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- **Introduction**

Many economists studied the relationship between the Purchasing Managers' Index (PMI) and other macroeconomic indicators such as GDP and general inflation. We decided to go down a narrower path and take the "output prices", a subindex of the PMI, and study its relationship with the Consumer Price Index (CPI). Output prices measure the average prices that private sector companies charge for their finished goods and services. Like the PMI, they are expressed by a diffusion index that ranges between 0 and 100, with the same standard 50 baseline. A reading above 50 indicates that prices are increasing on average while a reading below 50 indicates prices are decreasing on average. On the other hand, the CPI is an economic indicator that measures the average change over time of a reference "basket" of consumer goods and services. Both series are generally considered to be positively correlated along with time lags, given that the PMI – and thus the output prices – is considered a leading indicator. We decided to study the effect of the percentage point change in last month's PMI on this month's log change in CPI, therefore we initially used a simple linear regression model with a distributed 1-month lag. Later on, we built upon this model and added a dummy variable and finally an autoregressive term to arrive at an Autoregressive Distributed Lag (ARDL) model along with diagnostic tests to assess the impact and validity of the change in output prices more comprehensively.

- **Data Collection and Information**

The CPI data was retrieved from the Central Administration of Statistics while the output prices data was retrieved from S&P Global and BlomInvest. The data collected is from May 2013 to April 2026.

CPI data was transformed into log percentage change, whereby:

$$\Delta \ln(CPI_t) = \ln\left(\frac{CPI_t}{CPI_{t-1}}\right)$$

Since output prices are expressed as a diffusion index, we used percentage point change whereby:

$$\Delta P_{t-1} = P_{t-1} - P_{t-2}$$

Considering we are using MoM changes and lagging our data by 1 month, this excludes our first two sample points, therefore our sample period starts at July 2013 and ends at April 2026, hence a sample size of 154 months.

We used a 1-month lagged dummy variable “Variable LBP/USD” (denoted VLU) in Regression 2 which takes the value 0 when the exchange rate was pegged and the value 1 when it was not fixed, providing us with a proxy for the banking crisis. Of the 154 months observed, 48 of them had the value 1 and the remaining 106 had the value 0. The 48 months (when factoring the 1-month lag) started from November 2019 to October 2023.

• Regression 1: Output Prices

We first regressed the log change in CPI on the lagged output prices percentage point change and got the following results:

Regression Statistics	
Multiple R	0.1533
R Square	0.0235
Adjusted R Square	0.0171
Standard Error	0.0511
Observations	154

ANOVA					
	df	SS	MS	F	Significance F
Regression	1	0.009537705	0.00953771	3.65592276	0.057751483
Residual	152	0.396543179	0.00260884		
Total	153	0.406080884			

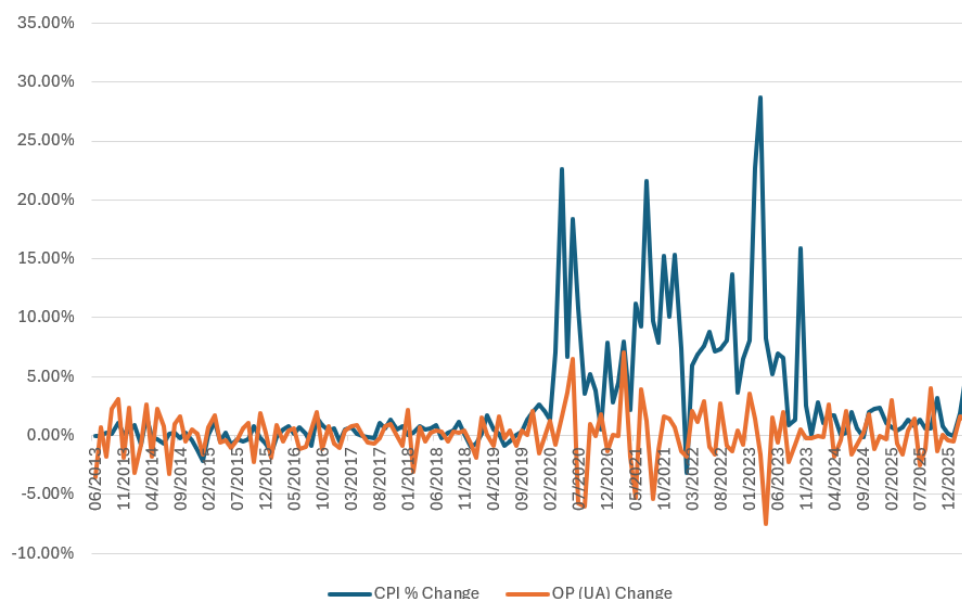
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.0290141	0.004116402	7.04841866	5.9157E-11	0.020881372	0.03714687
OP (UA) Change t-1	0.0039599	0.002071037	1.91204675	0.05775148	-0.00013182	0.00805166

The sample model is thus:

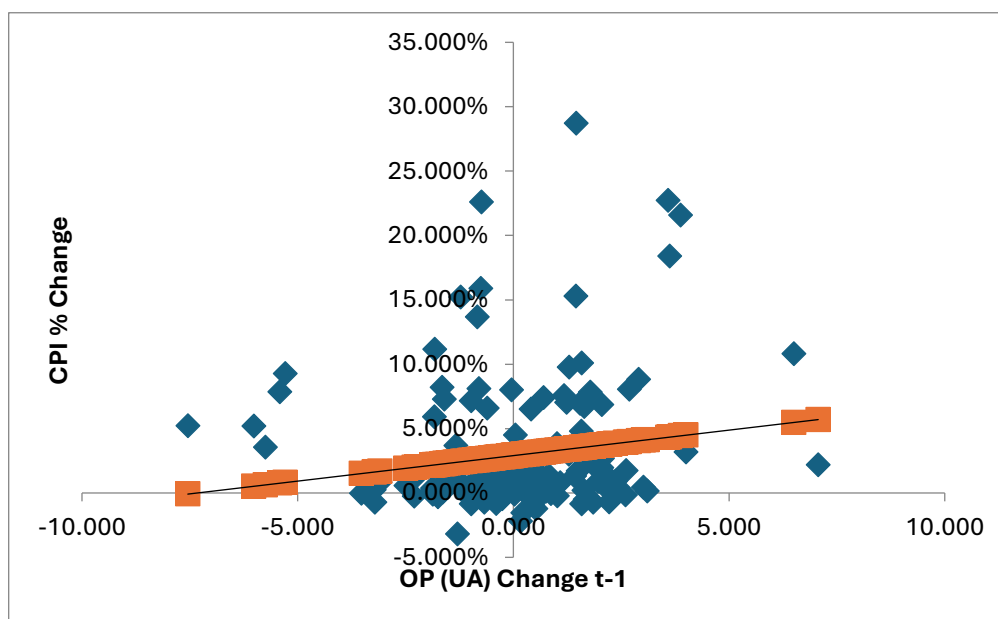
$$\Delta \ln(\widehat{CPI}_t) = \widehat{\beta}_0 + \widehat{\beta}_1 \Delta P_{t-1}$$

We can observe that the intercept is highly significant with a p-value of approximately 5.91×10^{-11} , which indicates that it is significant at the 5% level. On the other hand, the change in output prices – the parameter we actually care about – was borderline insignificant, as its p-value of 5.77% is a little bit higher than our threshold of 5%. Considering the sample period contained both calm periods and the 2019 banking crisis, the results may be distorted if we do not account for the regime shift. Therefore, we added the proxy dummy variable “Variable LBP/USD” with a 1-month lag which takes the value 0 if the exchange rate is stabilized/pegged and the value 1 if it is varying. It is a proxy for the hectic period of the Lebanese crisis whereby the period when the exchange rate was varying, the crisis and its effects persisted strongly whereas calmer periods were reflected by a stable exchange rate. The exchange rate began varying with the start of the crisis (October 2019) and then stabilized around September 2023 when things settled down, especially in the FX market itself.

The Relationship Between Lebanon PMI's Output Prices Subindex and the CPI – A Quantitative Study



To elaborate, we can visually observe that pre-2019, there was positive correlation between the lagged change in output prices and the log change in CPI. However, starting from October 2019 until around September 2026, correlation began breaking. From our regression output, we can see that our R-Squared was only 2.35%, meaning that last month's change in output prices explains only 2.35% of the variability of this month's log change in CPI. Obviously, this isn't favorable and contradicts economic theory and empirical research. However, the crisis heavily distorted the correlation between our two variables, so we need to account for it using "Variable LBP/USD" with the 1-month lag.



Moreover, in the above linear regression plot, we can see that a lot of the data points cluster around the lower end of the y-axis whereas periods of high inflation (7-8%+ monthly, highest was 28.6% change in CPI) that were seen in the crisis are rarer yet have a very strong impact, affecting the coefficient's significance and our R-Squared.

• Regression 2: Output Prices + Variable LBP/USD

We now regressed the log change in CPI on the lagged change in output prices and the lagged dummy “Variable LBP/USD” (denoted as VLU) and got the following results:

Regression Statistics	
Multiple R	0.7184
R Square	0.5160
Adjusted R Square	0.5096
Standard Error	0.0361
Observations	154

ANOVA					
	df	SS	MS	F	Significance F
Regression	2	0.209548612	0.10477431	80.5003674	1.5996E-24
Residual	151	0.196532273	0.00130154		
Total	153	0.406080884			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.00476	0.003504521	1.35827314	0.17640292	-0.00216413	0.01168432
OP (UA) Change t-1	0.00404	0.001462841	2.76197039	0.00645911	0.00115004	0.00693061
VLU t-1	0.077807	0.006276529	12.3964797	8.7283E-25	0.06540571	0.09020802

Our regression equation now becomes:

$$\Delta \ln(\widehat{CPI}_t) = \widehat{\beta}_0 + \widehat{\beta}_1 \Delta P_{t-1} + \widehat{\beta}_2 VLU_{t-1}$$

In this output, we can see immense changes. First, our intercept became insignificant with a p-value of around 17.64% while last month's change in output prices became significant at the 5% level with its p-value of approximately 0.645%. Its coefficient is 0.404%, meaning that for every 1 percentage point increase in output prices (i.e. jump from 52 to 53), CPI is expected to increase next month by an average of 0.404 percentage points, holding other variables constant. The new dummy variable VLU has a p-value of approximately 8.72×10^{-25} , making it highly significant at the 5% level. Its coefficient is 7.78%, which implies that if last month's VLU is 1, CPI is expected to increase this month by $e^{0.0778}$ percentage points. The more surprising result, however, is the R-Squared at a staggering 51.6%. Previously, without VLU, it was only 2.35%. Even though lagged VLU accounted for the regime shift – which is a crucial aspect of this model – such an immense increase may raise a few questions:

First, does this mean that the lagged change in output prices still merely accounts for 2.35% of the variability in the change in CPI, considering VLU “absorbed” the impact of the regime? To test this, we regressed the log change in CPI with only lagged VLU and received this output:

<i>Regression Statistics</i>	
Multiple R	0.7011
R Square	0.4916
Adjusted R Square	0.4882
Standard Error	0.0369
Observations	154

Now that we have the separate R-Squared of lagged VLU, we can compute the lagged change in output prices' individual variance explained:

$$\text{Pure Variance Explained by } \Delta P = 0.516 - R_{\text{Reduced}}^2$$

$$\text{Pure Variance Explained by } \Delta P = 0.516 - 0.4916$$

$$\text{Pure Variance Explained by } \Delta P = 0.0244$$

Since 2.44% is very close to the R-Squared seen in Regression 1 of 2.35%, we can conclude that the variability explained by the lagged change in output prices was unaffected by VLU. The minor discrepancy between 2.44% and 2.35% can be attributed to the small coincidental correlation between lagged VLU and output prices (which will be seen in Regression 3) and/or rounding errors.

The second question that arises revolves around serial correlation. Since a regime shift persists over a large period, our VLU values remain identical for several consecutive months. In our case, all of October 2019 to September 2023 had values of 1 and the remaining were all 0. This indicates that each VLU value is, in essence, dependent on the other, hence we suspect positive serial correlation. To confirm this, we performed a Durbin-Watson test¹ (DWT) on the model's residuals and got the following result:

$$d = \frac{0.2882}{0.1965} \approx 1.466$$

For reference, a DWT result less than 2 indicates positive serial autocorrelation, which means that the values are not independent, therefore confirming our suspicion. To fix

¹The formula for the Durbin-Watson test: $d = \frac{\sum_{t=2}^T (e_t - e_{t-1})^2}{\sum_{t=1}^T e_t^2}$

It is the sum of squared residual differences divided by the sum of squared residuals.

this, we added a 1-month lagged log change in CPI as an independent variable, which will be seen in Regression 3.

The third and final question addresses the reliability and limitations of the VLU as a proxy variable. Variability in the exchange rate does not inherently indicate what regime the economy is in. However, in the case of Lebanon and our sample period, it worked since the LBP/USD exchange rate lost its peg due to the crisis in the first place and it persisted throughout that period. For future reference, this same variable may no longer work.²

²There are 3 hypothetical cases for this:

1. If the Banque Du Liban (BDL) decides to let the exchange rate vary normally in a non-crisis period, that varying exchange rate can no longer be used as a proxy to specify a regime, since the nature of the exchange rate would no longer be tied to or reflective of a regime switch as it was during the 2019 crisis. The exchange rate can just behave normally similar to other countries.
2. Second, inversely, let's assume the exchange rate stays stable for the next 5 years. The new sample period will have a larger portion of months where the VLU is 0. In our data set, VLU = 0 makes up around 70% of the sample data and VLU = 1 makes up the rest. In 5 years, the new sample period will be around 18 years; that previous 30% composition would then make up one-sixth of the sample data set while the previous 70% would make up the remaining five-sixths. Such a large discrepancy in the composition can make the dummy variable unreliable, as the period it helps account for would be relatively short and it thus may distort some metrics.
3. Third, instead of the next 5 years taking a VLU of 0, let's say another crisis persists and because of it the exchange rate varies again (VLU = 1). The new crisis may not be as accurately reflected by VLU anymore, since each crisis will likely have different magnitudes or behave differently than one another. This will affect VLU's metrics, as the average effect on inflation may differ from one crisis to the other. This forces VLU to do the work for both crises and concluding that they have the same average coefficient, even though they probably don't individually.

• Regression 3: Output Prices + Variable LBP/USD + CPI

After adding the 1-month lagged log change in CPI, we get this output:

Regression Statistics	
Multiple R	0.7456
R Square	0.5559
Adjusted R Square	0.5470
Standard Error	0.0347
Observations	154

ANOVA					
	df	SS	MS	F	Significance F
Regression	3	0.22574444	0.075248147	62.58980015	2.67446E-26
Residual	150	0.180336444	0.001202243		
Total	153	0.406080884			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.0031743	0.003395784	0.934789444	0.351399242	-0.00353541	0.009884092
OP (UA) Change t-1	0.0034776	0.00141427	2.458920476	0.015072708	0.000683114	0.006272039
VLU t-1	0.0580536	0.00808417	7.181150643	2.99442E-11	0.042080086	0.074027193
CPI % Change t-1	0.2681621	0.073062067	3.670332965	0.000336086	0.123798385	0.412525839

Finally, our regression equation is now:

$$\Delta \ln(\widehat{CPI}_t) = \widehat{\beta}_0 + \widehat{\beta}_1 \Delta P_{t-1} + \widehat{\beta}_2 VLU_{t-1} + \widehat{\beta}_3 \Delta \ln(CPI_{t-1})$$

Re-running a DWT, we get:

$$d = \frac{0.3661}{0.1803} \approx 2.03$$

Our result is freakishly close to 2, meaning that adding the lagged CPI log change successfully eliminated the problem of serial autocorrelation.

Moreover, we observe that both the lagged change in output prices and lagged VLU are still significant at the 5% level. The same can be said about the lagged CPI log change, which thus suggests that inflation clusters on a monthly basis. In other words, inflation last month can persist throughout this month.

Previously, we tested in the second regression if the pure variance explained by output prices differs from the first regression. Since we concluded that it does not, this can be attributed to the fact that output prices themselves have no correlation with any of the other explanatory variables. To test this, we ran a Variance Inflation Factor (VIF) test, which tests for multicollinearity. In other words, it checks to see if the explanatory variables themselves are correlated, which would inflate R-Squared thus giving false merit to the variables.

After regressing the lagged change in output prices on lagged VLU and lagged log change in CPI, we get the following result:

<i>Regression Statistics</i>	
Multiple R	0.1085
R Square	0.0118
Adjusted R Square	-0.0013
Standard Error	1.9951
Observations	154

The formula for the VIF test is:

$$VIF_i = \frac{1}{1 - R_i^2}$$

$$VIF_i = \frac{1}{1 - 0.0118}$$

$$VIF_i \approx 1.012$$

A VIF of 1.012 is very low which reflects that none of the explanatory variables are interfering with one another. For reference, a VIF under 5 is generally considered acceptable, so 1.012 is practically perfect. Therefore, our model's R-Squared is valid and is not inflated due to multicollinearity.

This result also indirectly tells us something very interesting; it reiterates that the change in output prices is a leading indicator. Since all the variables were initially lagged by 1 month, we are essentially testing them now together with no lag. Therefore, as reflected by the low VIF, the change in outprices has no effect on the log change in CPI within the same month. The consensus changes when we add the 1-month lag as we've observed, which reconfirms the validity of the subindex as a leading indicator!³

³Moreover, we conducted a White test to test for heteroskedasticity and got statistically significant results, thus we should proceed with the results with some caution.

- **Conclusion**

In conclusion, our findings have shown an interesting outlook on the effect of traditionally correlated variables on the economy within the context of Lebanon. In the first regression, the output prices coefficient had a p-value of 5.78%, which made it insignificant at the 5% level. Noticing that the volatile period of the crisis could have distorted the p-value, we accounted for it using VLU. It increased our R-Squared in the second regression to 51.6% and both coefficients became significant. Considering the big jump in R-Squared, we had suspicions of serial autocorrelation, which we solved by adding a 1-month log change in CPI. In regression 3, all our coefficients (except the intercept) remained statistically significant at the 5% level, along with an R-Squared of 55.59%. The remaining 44.41% of the variability unexplained by our model could be attributed to factors that the PMI – and thus the output prices – does not include such as the prices of energy and agriculture, which hold a large weight in the CPI. Moreover, CPI includes both public and private services, whereas PMI only captures the latter. Other variables such as the money supply, local supply shocks caused by war destructions, and national panic/uncertainty could help explain the remaining variability if it is possible to quantify. Perhaps most importantly, our results give validity to the fact that the PMI's change in output prices is a leading indicator of changes in consumer prices. As such, it would be a useful forecast of future changes in real variables such as wages, interest rates, and money.

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