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SEM Analysis of Economic Indicators: Connecting Exchange Rates and GDP Dynamics

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Abstract
The pivotal role of Gross Domestic Product (GDP) and exchange rates in shaping the economic growth and development of India cannot be understated. Their intricate relationship holds significant implications for policy formulation and economic strategies. Recognizing the need for a comprehensive understanding of this nexus, this study emphasizes the importance of identifying a proper relationship between GDP and exchange rates to enhance their effective application. While past research often employed regression or separate analytical approaches, the interconnectivity of economic variables underscores the necessity of adopting Structural Equation Modelling (SEM). In this context, this research underscores the effectiveness of SEM in modelling the intricate relationship between GDP and exchange rates, considering influential factors such as Industrial Production (IP), Consumer Price Index (CPI), imports, exports, inflation, gold prices, and crude oil prices. The study not only demonstrates the potency of SEM in understanding this complex relationship but also reports the identification of significant economic indicators that directly impact both GDP and exchange rates. These findings contribute to the predictive model for economic enhancement and growth strategies. Ultimately, this research highlights the potency of SEM as a versatile tool that facilitates a more profound comprehension of the multifaceted dynamics between GDP, exchange rates, and diverse economic indicators.

Keywords: *Gross Domestic Product (GDP), Exchange Rate, SEM, economic variables*

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I. INTRODUCTION

The dynamics of exchange rates and GDP are influenced by a myriad of factors that span economic indicators, commodities, and financial parameters. This intricate interplay shapes the economic landscape of a nation and its global interactions. Several key factors, including Consumer Price Index (CPI), Industrial Production (IP), inflation, gold prices, crude oil prices, real interest rates, and Gross Domestic Product (GDP), exert significant influence on both exchange rates and GDP. Understanding the impact of each of these factors provides invaluable insights into the intricate dance of economies, trade, and financial markets. In this exploration, we delve into the effects of these factors on exchange rates and GDP, uncovering the nuanced relationships that underpin the modern economic world.

Relationship between Exchange Rate and Economic Indicators

The Consumer Price Index (CPI) serves as a metric to gauge the average fluctuations in prices that consumers pay for a designated collection of goods and services across time. A higher CPI often signifies inflationary pressures. Exchange rates can be affected as higher inflation erodes the purchasing power of a currency, leading to depreciation. Consequently, countries with high inflation may witness their exchange rates weaken against those of low-inflation countries. CPI also indirectly impacts GDP, as inflation levels can influence consumer spending patterns, business investment decisions, and government policies, all of which collectively impact economic growth. IP measures the output of industrial sectors, indicating the health and growth of manufacturing and production. Strong industrial production often points to a robust economy, leading to a positive impact on the exchange rate. A thriving manufacturing sector can attract foreign investment and boost the value of a currency. Additionally, higher IP generally signifies strong economic activity, which can correlate with higher GDP growth due to increased production, employment, and consumption.

Inflation, the rate at which general price levels rise, has profound implications for both exchange rates and GDP. High inflation can erode the value of a currency, leading to a decrease in its exchange rate. On the other hand, moderate inflation can signal a healthy economy, potentially attracting foreign investment and positively affecting exchange rates. In terms of GDP, moderate inflation can stimulate consumer spending and business investment, contributing to economic growth. However, hyperinflation can be detrimental to both exchange rates and GDP, causing economic instability.

Commodities like gold and crude oil play a pivotal role in global trade and finance. Gold is often viewed as a safe-haven asset, especially in times of economic uncertainty, and its price can influence investors' perceptions of currency stability. Fluctuations in crude oil prices impact countries differently based on their level of dependence on oil imports or exports. Changes in commodity prices can influence trade balances, current account deficits, and fiscal policies, subsequently affecting exchange rates and GDP growth.

Real interest rates, adjusted for inflation, impact exchange rates and GDP through their influence on capital flows. Higher real interest rates can attract foreign investment seeking better returns, leading to an appreciation of the local currency. Conversely, lower real interest rates can discourage capital inflows and potentially lead to currency depreciation. Real interest rates also affect borrowing costs, influencing consumer spending, business investments, and overall economic growth. GDP, a comprehensive measure of economic activity within a country, has a reciprocal relationship with exchange rates. A strong GDP growth rate can attract foreign investment, increasing demand for the local currency and potentially leading to appreciation. Conversely, a weak GDP growth rate can lead to a depreciating currency. Additionally, GDP growth is intertwined with various economic indicators; for instance, increased IP, consumer spending, and investment collectively contribute to higher GDP growth.

The literature review provides various studies that have explored the intricate relationships between exchange rates, economic growth, inflation, and other significant economic indicators. Beginning with Jonathan's (1999) investigation, it revealed that the influence of exchange rates and import prices on domestic price inflation was limited. Moving forward, Onuoha's (2014) study on Nigeria's economic growth highlighted a noteworthy positive correlation between the exchange rate and inflation, while also noting a negative association with economic growth. This emphasis on the importance of exchange rate stability and controlled inflation for sustained economic progress echoed through the findings. Shandre's (2004) study further contributed by revealing qualitative differences in the impacts of exports and imports on labour productivity, challenging the notion of export-led productivity growth in certain countries. Raphael's (2011) examination of South Africa's economic dynamics focused on interest rates, exchange rates, and oil prices' influence on inflation. This study identified strong positive relationships between money supply, exchange rates, and inflation, emphasizing the need for careful management of these factors. Fast-forwarding, Halder's (2019) research on Bangladesh offered insights into the contrasting influences of macroeconomic variables on GDP growth. While export and import exerted a significant positive impact, the study found no significant relationship between exchange rate and inflation with the variables studied.

Amirdha's (2019) investigation explored the linear relationship between the real exchange rate and economic growth, establishing Granger causality between exchange rates and exports. Meanwhile, Thanh et al.'s (2019) use of a VAR model to assess the impact of exchange rates on inflation and economic growth in Vietnam's context enriched the understanding of these relationships in a specific setting. Most recently, Kulal's (2023) comprehensive study cantered around the dollar to rupee exchange rate's influence on key economic indicators in India. While evidence of a long-run relationship remained weak, the study highlighted the potential benefits of diversification into gold and the short-term links between exchange rates and spot prices. These varied studies collectively offer valuable insights into the multifaceted interactions between exchange rates, economic growth, inflation, and broader economic indicators across different time periods and geographical contexts.

The objective of this study is to analyse the intricate relationships between key economic indicators, commodities, and financial parameters, and their impacts on exchange rates and Gross Domestic Product (GDP). By examining factors like CPI, IP, inflation, gold and crude oil prices, real interest rates, and GDP, the study aims to uncover correlations, causal effects, and predictive insights regarding their influence on exchange rate movements and GDP growth. Additionally, the research aims to evaluate cross-impacts, assess policy implications, identify economic risks, and provide insights into trade and investment dynamics. Through these objectives, the study endeavours to enhance our understanding of the multifaceted interplay that shapes economies and contributes to informed economic decision-making.

II. MATERIALS AND METHODS

The information and data are used from different website Investing.com. The quarterly time series data of 9 variables namely the Exchange rate, CPI, IP, Inflation rate, Import Price, Export Price, GDP of India, Gold prices in India, and Crude oil prices in India have been used. The time considered for the study is 1996 Quarter 2 to 2023 Quarter 1.

Multiple Linear Regression(MLR)

In the context of multiple linear regression models, the dependent variable (Y) is influenced by several independent variables (X_1, X_2, ...,X_k), each associated with specific coefficients (β_1, β_2, ..., β_k). This relationship is expressed as

$$Y_t=\sum_{i=1}^{k} X_{ti}\,\beta_i + \varepsilon_t,\ t = 1,2 \ldots\ldots n$$

For each observation (t) within a dataset of size (n). The MLR model relies on certain assumptions, and if all these assumptions are met, Ordinary Least Squares (OLS) provides efficient, unbiased, and superior estimators.

Multicolinearity

Multicollinearity is a critical issue in regression analysis, arising when predictor variables are strongly correlated, leading to unstable parameter estimates and hindering interpretation. It inflates standard errors, making coefficients imprecise and complicating the isolation of individual predictors' effects on the dependent variable. To tackle this problem, various measures are employed. The Variance Inflation Factor (VIF) gauges the extent of multicollinearity by assessing how much a predictor's variance is increased due to correlation with others.

Methods to deal with Multicollinearity

Ridge, Lasso, and Elastic Net regression models are sophisticated techniques employed to mitigate the effects of multicollinearity in regression analyses, where predictor variables exhibit high correlations. Ridge regression introduces a penalty term that shrinks the magnitude of regression coefficients, reducing their susceptibility to extreme values caused by multicollinearity. This regularization technique balances the trade-off between bias and variance, yielding more stable coefficient estimates. On the other hand, Lasso regression enforces L1 regularization, which not only shrinks coefficients but also has the remarkable ability to drive some coefficients to exactly zero. This feature performs automatic variable selection by excluding irrelevant predictors from the model, simplifying interpretation. Elastic Net combines the strengths of Ridge and Lasso by adding both L1 and L2 penalties. This approach offers a middle ground, as it encourages sparsity in the coefficient matrix like Lasso while still benefiting from the stabilizing effects of Ridge. The parameter α in Elastic Net determines the balance between these penalties, allowing practitioners to tailor the model's behaviour according to the specific data characteristics.

Structural Equation Model (SEM)

The increasing availability of data in today's information-driven society highlights the necessity for effective analysis tools. Data mining and applied statistics are proposed as powerful means to extract insights from large datasets. Multivariate analysis techniques have gained prominence due to the complex and non-homogeneous nature of reality, enabling researchers to understand relationships among multiple variables simultaneously. Among these methods, Structural Equation Models (SEM) have gained significant traction since the 1970s. SEM enables the analysis of both relationships between latent variables (Structural Model) and connections between latent variables and their observed indicators (Measurement Model). Techniques like Linear Structural Relations (LISREL) and Covariance Structural Analysis (CSA) form the foundation of SEM. The method known as Partial Least Square (PLS) for SEM offers a distribution-free approach suitable for predictive analysis with complex and theoretically limited scenarios. Covariance Structure Analysis combines confirmatory factor analysis and structural equation modelling to explain patterns among latent variables measured by manifest indicators. This second generation multivariate technique involves a structural model specifying relationships between latent variables and a measurement model confirming its consistency with empirical data through covariance comparisons.

The general representation of SEM is,

$$\eta = \beta\eta + \Gamma\,\xi + \zeta$$

Where $,\xi and\ \zeta$ are three vector of the endogenous and exogenous variables and errors, respectively. β(beta) and Γ (gamma) are two matrix of structural coefficients between the endogenous variables, and between the exogenous and endogenous variables, respectively.

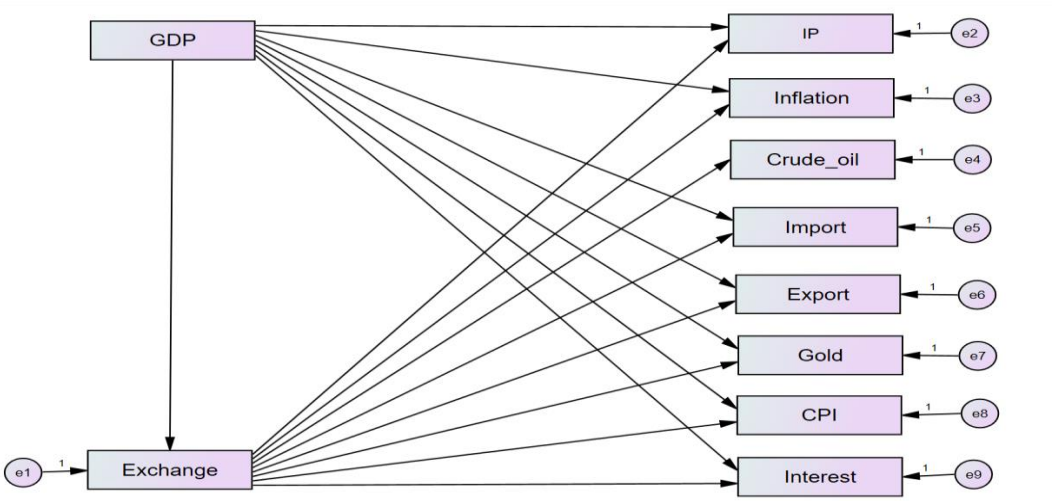

Figure-1: Proposed SEM for Exchange rate and GDP

III. ANALYSIS AND DISCUSSION

After verifying the initial basic conditions, the analysis revealed significant multicollinearity within the data. In response, a range of regression models were employed to address this issue effectively.

Table-3.1: Model performance comparison for Exchange rate.

Methods	R Square	RMSE
MLR	0.7574	0.6010
Ridge	0.5890	0.5473
Lasso	0.7635	0.5292
Elastic Net	0.6535	0.5291

Upon conducting a comprehensive comparison of the performance of multiple regression techniques, including Multiple Linear Regression (MLR), Lasso, Ridge, and Elastic Net, it is noteworthy that the Lasso regression model exhibited the most remarkable performance, achieving an impressive R-squared value of 0.7635.

Table-3.2: Results of Lasso regression, estimate standard error and p value for Exchange Rate

	Estimate	Std.error	t value	Pr(>|t|)	Decision
(Intercept)	-0.0230	0.0706	-0.3260	0.7453	Insignificant
Import	-2.3152	1.0228	-2.2640	0.0269	Significant
Export	-2.7855	1.1446	-2.4340	0.0177	Significant
GDP	4.2353	1.3186	3.2120	0.0021	Significant
CPI	-1.4025	1.1632	-1.2060	0.2323	Insignificant
IP	-0.0502	0.2004	-0.2510	0.8029	Insignificant
Inflation	0.4761	0.2011	2.3670	0.0209	Significant
Interest	-0.4786	0.2300	-2.0810	0.0414	Significant
Gold	0.8070	0.2777	2.9060	0.0050	Significant
Crude oil	0.6641	0.1555	4.2710	0.0001	Significant

Table-3.3: Model performance comparison for GDP

Methods	R Square	RMSE
MLR	0.9918	0.0935
Ridge	0.9863	0.1139
Lasso	0.9915	0.0948
Elastic Net	0.9874	0.1132

For the GDP also the comparison of different regression methods for analysis reveals distinctive levels of predictive accuracy. Lasso Regression exhibited the best performance in terms of R Square and RMSE, suggesting its effectiveness in capturing the relationship between variables.

Table-3.4: Results of Lasso regression, estimate standard error and p value for GDP

	Estimate	Std.error	t value	Pr(>|t|)	Decision
(Intercept)	-0.0001	0.0080	-0.0140	0.9887	Insignificant
Import	0.2757	0.0845	3.2630	0.0018	Significant
Export	0.1174	0.1089	1.0780	0.2849	Insignificant
CPI	0.7065	0.0481	14.6800	< 0.001	Significant
IP	-0.0078	0.0069	-1.1280	0.2635	Insignificant
Exchange	0.0316	0.0104	3.0370	0.0034	Significant
Inflation	0.0096	0.0248	0.3870	0.7001	Insignificant
Interest	0.0724	0.0238	3.0410	0.0034	Significant
Gold	-0.0706	0.0293	-2.4090	0.0188	Significant

Given the challenge of high multicollinearity among economic indicators, the importance of Structural Equation Modelling (SEM) remains evident in modelling the relationship between GDP and exchange rates, even when all observed indicator variables are considered. SEM's strength in revealing nuanced relationships beyond simple correlations becomes pivotal. Through SEM, researchers can unravel the underlying causal pathways among observed variables, shedding light on how GDP and exchange rates interact. In essence, SEM equips economists and policymakers to shape refined strategies based on a strong grasp of the intricate interplay between GDP and exchange rates, utilizing the comprehensive insights from observed economic indicators.
Several SEM models are constructed, incorporating modification indices and suggestions to introduce covariances among error terms. The finalized and improved model that accurately measures the concurrent relationship between exchange rates and GDP is reported.

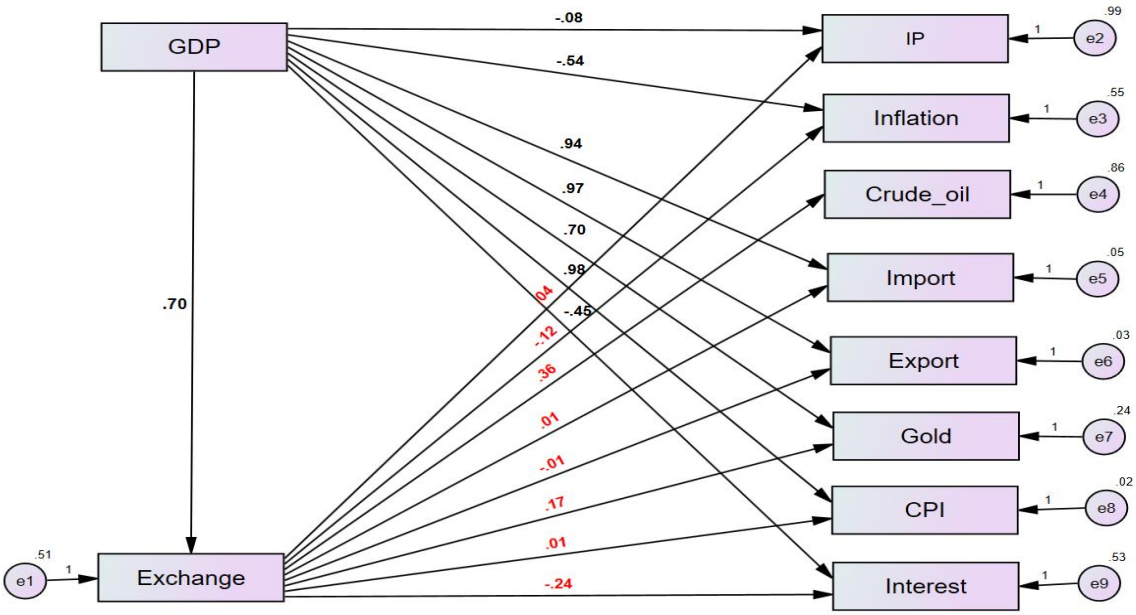

Figure-2: Fitted SEM for Exchange rate and GDP

Table-3.5: Structural equation model parameters, Standard error and p value

			Estimate	S.E.	C.R.	P	Decision
Exchange	<---	GDP	0.7	0.069	10.142	<0.001	Significant
IP	<---	GDP	-0.077	0.135	-0.572	0.567	Insignificant
Inflation	<---	GDP	-0.536	0.091	-5.854	<0.001	Significant
Import	<---	GDP	0.941	0.017	55.623	<0.001	Significant
Export	<---	GDP	0.973	0.014	69.419	<0.001	Significant
Gold	<---	GDP	0.701	0.05	14.102	<0.001	Significant
CPI	<---	GDP	0.983	0.018	53.415	<0.001	Significant
Interest	<---	GDP	-0.454	0.088	-5.137	0.001	Significant
Inflation	<---	Exchange	-0.116	0.096	-1.203	0.229	Insignificant
Crude oil	<---	Exchange	0.359	0.09	3.973	0.004	Significant
Import	<---	Exchange	0.01	0.024	0.412	0.681	Insignificant
Export	<---	Exchange	-0.012	0.019	-0.627	0.531	Insignificant
Gold	<---	Exchange	0.166	0.059	2.824	0.005	Significant
CPI	<---	Exchange	0.006	0.018	0.344	0.731	Insignificant
Interest	<---	Exchange	-0.236	0.094	-2.507	0.012	Significant
IP	<---	Exchange	0.036	0.135	0.266	0.791	Insignificant

This analysis reveals distinct relationships between these factors and GDP. Importantly, strong positive correlations between GDP and variables like Export, Import, CPI, and Exchange Rate highlight their potentially influential roles in driving economic growth. Conversely, the negative correlations with Inflation and Real Interest Rates point to the potential challenges these factors might pose to GDP expansion. These findings provide valuable insights into the complex web of interactions that shape a nation's economic performance.Inflation holds a negative influence on the Exchange Rate, implying that higher inflation tends to weaken the exchange rate. Conversely, crude oil prices exhibit a positive impact, indicating that higher prices in the crude oil market tend to strengthen the exchange rate. Import's effect on the Exchange Rate is minimal yet positive, suggesting that increased imports contribute slightly to a stronger exchange rate. Conversely, export showcases a negligible negative impact, suggesting a subtle connection between a robust exchange rate and decreased exports. Gold prices manifest a positive impact, indicating that elevated gold prices correlate with a stronger exchange rate. The Consumer Price Index (CPI) reveals a minimal positive impact, hinting at a subtle relationship between a higher exchange rate and increased CPI. Meanwhile, real interest rates exert a negative impact, as higher real interest rates tend to weaken the exchange rate. Lastly, industrial production (IP) bears a slight positive impact, signifying a minor connection between a strengthened exchange rate and increased industrial production. Overall, these findings shed light on the varying strengths of influence that different factors exert on the exchange rate, enhancing our understanding of the intricate interplay within the economic landscape.

Table-3.6: Indirect effect along with its confidence interval

	Indirect	LB	UB	p-value	Decision
		GDP	GDP	Exchange	
Exchange	------	-----	----	----	
Crude oil	0.251	0.139	0.361	0.01	Significant
Interest	-0.165	-0.277	-0.04	0.045	Significant
CPI	0.004	-0.021	0.024	0.703	Insignificant
Gold	0.116	0.038	0.197	0.013	Significant
Export	-0.008	-0.0324	0.016	0.57	Insignificant
Import	0.007	-0.02	0.037	0.644	Insignificant
Inflation	-0.081	-0.183	0.036	0.261	Insignificant
IP	0.025	-0.162	0.202	0.782	Insignificant

The outcomes of the conducted SEM model yield a comprehensive understanding of the intricate relationships among various economic indicators and their collective impact on exchange rates. The analysis reveals that certain variables, such as exports, imports, inflation, and CPI, possess direct effects on exchange rates, indicating their immediate influence on currency valuation. Moreover, the model uncovers partial mediation, where interest rates and gold prices influence exchange rates indirectly through the mediating effect of GDP. This suggests that changes in interest rates and gold prices impact exchange rates by influencing GDP, showcasing the intricate web of interactions at play. Additionally, the non-significant relationship between industrial production (IP) and exchange rates or GDP signifies the model's discerning ability to distinguish complex interactions within the economic framework. The presence of both direct and mediated effects emphasizes the need to consider comprehensive models when studying the factors influencing exchange rates. These findings hold valuable implications for policymakers, researchers, and businesses seeking a deeper understanding of currency valuation within the broader economic context. The model fit indices shows that RMSE=0.08, CFI = 0.998, TLI = 0.986, GFI = 0.976, $\frac{\chi^2}{df}$ =1.688.Overall, the fit indices collectively suggest that the proposed model aligns well with the observed data, contributing to a robust understanding of the underlying relationships being studied.

IV. CONCLUSION

In summary, the exploration of the impact of economic indicators on exchange rates and GDP has been the focal point of this study. Commencing with the implementation of the Multiple Linear Regression (MLR) model, initial insights were obtained. However, the presence of high multicollinearity, as revealed by the Variance Inflation Factor (VIF), prompted the exploration of advanced techniques. The Lasso, Ridge, and Elastic Net regression methods were subsequently employed, with Lasso regression method proving to be the most effective in both predicting GDP and exchange rates. Recognizing the complexity of the relationships among economic variables, the adoption of Structural Equation Modelling (SEM) emerged as a pivotal step. SEM enabled a comprehensive understanding of not only direct impacts but also indirect effects, a hallmark of economic interdependencies. This approach revealed the nuanced interplay between variables commonly found in economics, providing insights into both mediating effects and the identification of pivotal variables for exchange rates and GDP.

In conclusion, this study highlights the value of progressively advanced methodologies in dissecting intricate economic relationships. The application of SEM, in particular, allowed for a holistic comprehension of the intricate web of direct and indirect effects among economic indicators, illuminating the pathways through which they influence exchange rates and GDP. This study not only contributes to our understanding of these relationships but also underscores the significance of robust methodologies in analysing complex economic phenomena. This deeper understanding made possible by SEM allows us to comprehensively assess the total effect of economic indicators on both GDP and exchange rates. Such insights are invaluable for investors seeking informed decisions, policy-makers devising effective strategies, and countries aiming for sustainable development. The study's journey, from initial regression methods to the sophisticated SEM analysis, underscores the evolving nature of economic research and its potential to unravel intricate relationships. By offering a holistic view of direct, indirect, and mediating effects, SEM provides a nuanced roadmap for enhancing economic decision-making and fostering economic growth in an increasingly interconnected world.

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