0.068	0.086
σ_{μ^T}	0.049	0.004	0.042	0.057	0.025	0.005	0.017	0.032
ρ	0.710	0.080	0.550	0.790	-0.280	0.190	-0.600	0.050
ϕ_1	1.050	0.041	0.979	1.110	1.030	0.049	0.951	1.110
ϕ_2	-0.665	0.050	-0.748	-0.580	-0.574	0.049	-0.655	-0.494
σ_{ε}	0.010	0.002	0.007	0.014	0.010	0.002	0.007	0.013
Per Capita Investment								
σ_{μ^P}	0.179	0.007	0.168	0.190	0.097	0.006	0.087	0.106
σ_{μ^T}	0.050	0.005	0.042	0.058	0.030	0.005	0.022	0.038
ρ	0.740	0.050	0.640	0.800	-0.090	0.180	-0.370	0.210
ϕ_1	1.040	0.046	0.961	1.110	1.040	0.053	0.958	1.130
ϕ_2	-0.596	0.049	-0.676	-0.514	-0.588	0.049	-0.669	-0.507
σ_{ε}	0.011	0.002	0.007	0.014	0.010	0.002	0.007	0.013
Per Capita Fiscal Spending								
σ_{μ^P}	0.170	0.007	0.159	0.181	0.103	0.006	0.093	0.114
σ_{μ^T}	0.050	0.005	0.042	0.058	0.032	0.005	0.024	0.040
ρ	0.750	0.050	0.650	0.800	0.250	0.170	-0.030	0.530
ϕ_1	0.999	0.048	0.919	1.080	1.020	0.050	0.934	1.100
ϕ_2	-0.586	0.048	-0.666	-0.506	-0.593	0.049	-0.673	-0.512
σ_{ε}	0.011	0.002	0.007	0.014	0.010	0.002	0.007	0.014
Per Capita Exports								
σ_{μ^P}	0.181	0.007	0.169	0.192	0.099	0.006	0.089	0.110
σ_{μ^T}	0.055	0.005	0.047	0.063	0.031	0.005	0.023	0.038
ρ	0.770	0.030	0.700	0.800	0.180	0.180	-0.100	0.480
ϕ_1	0.986	0.048	0.908	1.060	1.030	0.049	0.945	1.110
ϕ_2	-0.603	0.047	-0.678	-0.524	-0.595	0.049	-0.676	-0.515
σ_{ε}	0.011	0.002	0.008	0.014	0.010	0.002	0.007	0.014
Per Capita Imports								
σ_{μ^P}	0.171	0.006	0.161	0.182	0.093	0.006	0.084	0.103
σ_{μ^T}	0.051	0.005	0.043	0.058	0.030	0.005	0.022	0.038
ρ	0.740	0.050	0.640	0.800	-0.060	0.170	-0.330	0.240
ϕ_1	1.010	0.043	0.939	1.080	1.040	0.051	0.957	1.130
ϕ_2	-0.637	0.052	-0.723	-0.553	-0.590	0.050	-0.671	-0.508
σ_{ε}	0.010	0.002	0.007	0.014	0.010	0.002	0.007	0.013

SD: standard deviation; Q5: 5th percentile; Q95: 95th percentile

Table 4: Posterior Estimates of Trend-Cycle Decomposition for Peruvian Per Capita Macroeconomic Series - Pre- vs Post-Reforms (Local Linear Trend)

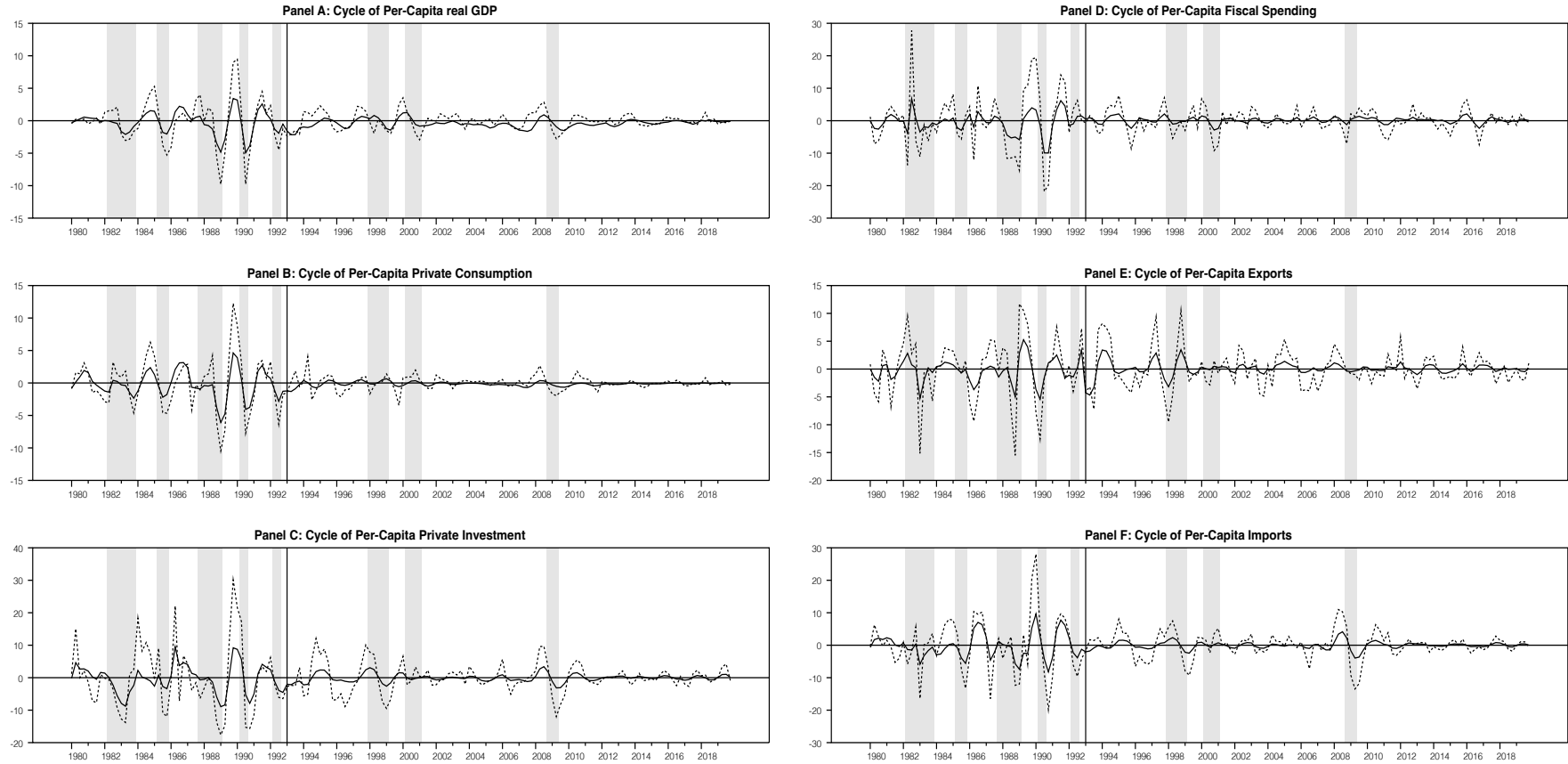
Variable	Pre-Reforms				Post-Reforms			
	mean	SD	Q5	Q95	mean	SD	Q5	Q95
Per Capita Output								
$\sigma_{\Delta\mu^P}$	0.042	0.004	0.035	0.048	0.011	0.003	0.007	0.015
σ_{μ^T}	0.080	0.004	0.074	0.086	0.034	0.003	0.029	0.039
ρ	0.230	0.130	0.010	0.430	0.100	0.190	-0.210	0.410
ϕ_1	0.996	0.043	0.924	1.070	1.040	0.047	0.964	1.120
ϕ_2	-0.652	0.037	-0.713	-0.591	-0.532	0.044	-0.604	-0.461
σ_ε	0.013	0.002	0.009	0.017	0.013	0.002	0.009	0.016
Per Capita Consumption								
$\sigma_{\Delta\mu^P}$	0.060	0.004	0.053	0.067	0.015	0.003	0.011	0.021
σ_{μ^T}	0.095	0.004	0.089	0.102	0.044	0.004	0.037	0.050
ρ	0.510	0.090	0.360	0.660	0.450	0.180	0.140	0.730
ϕ_1	0.962	0.040	0.897	1.030	0.961	0.050	0.879	1.040
ϕ_2	-0.627	0.039	-0.691	-0.565	-0.518	0.047	-0.595	-0.442
σ_ε	0.015	0.002	0.011	0.019	0.016	0.002	0.012	0.020
Per Capita Investment								
$\sigma_{\Delta\mu^P}$	0.068	0.004	0.061	0.074	0.026	0.004	0.020	0.032
σ_{μ^T}	0.110	0.004	0.104	0.116	0.056	0.003	0.051	0.062
ρ	0.740	0.050	0.640	0.800	0.210	0.160	-0.040	0.470
ϕ_1	0.890	0.039	0.825	0.955	1.040	0.049	0.962	1.120
ϕ_2	-0.444	0.029	-0.498	-0.405	-0.527	0.042	-0.595	-0.457
σ_ε	0.015	0.002	0.011	0.019	0.013	0.002	0.010	0.017
Per Capita Fiscal Spending								
$\sigma_{\Delta\mu^P}$	0.049	0.004	0.042	0.056	0.023	0.005	0.015	0.031
σ_{μ^T}	0.115	0.003	0.110	0.121	0.070	0.004	0.064	0.076
ρ	0.770	0.030	0.710	0.800	0.420	0.150	0.170	0.660
ϕ_1	0.820	0.017	0.801	0.854	0.925	0.048	0.845	1.000
ϕ_2	-0.432	0.024	-0.477	-0.403	-0.497	0.043	-0.569	-0.428
σ_ε	0.015	0.002	0.011	0.019	0.015	0.002	0.011	0.019
Per Capita Exports								
$\sigma_{\Delta\mu^P}$	0.056	0.005	0.048	0.064	0.024	0.005	0.017	0.032
σ_{μ^T}	0.122	0.004	0.116	0.128	0.066	0.004	0.060	0.072
ρ	0.750	0.040	0.670	0.800	0.490	0.150	0.220	0.720
ϕ_1	0.821	0.018	0.801	0.856	0.953	0.049	0.872	1.030
ϕ_2	-0.457	0.031	-0.512	-0.410	-0.495	0.042	-0.566	-0.428
σ_ε	0.014	0.002	0.010	0.018	0.015	0.002	0.011	0.019
Per Capita Imports								
$\sigma_{\Delta\mu^P}$	0.062	0.004	0.055	0.069	0.024	0.004	0.019	0.030
σ_{μ^T}	0.107	0.004	0.102	0.113	0.056	0.003	0.051	0.062
ρ	0.720	0.060	0.610	0.790	0.240	0.150	-0.010	0.490
ϕ_1	0.853	0.032	0.807	0.912	1.040	0.047	0.966	1.120
ϕ_2	-0.526	0.039	-0.590	-0.462	-0.519	0.042	-0.588	-0.451
σ_ε	0.014	0.002	0.010	0.018	0.014	0.002	0.010	0.018

SD: standard deviation; Q5: 5th percentile; Q95: 95th percentile

volatilities of per capita fiscal spending, per capita exports, and per capita imports are close to that of per capita investment. In addition, for the pre-reform period, the correlation between the permanent shock—which captures shocks to the slope and intercept of the trend—and the temporary shock is positive and significant for all cases, specifically exceeding 0.7 for per capita investment, fiscal spending, exports, and imports. Post-reform, the correlation between both shocks is not significant for per capita output, per capita investment, and per capita imports and, for per capita consumption, per capita fiscal spending and per capita exports, the correlation is between 0.4 and 0.5.

Figure 1 reports the cycles of Peru’s major macroeconomic aggregates obtained from both approaches, contrasting periods before and after the 1990s reforms, with recession periods shaded following [Martinez, Martín and David Florián \(2019\)](#). Graphically, volatility diminishes across cycles, although those obtained from LLM exhibit less variability compared to LLT. Under LLM, per capita investment cycle exhibits the greatest volatility among domestic aggregates across sub-samples, with our model estimating pre-reform cyclical fluctuations of 4.40%—substantially lower than the 19.47% suggested by the HP filter. Post-reform, per capita investment cycle volatility declines to 1.19% in our specification versus 8.05% for HP. Output and consumption cycles show more moderate but still economically significant fluctuations in our model, decreasing from 1.77% and 2.16% pre-reform to 0.63% and 0.32% post-reform, respectively. The HP filter estimates for these series (6.97% and 8.01% before reform, declining to 1.98% and 2.09% after reform) appear to be exaggerated cycle magnitudes. Per capita imports cycle shows the highest volatility among external aggregates, with our model estimating 3.87% pre-reform versus 14.65% for HP.

Figure 1: Cycles of per capita macroeconomic aggregates- Local Level vs. Local Linear Trend



Note: Following [Martinez, Martín and David Florián \(2019\)](#), the recession periods are in shadow bars: 1982:Q2-1983:Q4; 1985:Q2-1985:Q4; 1987:Q4-1989:Q1; 1990:Q2-1990:Q3; 1992:Q2-1992:Q3; 1998:Q1-1999:Q1; 2000:Q2-2001:Q1; and, 2008:Q4-2009:Q2. Solid line represents the Local Level model; dotted line represents the Local Linear Trend model.

For LLT, per capita investment also exhibits the highest volatility among macro time series across sub-samples. In the first regime, it reached 10.52%, and in the second regime, 4.22%. Output and consumption cycles show more moderate fluctuations, decreasing from 3.69% and 4.17% pre-reform to 1.21% and 1.00% post-reform, respectively. Similarly, per capita imports display the highest volatility among external time series, reaching 8.86% pre-reform. Both specifications, LLM and LLT, produce smoother cycles than those obtained using the Hodrick-Prescott filter. The smoother cycles from the UCM can provide more reliable signals for monetary and fiscal policymakers.

Across both specifications, for the first sub-sample, these results align with [Terrones, Marco and César Calderón \(1993\)](#), who found that investment and imports exhibited higher volatility across macroeconomic aggregates, while consumption showed one of the lowest. This dramatic reduction in volatility across all components underscores the stabilizing effect of the reforms. The finding that output and consumption exhibit the lowest volatility post-reform is consistent with [Castillo, Paul et al. \(2006\)](#), who document increased macroeconomic stability following the 1990s reforms.

Table 5 reports model comparisons using the Expected Log Predictive Density (ELPD).⁷ We explicitly assess the inclusion of a time-varying growth component (Local Linear Trend, LLT) relative to the baseline Local Level Model (LLM). Across both regimes and all per capita variables, the LLT specification exhibits a substantial deterioration in predictive performance. Moreover, the cyclical component implied by the LLM is visually smoother and more stable than that obtained under the LLT specification, which tends to absorb short-run fluctuations into the stochastic trend. Taken together, these results indicate that the LLM provides the most parsimonious and theoretically coherent framework for identifying the cyclical component of Peruvian per capita macroeconomic aggregates.

⁷ELPD_{LOO} = $\sum_{i=1}^n \log p(y_i | y_{-i})$, where y_i denotes the i -th observation and y_{-i} the sample excluding observation i . Higher values indicate better out-of-sample predictive performance. Differences in ELPD across models can be interpreted as evidence of relative predictive superiority. (see [Vehtari, Aki et al. \(2017\)](#))

Table 5: Model Comparison Using Expected Log Predictive Density (ELPD)

Variable	Pre-Reforms		Post-Reforms		Full Sample	
	LLM	LLT	LLM	LLT	LLM	LLT
Per Capita Output	126.3	88.78	279.8	240.71	405.93	346.00
Per Capita Consumption	124.3	62.64	265.8	190.91	393.70	290.98
Per Capita Investment	120.5	60.55	269.9	216.68	385.45	278.90
Per Capita Fiscal Spending	120.4	58.70	260.0	172.56	372.46	277.30
Per Capita Exports	128.2	73.16	267.8	178.96	395.70	266.40
Per Capita Imports	128.8	75.50	279.0	204.34	395.90	272.70

4.2. The Relative Importance of the Structural Shocks

Table 6 presents the contribution of temporary shocks to forecast error variance across ten quarters for both sub-periods. For LLM, while permanent shocks remain the dominant driver of fluctuations in both periods—accounting for more than 80% of variance by quarter 10—the relative importance of temporary shocks increased after the reforms. Across sub-samples, temporary shocks exhibit an initial increase in the second quarter before gradually diminishing while maintaining economically meaningful persistence beyond ten quarters.

Under the Local Linear Trend (LLT) specification, temporary shocks play a substantially larger role at short horizons. In the pre-reform subsample, temporary shocks account for more than 60% of per capita output fluctuations and over 35% of per capita consumption fluctuations in the first quarter, while explaining around 20% for the remaining aggregates. These contributions decline steadily and fall below 3% by the tenth quarter. In the post-reform period, temporary shocks dominate short-run fluctuations for per capita output, investment, and imports—exceeding 80% in the first quarter—and account for between 50% and 60% of fluctuations in consumption, fiscal spending, and exports. As in the pre-reform period, these effects decay over time, declining to between 3% and 7% by the tenth quarter.

The post-reform period reveals three key findings across all aggregates. First, there is an expected substantial decline in the variance of both permanent and temporary structural shocks across all macroeconomic aggregates, indicating a marked reduction in absolute volatility. Second, the relative importance of temporary shocks increased post-reform. While both types of shocks became less volatile, the reduc-

Table 6: Role of Temporary Shocks in Forecast Error Variance(%)

quarters	Per capita					
	Output	Consumption	Investment	Fiscal spending	Exports	Imports
Local level model						
Pre-reforms						
1	4.79	3.08	2.39	2.46	2.42	2.59
2	4.98	3.21	2.47	2.46	2.40	2.61
3	3.92	2.52	1.96	1.92	1.86	2.02
4	3.26	2.13	1.61	1.60	1.57	1.72
5	3.09	2.08	1.48	1.48	1.49	1.65
10	1.84	1.26	0.87	0.86	0.86	0.97
Post-reforms						
1	17.76	9.31	8.99	8.70	8.64	9.62
2	18.54	9.56	9.33	8.86	8.88	9.97
3	13.28	7.29	7.12	6.65	6.70	7.61
4	9.04	5.58	5.45	5.12	5.15	5.84
5	6.93	4.78	4.69	4.44	4.46	5.03
10	3.40	2.60	2.57	2.42	2.44	2.77
Local linear trend						
Pre-reforms						
1	62.69	36.47	19.74	22.23	23.06	22.19
2	46.42	24.79	13.02	15.87	16.13	14.69
3	29.08	15.02	8.07	10.95	10.88	9.23
4	18.98	10.11	5.27	8.01	7.87	6.46
5	13.51	7.28	3.57	5.80	5.63	4.53
10	2.37	1.20	0.61	1.03	0.74	0.73
Post-reforms						
1	91.29	55.42	82.64	59.54	50.72	84.41
2	81.36	44.31	66.47	48.07	39.82	69.26
3	64.10	32.53	44.83	35.74	28.78	48.11
4	45.45	24.04	27.50	26.70	20.95	30.22
5	31.91	18.17	17.55	20.14	15.58	19.49
10	6.57	3.61	3.09	4.01	3.06	3.49

tion in permanent shocks was more pronounced, shifting the relative contribution of fluctuations toward temporary disturbances.

This pattern can be explained by the smoother stochastic trend following the reforms, which reduced the relative dominance of permanent shocks and thereby increased the relative contribution of temporary innovations. Third, temporary shocks exhibit greater persistence, with their effects extending beyond ten quarters in the post-

Table 7: The Role of Temporary Shocks (%) 1993:Q1–2019:Q1

Quarters	Per capita Private Output	Per capita Consumption	Per capita Investment
1	15.52	5.88	8.26
	94.12	46.11	80.00
	(8.40)	(21.65)	(37.29)
2	16.05	6.05	8.64
	94.17	45.59	80.79
	(11.26)	(17.83)	(61.02)
3	12.50	4.56	6.63
	92.37	49.94	76.50
	(7.45)	(6.12)	(71.09)
4	9.70	3.47	5.07
	90.08	54.20	70.98
	(2.73)	(2.08)	(44.27)
5	8.35	2.97	4.34
	88.26	58.62	66.67
	(0.89)	(0.48)	(0.80)
10	4.65	1.61	2.38
	79.69	73.23	51.15
	(0.00)	(0.00)	(0.00)

Note: The first row corresponds to the Local Level Model (LLM), the second row to the Local Linear Trend (LLT), and the third row (in parentheses) reproduces the results from [Sobrinho, Cesar R \(2021\)](#) (Table 5). Following [King, Robert G. et al. \(1988\)](#), per capita private output is defined as real GDP minus deflator-adjusted fiscal expenditure, divided by population.

reform period. This suggests that although these shocks are transitory by nature, their influence on macroeconomic aggregates has become more prolonged over time.

In addition, Table 7 reports the role of the temporary shock on per capita private output (defined as per capita real GDP minus per capita fiscal spending), per capita consumption, and per capita investment for the period 1993:Q1–2019:Q1, which corresponds to the analysis period in [Sobrinho, Cesar R \(2021\)](#). Following a procedure similar to that of [Issler, Joao Victor and Farshid Vahid \(2001\)](#), this study employs these variables in accordance with the RBC model of [King, Robert G. et al. \(1988\)](#).

Substantial methodological differences distinguish the two approaches. Overall, these differences highlight that the choice between multivariate and univariate frameworks is not innocuous, as it materially affects the inferred importance of cyclical dynamics. While [Sobrinho, Cesar R \(2021\)](#) employs a multivariate VECM to

capture the joint dynamics and co-movement across variables, our analysis relies on univariate Bayesian unobserved-components models that isolate the stochastic properties of each aggregate. Focusing on the preferred Local Level Model (LLM), temporary shocks account for a larger share of short-run fluctuations in per capita private output than in the multivariate VECM—15.5% at the one-quarter horizon compared with 8.4% in [Sobrinho, Cesar R \(2021\)](#). This difference suggests that when output is analyzed in isolation, without imposing a common stochastic trend across aggregates, its cyclical component appears more prominent. Under the Local Linear Trend (LLT) specification, by contrast, temporary shocks explain a substantially larger share of short-run fluctuations across all series, underscoring the sensitivity of variance decompositions to assumptions about trend dynamics.

For per capita investment, [Sobrinho, Cesar R \(2021\)](#) finds a markedly higher contribution of temporary shocks at short horizons (37.3% at one quarter) than either univariate specification. This pattern is consistent with the interpretation that the multivariate framework attributes a larger share of investment volatility to a common cyclical component shared with consumption and output, reflecting the strong co-movement emphasized in RBC models. Across all approaches, the contribution of temporary shocks declines monotonically with the forecast horizon. Moreover, under both the LLM and LLT specifications, temporary shocks display greater persistence, beyond ten quarters, than in the VECM framework.

5. Discussion

Under the preferred Local Level Model (LLM), the results indicate a clear post-reform transformation in the nature of macroeconomic fluctuations in Peru. Following the 1990s reforms, both permanent and temporary shocks exhibit a marked decline in absolute variance, while the relative contribution of temporary shocks increases and their persistence rises. At the same time, the relative importance of permanent shocks declines, consistent with the emergence of a smoother stochastic trend. Taken together, these findings suggest that stabilization policies were associated not only with lower overall volatility but also with a rebalancing of the sources of fluctuations toward more transitory disturbances.

The observed reduction in output volatility in the second sub-sample is consistent with the objectives of Peru's structural reform agenda. Trade and financial liberalization, privatization, central bank independence, pension system reform, and labor market deregulation jointly induced a structural break by altering the distribution and transmission of macroeconomic shocks. In addition, the adoption of inflation targeting in 2002 likely contributed to reduced output volatility, a stylized fact documented for inflation-targeting regimes by [Corbo, Vittorio and Klaus Schmidt-Hebbel \(2001\)](#) and [Schmidt-Hebbel et al. \(2002\)](#). Post-reform cyclical volatility also declines, reinforcing the evidence of macroeconomic stabilization documented by [Castillo, Paul et al. \(2006\)](#) for output and consumption.

Despite this stabilization, permanent shocks continue to account for the majority of output fluctuations in both sub-periods, consistent with evidence for emerging markets in [Mitra, Sinchan and Tara M. Sinclair \(2010\)](#). However, their relative dominance diminishes after the reforms as the long-run trend becomes more stable. Concurrently, temporary shocks become more persistent in the post-reform period, remaining economically relevant for up to ten quarters. These patterns are consistent with a smoother long-term trend that attenuates the influence of permanent shocks while allowing cyclical forces to play a more prominent short-run role.

5.1 Theoretical Implications

A central result of the analysis is the identification of a structural change in the correlation between permanent and temporary shocks. Under the LLM specification, correlations are uniformly positive and statistically significant prior to the reforms, whereas the post-reform period is characterized by a significant negative correlation for per capita output, afterward, shifting from 0.58 to -0.57. This reversal signals a change in the nature of macroeconomic adjustment: cyclical fluctuations increasingly reflect short-run adjustment dynamics in response to permanent shocks rather than acting as independent sources of long-run volatility.

In the pre-reform period, the dominance of permanent shocks and the limited persistence of temporary disturbances are consistent with the Cycle-is-the-Trend Hypothesis (CTH) of [Aguilar, Mark and Gita Gopinath \(2007\)](#), whereby output fluctuations reflect shocks with persistent level effects rather than transitory deviations

around a stable trend. Such dynamics are characteristic of economies exposed to frequent policy shifts, fiscal instability, and sudden stops in capital flows. Supporting this interpretation, [Bluedorn, John C. and Daniel Leigh \(2018\)](#) show that professional forecasters expect output shocks to have largely permanent effects across a broad set of emerging markets, including Peru.

Table 8 further highlights the importance of sample splitting: under the LLM, full-sample estimates yield non-significant correlations for output and consumption while remaining positive for other aggregates, masking the regime change revealed by the split-sample analysis.

Table 8: Summary of Posterior Estimates for ρ - Full sample

Variable	Mean	SD	Q5	Q95
Local level model (LLM)				
Per capita output	-0.09	0.16	-0.36	0.18
Per capita consumption	0.20	0.16	-0.06	0.47
Per capita investment	0.38	0.16	0.12	0.65
Per capita fiscal spending	0.71	0.07	0.57	0.79
Per capita exports	0.37	0.16	0.10	0.65
Per capita imports	0.34	0.16	0.07	0.61
Local linear trend (LLT)				
Per capita output	0.06	0.15	-0.18	0.31
Per capita consumption	0.41	0.15	0.14	0.66
Per capita investment	0.62	0.10	0.44	0.78
Per capita fiscal spending	0.76	0.04	0.69	0.8
Per capita exports	0.45	0.20	0.07	0.73
Per capita imports	0.47	0.11	0.29	0.64

5.2 Policy Relevance and Interpretation

The findings distinguish between policies aimed at long-run growth and short-run stabilization tools. The stabilization in permanent shock variance suggests that long-term policies should continue focusing on structural factors such as productivity-enhancing reforms and institutional strengthening. In the short term, the findings are linked to the success of Peru's stabilization framework, including inflation targeting and strengthened fiscal institutions.

As a small open commodity-exporting economy, Peru is highly exposed to terms-of-trade shocks. While traditional VAR studies (such as [Bendezú-Jiménez, Héctor](#)

et al. (2025), Ganiko, Gustavo and Alvaro Jiménez (2023), and Nolzco, Jose et al. (2016)) focus on stationary growth rates and short-run dynamics, our unobserved-components framework operates in levels, allowing for a characterization of the evolution of the stochastic trend and business cycle. Our findings reconcile the strong short-run impact of terms-of-trade shocks with structural trends: while these shocks generate persistent cyclical fluctuations, they are fundamentally mean-reverting and do not dictate the long-run trajectory of the economy, particularly in the post-reform era where the trend has become more stable.

5.3 Limitations and Future Research Agenda

While this study provides a robust characterization of regime-specific shock dynamics, it is subject to certain limitations. A primary limitation is the univariate nature of the analysis, which does not allow for the identification of transmission channels across macroeconomic aggregates. Future research could address this limitation by employing multivariate unobserved components models. Recent advances in this area, such as Jahan-Parvar, Mohammad R. et al. (2024), show how cross-sectional information can be exploited to uncover these mechanisms, representing a promising direction for future research on Peru's reform period.

Additionally, the break date is imposed exogenously rather than estimated within a Bayesian multiple-break framework (e.g., Wang, Jiahui and Eric Zivot (2000)). Allowing for endogenous break detection constitutes a natural extension of the present analysis. To empirically validate our choice of 1993:Q1 as the cutoff, we apply the multiple structural break tests of Bai, Jushan and Pierre Perron (2003a) and Bai, Jushan and Pierre Perron (2003b) to the quarterly growth rates (first differences of log levels) of each per capita aggregate, detecting breaks in both the conditional mean and conditional variance.

The results, summarized in Table 9, consistently identify a break in the early 1990s across most series (Bai and Perron, 2003a). For per capita GDP growth, the mean break occurs at 1992(3) and the variance break at 1991(4). Consumption growth shows a variance break at 1994(3); investment growth at 1991(3); fiscal spending growth at 1992(2); export growth at 1994(1); and import growth at 1991(3). The estimated break dates vary slightly across series, reflecting the fact that different

macroeconomic aggregates may respond to structural reforms with heterogeneous lags. However, all identified breaks fall within a common window of 1990–1995, and 1993:Q1 represents a defensible common cutoff point that lies within this window for every series. This provides strong empirical justification for estimating our unobserved components models separately over the pre-reform (1980–1992) and post-reform (1993–2019) periods, ensuring comparability of results while respecting the underlying structural change in each series.

While endogenous break estimation within a unified Bayesian framework represents a valuable extension, the objective of this paper is to compare shock dynamics across historically and empirically identified regimes. In this context, imposing a common break date enhances comparability across aggregates and facilitates economic interpretation

Table 9: Structural Breaks in Mean and Variance (Closest to 1993:Q1)

Growth rate of	Mean Break	Variance Break
per capita output	1992(3) [$m = 2$]	1991(4) [$m = 2$]
per capita consumption	1992(3) [$m = 2$]	1994(3) [$m = 2$]
per capita investment	1991(4) [$m = 5$]	1991(3) [$m = 2$]
per capita fiscal spending	1990(4) [$m = 1$]	1992(2) [$m = 2$]
per capita exports	1994(3) [$m = 5$]	1994(1) [$m = 2$]
per capita imports	1995(3) [$m = 2$]	1991(3) [$m = 2$]

Note: Break dates are reported as year(quarter). The Bai–Perron procedure allows up to five breaks ($m = 5$) with a minimum segment length of 15% ($h = 0.15$). The value in brackets indicates the number of breaks selected by the BIC for that series.

In addition, both the Local Level Model and the Local Linear Trend rely on relatively restrictive assumptions regarding trend dynamics. In particular, differences in how each specification attributes low-frequency variation between trend and cycle components may lead to variation in the estimated contribution of permanent and temporary shocks across models.

Finally, while stochastic volatility (SV) models—pioneered by [Harvey, Andrew et al. \(1994\)](#) and further developed by [Stock, James H. and Mark W. Watson \(2007\)](#)—provide a flexible framework to capture time-varying shock variances, they are not the focus of this study. Instead, this paper emphasizes the identification

of regime-dependent differences through historically grounded sample splitting. In this context, discrete structural breaks offer a transparent and economically interpretable framework for analyzing changes in macroeconomic dynamics. Incorporating stochastic volatility within a unified framework constitutes an important avenue for future research.

6. Conclusion

This study employs a Bayesian state-space unobserved components framework to decompose Peru's macroeconomic per capita time series into trend and cycle components, comparing the Local Level Model (LLM) and the Local Linear Trend (LLT). Using quarterly data from 1980:Q1 to 2019:Q4, model comparison based on predictive performance favors the LLM specification.

Under this preferred model, permanent shocks account for the majority of fluctuations across all aggregates in both sub-periods. However, temporary shocks remain economically relevant at business-cycle horizons and become more persistent in the post-reform period, increasing their relative contribution to overall fluctuations.

While the variances of both permanent and temporary shocks decline following the reforms, the relative importance of temporary shocks rises. This reflects the emergence of a smoother stochastic trend, which reduces the dominance of permanent disturbances. The overall decline in volatility is consistent with well-documented stylized facts of the Peruvian economy in the post-reform period.

A central contribution of the paper is the identification of a structural shift in the correlation between permanent and temporary shocks. Under the LLM specification, correlations are positive and statistically significant prior to the reforms, whereas the post-reform period is characterized by a significant negative correlation for per capita GDP. This reversal indicates a change in macroeconomic adjustment dynamics, with cyclical fluctuations increasingly reflecting short-run responses to permanent shocks rather than acting as independent sources of long-run variation.

In the pre-reform period, the dominance of permanent shocks and the limited persistence of temporary disturbances are consistent with the Cycle-is-the-Trend Hypothesis (CTH), whereby fluctuations largely reflect shocks with lasting effects on

the level of output. Such dynamics are typical of economies exposed to macroeconomic instability and frequent policy disruptions. In contrast, the emergence of a negative correlation in the post-reform period ($\rho = -0.59$) suggests a transition toward a more stable adjustment mechanism. Cyclical fluctuations increasingly serve as a margin of short-run adjustment—such as in response to external shocks—while the economy converges toward its long-run path. This pattern is consistent with improved macroeconomic stabilization, although it does not imply full insulation from permanent disturbances. These findings suggest that the Cycle-is-the-Trend Hypothesis provides a good characterization of the pre-reform period, but becomes less consistent with the data in the post-reform regime.

These findings have important implications for economic policy. The reduction in the variance of permanent shocks suggests gains in macroeconomic stability, reinforcing the importance of maintaining credible long-term policy frameworks. At the same time, the increased persistence and relative importance of temporary shocks highlight the role of countercyclical fiscal and monetary policies in smoothing short-run fluctuations and enhancing resilience to external shocks.

Finally, some limitations should be acknowledged. The univariate nature of the analysis does not allow for the identification of transmission channels across aggregates, and the structural break is imposed exogenously. Extending the framework to multivariate settings and incorporating endogenous break detection or stochastic volatility represents a natural avenue for future research.

Data availability statement

The data that support the findings of this study are available on <https://github.com/macroxcs/TCbayes.git>

References

- Aguiar, Mark and Gita Gopinath (2007). Emerging Market Business Cycles: The Cycle is The Trend. *Journal of Political Economy*, 115(1):69–102. doi.org/10.1086/511283.
- Bai, Jushan and Pierre Perron (2003a). Computation and Analysis of Multiple Structural Change Models. *Journal of Applied Econometrics*, 18(1):1–22. doi.org/10.1002/jae.659.
- Bai, Jushan and Pierre Perron (2003b). Critical Values for Multiple Structural Change Tests. *The Econometrics Journal*, 6(1):72–78. doi.org/10.1111/1368-423X.00102.
- Bendezú-Jiménez, Héctor, Gabriela Pérez, and Aldair Trujillo (2025). Impacto de los Choques Externos en el Crecimiento e Integración económica: Evidencias para la Alianza del Pacífico (2000-2019). *Global Business Administration Journal*, 9(1):e6742–e6742. doi.org/10.31381/gbaj.v9i1.6742.
- Beveridge, Stephen and Charles R. Nelson (1981). A New Approach to Decomposition of Economic Time Series into Permanent and Transitory Components with Particular Attention to Measurement of the ‘Business Cycle’. *Journal of Monetary Economics*, 7(2):151–174. [doi.org/10.1016/0304-3932\(81\)90040-4](https://doi.org/10.1016/0304-3932(81)90040-4).
- Bluedorn, John C. and Daniel Leigh (2018). *Is The Cycle the Trend? Evidence from the Views of International Forecasters*. International Monetary Fund. doi.org/10.5089/9781484363980.001.
- Castillo, Paul, Carlos Montoro, and Vicente Tuesta (2006). Hechos Estilizados de la Economía Peruana. *Documento de trabajo*, 5:2006. <https://www.bcrp.gob.pe/docs/Publicaciones/Documentos-de-Trabajo/2006/Documento-Trabajo-05-2006.pdf>.
- Corbo, Vittorio and Klaus Schmidt-Hebbel (2001). Inflation Targeting in Latin America. Documento de Trabajo ISSN (edición impresa) 0716-7334, ISSN

- (edición electrónica) 0717-7593, Pontificia Universidad Católica de Chile. <https://core.ac.uk/download/pdf/6602615.pdf>.
- Díaz González, Joaquín and Khertd Palermo (2022). Trend-Cycle Decomposition for Latin American and G7 Countries: Application and Empirical Comparison of Old and New Univariate Methodologies. <https://core.ac.uk/download/pdf/553623795.pdf>.
- Elliott, Graham, Thomas J. Rothenberg, and James H. Stock (1996). Efficient Tests for an Autoregressive Unit Root. *Econometrica*, 64(4):813–836. doi.org/10.2307/2171846.
- Engle, Robert F. and Sharon Kozicki (1993). Testing for Common Features. *Journal of Business & Economic Statistics*, 11(4):369–380. doi.org/10.1080/07350015.1993.10509966.
- Ganiko, Gustavo and Alvaro Jiménez (2023). Choques Externos en la Economía Peruana: Un Enfoque de Ceros y Signos en un Modelo BVAR. <https://www.bcrp.gob.pe/docs/Publicaciones/Documentos-de-Trabajo/2023/documento-de-trabajo-010-2023.pdf>.
- Grant, Angelia L. and Joshua Chan (2017). A Bayesian Model Comparison for Trend-Cycle Decompositions of Output. *Journal of Money, Credit and Banking*, 49(2-3):525–552. doi.org/10.1111/jmcb.12388.
- Gregory, Allan W. and Bruce E. Hansen (1996). Residual-based Tests for Cointegration in Models with Regime Shifts. *Journal of Econometrics*, 70(1):99–126. [doi.org/10.1016/0304-4076\(99\)00055-7](https://doi.org/10.1016/0304-4076(99)00055-7).
- Guillén, Ángel and Gabriel Rodríguez (2014). Trend-Cycle Decomposition for Peruvian GDP: Application of an Alternative Method. *Latin American Economic Review*, 23:1–44. doi.org/10.1007/s40503-014-0005-3.
- Harvey, Andrew, Esther Ruiz, and Neil Shephard (1994). Multivariate Stochastic Variance Models. *The Review of Economic Studies*, 61(2):247–264. doi.org/10.2307/2297980.

- Hatemi-J, Abdunnasser (2008). Tests for Cointegration with Two Unknown Regime Shifts with an Application to Financial Market Integration. *Empirical economics*, 35(3):497–505. doi.org/10.1007/s00181-007-0175-9.
- Issler, Joao Victor and Farshid Vahid (2001). Common Cycles and the Importance of Transitory Shocks to Macroeconomic Aggregates. *Journal of Monetary Economics*, 47(3):449–475. [doi.org/10.1016/S0304-3932\(01\)00052-6](https://doi.org/10.1016/S0304-3932(01)00052-6).
- Jahan-Parvar, Mohammad R., Charles Knipp, and Pawel Szerszen (2024). Trend-Cycle Decomposition and Forecasting Using Bayesian Multivariate Unobserved Components. dx.doi.org/10.17016/FEDS.2024.100.
- Johansen, Søren (1991). Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models. *Econometrica*, pages 1551–1580. doi.org/10.2307/2938278.
- Kim, Chang-Jin and Jaeho Kim (2022). Trend-Cycle Decompositions of Real GDP Revisited: Classical and Bayesian Perspectives on an Unsolved Puzzle. *Macroeconomic Dynamics*, 26(2):394–418. [doi:10.1017/S1365100520000218](https://doi.org/10.1017/S1365100520000218).
- King, Robert G., Charles I. Plosser, James H. Stock, and Mark W. Watson (1991). Stochastic Trends and Economic Fluctuations. *The American Economic Review*, 81(4):819–840. doi.org/10.3386/w2229.
- King, Robert G., Charles Plosser, and Sergio T. Rebelo (1988). Production, Growth and Business Cycles: II. New Directions. *Journal of Monetary Economics*, 21(2-3):309–341. [doi.org/10.1016/0304-3932\(88\)90034-7](https://doi.org/10.1016/0304-3932(88)90034-7).
- Lago, Ricardo (2022). La Reinserción Financiera del Perú: Testimonio. In Ortiz, M. and Winkelried, D., editors, *Hitos de la Reforma Macroeconómica en el Perú 1990-2020: La Recompensa de los Tamías*, pages 95–108. Universidad del Pacífico, Lima. doi.org/10.21678/978-9972-57-486-3-7.
- Maki, Daiki (2012). Tests for Cointegration Allowing for an Unknown Number of Breaks. *Economic Modelling*, 29(5):2011–2015. doi.org/10.1016/j.econmod.2012.04.022.

- Martinelli, César and Marco Vega (2018). Monetary and Fiscal History of Perú 1960-2010: Radical Policy Experiments, Inflation and Stabilization. doi.org/10.2139/ssrn.3241872.
- Martinez, Martín and David Florián, D. (2019). Identificación y Fechado del Ciclo Económico en el Perú a Partir de un Modelo de Componentes No Observables: 1980-2018. *Revista Moneda*, (179):25–30. www.bcrp.gob.pe/docs/Publicaciones/Revista-Moneda/moneda-179/moneda-179-05.pdf.
- Mitra, Sinchan and Tara M. Sinclair (2010). Macroeconomic Fluctuations in Emerging Economies: An Unobserved Components Approach. *Macroeconomics Research Group Discussion Paper Series*, 3911. <https://economics.uq.edu.au/files/47026/3911.pdf>.
- Narayan, Paresh K. (2008a). An Investigation of the Behaviour of Australia's Business Cycle. *Economic Modelling*, 25(4):676–683. doi.org/10.1016/j.econmod.2007.10.012.
- Narayan, Paresh K. (2008b). Understanding the Importance of Permanent and Transitory Shocks at Business Cycle Horizons for the UK. *Physica A: Statistical Mechanics and its Applications*, 387(12):2879–2888. doi.org/10.1016/j.physa.2008.01.023.
- Narayan, Paresh K. (2011). An Analysis of Indonesia's Business Cycle. *The Indian Economic Journal*, 59(1):162–173. doi.org/10.1177/0019466220110110.
- Nolazco, Jose, Patricia Lengua-Lafosse, and Nikita Céspedes (2016). Contribución de los Choques Externos en el Crecimiento Económico del Perú: Un Modelo Semi-Estructural. *Asociación Peruana Economía, Lima*. <https://perueconomics.org/wp-content/uploads/2016/12/WP-80.pdf>.
- Ortiz, M. and Winkelried, D., editors (2022). *Hitos de la Reforma Macroeconómica en el Perú 1990-2020: La Recompensa de los Tamías*. Universidad del Pacífico, Lima, 1 edition. <https://repositorio.up.edu.pe/backend/api/core/bitstreams/8a95ec82-d39f-4ced-a53a-6ec89f1967c9/content>.

- Parodi, Carlos (2022). Reformas Estructurales en el Perú. In Ortiz, Marco and Diego Winkelried, editors, *Hitos de la Reforma Macroeconómica en el Perú 1990-2020: La Recompensa de los Tamías*, pages 83–94. Universidad del Pacífico, Lima. doi.org/10.21678/978-9972-57-486-3-6.
- Perea, Hugo (2022). El Camino hacia la Inflación de un Dígito. In Ortiz, Marco and Diego Winkelried, editors, *Hitos de la Reforma Macroeconómica en el Perú 1990-2020: La Recompensa de los Tamías*, pages 57–68. Universidad del Pacífico, Lima. doi.org/10.21678/978-9972-57-486-3-4.
- Perron, Pierre and Tatsuma Wada (2009). Let's Take a Break: Trends and Cycles in US Real GDP. *Journal of monetary Economics*, 56(6):749–765. doi.org/10.1016/j.jmoneco.2009.08.001.
- Pérez-Forero, F. (2021). Trend-Cycle Decomposition of GDP: A Flexible Filter. <https://www.bcrp.gob.pe/docs/Publicaciones/Documentos-de-Trabajo/2021/documento-de-trabajo-008-2021.pdf>.
- Rossini, Renzo and Alejandro Santos (2015). Peru's Recent Economic History: From Stagnation, Disarray and Mismanagement to Growth, Stability and Quality Policies. *Peru: Staying the Course of Economic Success*, pages 9–36. www.elibrary.imf.org/display/book/9781513599748/ch002.xml.
- Schmidt-Hebbel, K., Werner, A., Hausmann, R., and Chang, R. (2002). Inflation targeting in brazil, chile, and mexico: Performance, credibility, and the exchange rate [with comments]. *Economia*, 2(2):31–89. doi.org/10.1353/eco.2002.0007.
- Seminario, Bruno and César Bouillón (1992). Ciclos y Tendencias en la Economía Peruana: 1950-1989. repositorio.up.edu.pe/item/96147969-9d81-4363-ab11-a8970f5fc7c6.
- Sobrinho, Cesar R (2021). Analyzing the Role of the Permanent and Temporary Shocks in Peru Using the Co-Movements Approach. *International Journal of Economics and Finance*, 13(11). doi.org/10.5539/ijef.v13n11p111.

- Stock, James H. and Mark W. Watson (2007). Why Has US Inflation Become Harder to Forecast? *Journal of Money, Credit and Banking*, 39:3–33. doi.org/10.3386/w12324.
- Terrones, Marco and César Calderón (1993). El Ciclo Económico en el Perú. Technical report. www.grade.org.pe/wp-content/uploads/ddt20.pdf.
- Vahid, Farshid and Robert F Engle (1993). Common Trends and Common Cycles. *Journal of Applied Econometrics*, pages 341–360. doi.org/10.1002/j.1099-1255.1993.tb00002.x.
- Valderrama, José (2022). Reglas e Instituciones Fiscales. In Ortiz, Marco and Diego Winkelried, editors, *Hitos de la Reforma Macroeconómica en el Perú 1990-2020: La Recompensa de los Tamías*, pages 123–142. Universidad del Pacífico, Lima. [/doi.org/10.21678/978-9972-57-486-3-9](https://doi.org/10.21678/978-9972-57-486-3-9).
- Végh, C. A. (2022). Programas de estabilización en américa latina. In Ortiz, M. and Winkelried, D., editors, *Hitos de la Reforma Macroeconómica en el Perú 1990-2020: La Recompensa de los Tamías*, pages 31–44. Universidad del Pacífico, Lima. doi.org/10.21678/978-9972-57-486-3-2.
- Vehtari, Aki, Andrew Gelman, and Jonah Gabry (2017). Practical Bayesian Model Evaluation Using Leave-One-Out Cross-Validation and WAIC. *Statistics and computing*, 27(5):1413–1432. doi.org/10.1007/s11222-016-9696-4.
- Wang, Jiahui and Eric Zivot (2000). A Bayesian Time Series Model of Multiple Structural Changes in Level, Trend, and Variance. *Journal of Business & Economic Statistics*, 18(3):374–386. doi.org/10.2307/1392269.