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The Learning Curve: Studying the Relationship Between Output and Inflation

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Abstract: This study investigates the Phillips curve, and changes in the curve, in the context of developing nations. First, after conducting a cross-country panel analysis for 94 countries from 1990 to 2023, the results indicate a difference in the behaviour of the curve among nations of various income levels, with a stronger flattening of the curve seen in developing nations. Additionally, the pass-through for production price index (PPI) inflation, which is viewed as a leading indicator for consumer inflation, has increased significantly since the Global Financial Crisis of 2007 in developing nations. The second part of the paper turns to a microeconomic price-setting model for small-scale agriculture producers in Bangladesh, to evaluate a marginal-cost-based Phillips curve. The results show a steeper gradient on the cost-based Phillips curve than the aggregate version, consistent with similar studies, as well as an increase in the gradient. This shows that the pass-through of costs to the product price has increased for small-scale farmers, making input prices an indicator of interest for monetary policymakers in Bangladesh to enact supply-side policies intended to ease inflationary pressures.

Keywords: Phillips Curve, Marginal Cost Phillips Curve, Agriculture, Bangladesh, Producer Price Index, Pass-Through, Price-Setting Model
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1 Introduction

Ever since money has existed, so has inflation – and similarly, so have attempts to mitigate it.

The previous century brought with it modern monetary policy approaches such as inflation targeting and central bank independence, which brought an end to what was called the Great Inflation era. However, the onset of the COVID-19 pandemic returned inflation to the forefront of economic challenges being faced by countries around the world.

Global average annual inflation in consumer prices reached a 25-year peak in 2022 at 8.7%, which is estimated to slow to 5.8% in 2024 (International Monetary Fund, 2024) – still exceeding levels seen since 2008 prior to the pandemic. Policymakers have responded by tightening monetary policy, with more than 75 central banks and monetary authorities around the world hiking interest rates – many of which had been maintaining historically low rates (Smialek & Nelson, 2022).

Of the theories attempting to understand inflation, the most attention has been given to its link to output. The relationship between price levels and economic activity has been the subject of economic research for over 200 years. The Phillips curve is the simplest yet most cited model resulting from this research, claiming an inverse relationship between unemployment and inflation.

Over the past two decades, empirical studies have repeatedly shown that this relationship has diminished, and may even have fallen apart to the extent that inflation has become an exogenous process to output (Stock & Watson, 2007; Cecchetti et al., 2017; Dotsey, Fujita, & Stark, 2017). These studies largely focus on advanced economies such as the US, UK, and European nations, and show that the Phillips curve has performed inferiorly in explaining and predicting inflation compared to univariate processes (Stock & Watson, 2009). A number of reasons have been identified behind the decline of this relationship, including strongly-anchored inflation expectations (Ball & Mazumder, 2011) and increased dependence on global factors and prices over domestic ones (Forbes, 2019).

However, when it comes to monetary policy implementation in practice, the Phillips curve still emerges as a stalwart and essential component of macroeconomic forecasting. Despite the evidence pointing to a weakening relationship, globally critical central banks including the Federal Reserve (Powell, 2018) and the European Central Bank (Draghi, 2017) still rely on it for policy guidance. This makes understanding the shifts in the Phillips curve, and the causes behind those shifts, critical to form optimal monetary policy (McLeay & Tenreyro, 2020). Moreover, recent studies indicate that the curve may not be as flat anymore as previously claimed; in fact, pandemic-related inflation may be a sign of the return of the Phillips curve, with researchers finding both upwards shifts and a steepening of the curve gradient (Ari, Garcia-Macia, & Mishra, 2023;

Gudmundsson, Jackson, & Portillo, 2024; Hobijn et al., 2023).

The first part of the paper is a cross-country macroeconomic considering inflation and output in 94 countries – a larger group than considered by most studies. I find that the Phillips curve has, on average, weakened since 2000Q1 with both downward shifts in the curve and a decrease in the slope, followed by a small upward shift since 2020Q1. However, when I split the sample into high-income countries and other-income countries (including upper-middle-income, lower-middle-income, and low-income nations), the story is different for the two groups. High-income countries start off with a very weak Phillips curve prior to the beginning of the century but see small increases in the curve gradient throughout the decades since.

While other-income countries start with a strong Phillips curve relationship, the gradient of the curve has been weakening every decade since 2000Q1, including in the 2020s. This is accompanied by downwards shifts in the curve as well. As such, it is evident that the inflation story being told in developed and developing countries is not congruous. The findings of recent studies citing a stronger Phillips curve for advanced economies after the pandemic cannot be extended to those less advanced, and indeed, the curve appears very different for the two groups.

Having established that the curve is changing, and also that the changes are occurring differently, I turn my eye next to evaluating production pricing as a possible source of these shifts. The well-known cost-push theory of inflation posits that increases in input prices are passed on through final product price hikes, which is to blame for the inflation faced by consumers. This is dependent on the pricing strategy of producers and retailers, which many papers have attempted to model and study.

At an aggregate level, the producer price index (PPI) represents the prices faced by wholesalers and manufacturers before they finish processing and pass the product on to the final consumer. In other words, it represents the prices received by sellers, or the cost of inputs (either raw or processed). It is well-established in the literature that PPI inflation leads CPI inflation, and this relationship has led supply shocks and commodity prices to be blamed as the key reasons for pandemic-era inflation (C. J. Williams, 2023). If the pass-through of PPI to CPI has increased, it would mean stronger reactions in consumer inflation after supply shocks impact producer prices.

I run a two-part model to evaluate changes in producer price pass-through, incorporating an error correction term. The findings from this section show that, controlling for changes in output levels, the pass-through of producer prices from one quarter to consumer prices in the immediate next quarter has increased – a surprising finding when we consider that the Phillips curve had been getting weaker. Notably, the increase in pass-through is mainly driven by other-income nations, with only a minimal increase seen in high-income countries.

While the findings for lower-income economies show a different story than the one told for high-income ones, it is hard to discern the change over time convincingly due to the limited availability of data. Very few countries outside the OECD have quarterly data reported for a sufficient historic period, especially into the past century. Moreover, the common practice of studying the Phillips curve and its underlying mechanisms using indicators aggregated at the economy-level suffers from a host of identification challenges, including the endogeneity of monetary policy responses. Many recent papers have thus taken a bottom-up approach to the Phillips curve, attempting to estimate it based on its microeconomic foundations and firm-level pricing theory. Determining the relationship between inflation and marginal costs can avoid the challenges of measuring the output gap, as the latter acts as a more appropriate proxy for real economic activity. Moreover, costs are more responsive to supply shocks than output gap estimates, allowing a better study of how they move through producers to final consumer prices.

In the second part of the paper, I consider a microdata approach and shift focus to Bangladesh small-scale agriculture producers to attempt to study a change in this primitive form of the Phillips curve. Agriculture is an economically and socially critical sector for Bangladesh, and is a source of livelihood for 37% of the population (The World Bank, 2022c). The sector is also important to monetary policymakers, with Bangladesh Bank focusing on providing liquidity support to agricultural producers to ease supply-side constraints and absorb cost shocks (Bangladesh Bank, 2024). This warrants a closer look at how farmers are passing on costs to the pricing of their crops.

Leveraging three harmonized rounds of the Bangladesh Integrated Household Survey (BIHS), I evaluate how agricultural producers pass on changes in their input costs to the final price charged for the good. Treating households who report on growing and selling their agricultural output as small-scale producers, I reach a panel 3,665 households, who combined produce 104 varieties of crop, across the three rounds.

The theoretical model assumes producers engage in monopolistic competition as price-setters. I regress prices against average costs and unit labour costs separately to form what can be considered a primitive-form Phillips curve, where average costs or unit labour costs (as proxies for marginal variable costs) take the place of the real activity variable. The results indicate an increase in the pass-through of costs to prices. This appears to align with the findings of the aggregate level: producers and retailers are passing on more costs to consumers than before. However, while the primitive Phillips curve has become stronger, the aggregate Phillips curve is weaker. This is may be due to the weak proportional relationship between the output gap and marginal cost, as determined by Gagliardone et al. (2023).

This paper's contribution is twofold: first, I conduct a broader cross-country study, than done recently, of the Phillips curve and its relation to producer prices, with a focus on developing countries, finding that results that hold true for developed nations will not necessarily do the same for lower-income countries.

Secondly, I introduce Bangladesh to the countries being evaluated through a microeconomic lens for the marginal-cost-based Phillips curve and underlying pricing foundations. While most micro-foundation studies leverage rich price datasets from advanced economies, I use data from an agriculture-focused survey in a novel approach and treat households as producers.

The paper is organized as follows. Section 2 provides a literature review. In Section 3, I present the underlying theoretical model for the firm-level problem being studied. Section 4 covers the macroeconomic analysis of my paper, looking at relationships among aggregate-level inflation, output, and producer prices for 94 countries. I present the data, methodology, and overall results here. This is followed by Section 5's microeconomic analysis, which shifts focus to Bangladesh's small-scale agriculture industry and the primitive Phillips curve. In Section 6, I discuss the results, and Section 7 concludes.

2 Literature Review

The body of literature considering the Phillips curve is considerable and has evolved significantly over time. The original curve as proposed by William Phillips in 1958 has been upgraded with a number of elements, including backwards-looking inflation lags, forward-looking inflation expectations, and controls such as exchange rate appreciation and commodity prices.

The literature is largely agreed upon the fact that the Phillips curve gradient, at least in the 21st century, is low to the extent that the curve appears flat, and inflation appears to be exogenous to output (Ball & Mazumder, 2011; Hall et al., 2013; Blanchard, Cerutti, & Summers, 2015; Coibion & Gorodnichenko, 2015). The flattening has been attributed to several possible reasons, including stronger monetary policy frameworks (McLeay & Tenreyro, 2020; Fitzgerald, Nicolini, et al., 2014), inflation expectations anchoring (Orphanides & J. Williams, 2004; Blanchard, Cerutti, & Summers, 2015), and globalization (Forbes, 2019). Del Negro et al. (2020) survey in detail the various explanations present in the literature.

However, the empirical estimation of the Phillips curve is riddled with challenges. McLeay & Tenreyro (2020) note that the relationship between output and inflation is endogenous as central bank reactions to inflation mean that the curve will appear less steep than it is in reality, as monetary policy enacts a negative correlation between the output gap and inflation – a simultaneity bias. Additionally, challenges in estimating the output gap itself have been well-documented in the literature (Mavroeidis, 2005). Galí & Gambetti (2019) attempt to address these issues using a vector autoregression with demand shocks instrumenting for the output gap, and find a flattening of the curve in the US. Regardless, the inherent challenges of estimating the curve and the lower variation in the output gap in recent time periods has led some researchers to conclude that the Phillips curve may not be as "dead" as literature suggests

(Hooper, Mishkin, & Sufi, 2020).

Recent papers evaluating the change in the curve in advanced economies before and after the COVID-19 pandemic indicate a steepening in the curve (Gudmundsson, Jackson, & Portillo, 2024; Hobijn et al., 2023). Ari, Garcia-Macia, & Mishra (2023) determine increasing digitization as one of the underlying structural causes for the change, as online prices are easier to adjust; they also consider a hypothetical deglobalization scenario, showing that it would also steepen the curve.

There is substantial empirical evidence that producer prices lead consumer prices, and that the direction of causality is one-way (Caporale, Katsimi, & Pittis, 2002; Akcay, 2011). The underlying theory is consistent with the New-Keynesian cost-push view of inflation: rising input prices are passed on to consumers through increased final product prices (Belton & Nair-Reichert, 2007). C. J. Williams (2023) finds a significant but decreasing producer price pass-through in the US, but notes that the results vary across sectors. Considering a larger group of countries, Wei & Xie (2022) find the same in terms of a decrease in the correlation between CPI and PPI inflation as the average number of production stages around the world has increased.

Huang & Liu (2005) find that inflation-targeting models that do not take into account PPI and sector-specific shocks lead to welfare losses. This, and the clear linkage between the prices of intermediate goods and final goods, makes the study of producer price pass-through of interest to policymakers, as stabilizing PPI could be the key to stabilizing consumer inflation as well (Rotemberg & Woodford, 1999).

Since the usage of aggregate data is prone to estimation challenges, many researchers have turned to microdata approaches to better understand pricing decisions taken by firms. Most of the papers in this vein take advantage of rich product-level price datasets which are more likely to be available in advanced economies, such as Baumgartner et al. (2005) in Austria and Nakamura & Steinsson (2008) in the US. Ahlander, Carlsson, & Klein (2023) study the pass-through of PPI inflation to CPI inflation using the underlying microdata from official Swedish indices, finding that producer prices strongly lead consumer prices.

The usage of microeconomic foundations with rational, optimization-seeking agents in the macroeconomic literature is quite recent but has seen growing attention in the 21st century (Goodfriend & King, 1997).These papers build on firm-level models focused on evaluating the behaviour of price-setting, forward-looking producers who aim to maximize profits and face constraints such as menu costs, sticky information, and consumer anger. Álvarez (2008) surveys 25 such models as presented in the literature.

Similarly, Gagliardone et al. (2023) estimate a bottom-up marginal cost-based Phillips curve for Belgian manufacturing firms, finding that while the pass-through of marginal costs to prices is high, marginal costs are not elastic in response to output levels, creating a less steep aggregate Phillips curve. This primitive-form Phillips curve has also been studied by Galí & Gambetti (2019) and Sbordone (2002), with the view that real marginal costs are a better proxy for real economic activity than aggregate-level estimations of the output gap, which suffers from identification challenges as mentioned previously. Both papers find that real marginal cost outperforms the output gap in predicting inflation. Carlsson & Skans (2012) find a significant coefficient in the marginal-cost-based Phillips curve, but note that the pass-through of cost shocks is neither immediate nor full. Other approaches include Köberl & Lein (2011) who consider capacity utilization as an indication of price adjustment pressure faced by firms to derive a Phillips curve based on the non-inflationary rate of capacity utilization (NIRCU).

3 Theoretical Framework

3.1 The Traditional Approach

The traditional Keynesian approach assumes that markets are imperfect and firms have some ability to exert market power and set prices. The wage market, on the other hand, is assumed to be competitive such that employers are wage-takers, not wage-setters. Prices are assumed to be set based on a markup charged on the average (unit) labour cost and the average raw material cost, as such:

$$P_f = M_f \times L_q + R \tag{1}$$

The price P_f set by firm f thus depends on the markup it can charge through its market power, M_f, the average labour cost L_q which depends on the level of production q, and the average raw material cost R.

Assuming that R and M_f are constant, changes in P_f over time will depend on L_q. This allows us to directly relate price inflation and wage inflation. Notably, as L_q depends on the level of production, price inflation will depend on worker productivity as well:

$$L_q = \frac{\text{Total labour cost}}{\text{Total quantity produced}}$$

$$L_q = \frac{\text{Labour cost per employee}}{\text{Quantity producer per employee}} = \frac{\text{Wage rate}}{\text{Labour productivity}}$$

Price inflation is thus positively related to wage rate increases and negatively related to labour productivity. Using the operator Δ to indicate percentage growth (where ΔX is found by taking logs of X_t/X_{t-1}), the following is true:

$$\Delta P = \Delta W - \Delta Z$$

Where W is the average wage rate and Z is worker productivity. As these are assumed to be equal for all firms, I remove the firm subscript from the price inflation term.

The underlying assumption for the labour market is that the growth rate of wages depends on labour market slack, i.e., unemployment, changes in worker productivity, and inflation expectations. This implies that:

$$\Delta W = \Delta Z - \Delta f(U - U^*) + \Delta P_E$$

Placing this in equation 3.1:

$$\Delta P = \Delta Z - \Delta f(U - U^*) + \Delta P_E - \Delta Z$$

$$\Delta P = -\Delta f(U - U^*) + \Delta P_E$$

The above is considered the traditional expectations-augmented Phillips curve. The empirical specification incorporates these elements:

$$\pi_t = \beta(y_t - y^*) + \lambda E_t(\pi_{t+1}) + u_t \tag{2}$$

In words, inflation in period t depends upon the output gap, $y_t - y^*$, and inflation expectations for the next period. The output gap has an inverse relationship to unemployment, so inflation is increasing in both the output gap and inflation expectations.

When moving from the firm-level Phillips curve in equation 1 to the aggregate economy level curve in equation 2, the average cost term is being replaced by the output gap (or unemployment, depending on the version being used) as reflective of real economic activity. However, there are a number of assumptions taken in these equations that may not hold in real life. One is, of course, that wages and prices are perfectly flexible (Galí & Gambetti, 2019). Additionally, marginal cost needs to be proportional to the output gap, which does not often hold in real life (Gagliardone et al., 2023). Most importantly, output gap is difficult to estimate with accuracy using aggregate data. Regardless, I proceed with this specification in Section 4, as do most studies considering the Phillips curve.

3.2 The New Keynesian Phillips Curve

Increasingly, researchers have shifted to the New Keynesian Phillips Curve (NKPC) to incorporate microeconomic foundations in the estimation of the curve. Similarly, I consider a simplified version of the firm's price-setting problem[1] to provide the context for the microeconomic analysis in Section 5.

There are m ex-ante homogenous firms producing heterogeneous products that are imperfect substitutes, and each producer is small relative to the aggregate economy. As such, firms are price-takers when it comes to what they pay for their inputs.

Firms set their prices in each period t with the goal of maximizing profits. I assume here that producers do not face price rigidities, as agricultural prices are flexible in comparison to non-agricultural products and adjusted in higher frequency (Gouel, 2012; Álvarez, 2008). The inverse demand curve faced by each producer depends on the price P_{it} that they set, the industry price index P_t, and the elasticity of substitution θ_t.

$$Y_{ft} = \left(\frac{P_{it}}{P_t}\right)^{-\theta_t} \frac{Y_t}{m_t}$$

The production technology is Cobb-Douglas with J outputs, where firms use external inputs x_{fjt} as well as internally-sourced inputs n_{fjt}, of which they have a finite amount:

$$Y_{ft} = \prod_{j=1}^{J} (x_{fjt} + n_{fjt})^{\alpha_{jt}}$$

In order to maximize profits, producers follow a price rule that charges a markup on the marginal cost[2]:

$$P_{ft} = \mu_t MC_{ft} \tag{3}$$

Where $\mu = \frac{\theta_t}{\theta_t - 1}$. Thus, changes in prices should be explained by changes in marginal cost or changes in the elasticity of substitution. Compared to the traditional framework, this model allows heterogeneity in the price-setting behaviour of firms between periods.

[1] Consider Gagliardone et al. (2023), Galí & Gambetti (2019) and Calvo (1983) for more detailed versions.

[2] Refer to Appendix A for derivations.

4 Macroeconomic Analysis

This section features a cross-country analysis of the traditional Phillips curve, in the form of equation 2, to study changes in the curve across countries, as well as changes in PPI pass-through.

4.1 Methodology

4.1.1 Data

Estimating the traditional Phillips curve requires two key variables: the output gap and inflation. Data on Gross Domestic Product was collected from the International Financial Statistics database, maintained by the International Monetary Fund. The specific variable considered is the real GDP, not seasonally adjusted, measured in the local currency[3]. This database covers almost every country which publishes quarterly GDP data, but I append data for 6 countries, published by the relevant government statistical authorities[4]. Derivation of the output gap is done by applying the Hodrick-Prescott filter to the natural log of real GDP. The Hodrick-Prescott filter is a method to separate the cyclical and trend components of time series data, allowing the calculation of a potential output, and thus the deviation from that potential GDP.

Inflation data is from "A Global Database of Inflation", constructed by the World Bank. The specific variables taken are the official core consumer price index as reported by government sources[5], and the producer price index for all commodities. Using core consumer prices as the indicator for inflation allows some of the cost-push correlation and passing supply shocks to be stripped out, which partly addresses the identification challenges mentioned earlier (McLeay & Tenreyro, 2020).

Real effective exchange rate (REER) data, used as a control, is collected from a database published under the think tank Bruegel. The REER variable used is the one calculated considering 51 trading partners for each economy, to cover as many time periods and countries as possible and ensure minimal data loss.

Data for all three variables was collected on a quarterly basis from 1990 to the latest quarter available (in most cases, 2022Q4). Combining the three sources leads to a dataset of over 7,000 observations from 94 countries. Country income group classifications are taken as assigned by the World Bank.

[3] Base years vary by country.
[4] These countries are Bahrain, Bangladesh, Nepal, Pakistan, Tunisia, and Zambia.
[5] Where this is unavailable, I take the estimated core inflation as generated by Ha, Kose, & Ohnsorge, 2023

4.1.2 Empirical Specification

I start by attempting to evaluate changes in the curve over four time partitions:

- Period 1: Before 2000Q1
- Period 2: 2000Q1 - 2009Q4
- Period 3: 2010Q1 - 2019Q4
- Period 4: After 2019Q4

The empirical specification to estimate the shift in the curve is given as:

$$\begin{aligned}\pi_{it}^{CPI} = \alpha_i + \beta_1 y_{it} + \Sigma_{j=1}^{4}\beta_{2j}P_{jt} + \Sigma_{j=1}^{4}\beta_{3j}P_{jt} * y_{it} \\ + \Sigma_{n=4}^{4}\lambda_n \pi_{i,t-n}^{CPI} + \delta REER_{it} + \epsilon_{it}\end{aligned} \tag{4}$$

Where:

π_{it}^{CPI} : core inflation for country i in quarter t, annualized based on log CPI
α_i : country fixed-effects
y_{it} : output gap for country i in quarter t
P_{jt} : dummy variables for each time period j, e.g., $P_{1t} = 1$ if the quarter is before 2000Q1, else it is zero
$REER_{it}$: Real effective exchange rate, used as a control

Errors are clustered at the country level. The equation considers lagged inflation terms for four quarters prior, which allows for inflation expectations assuming a backwards-looking information set, following the method of Ball & Mazumder (2011) and Coibion & Gorodnichenko (2015)[6]. Inflation expectations data based on surveys or expert analysis, while desirable for the analysis, is not readily available for such a large set of countries in the public domain. However, there is significant proof of inflation expectations becoming increasingly anchored due to inflation-targeting monetary policy around the world, which allows one to assume that the expectations essentially become a constant that would be added to the intercept term.

The first set of coefficients of interest here is β_{3j}, where a positive value would show a steepening of the Phillips curve in period j. This would mean price levels have become more reactive to changes in the output gap, i.e., a small increase in GDP relative to potential GDP would lead to a greater increase in inflation than in the previous period. The second set of key coefficients is β_{2j}, which indicates a shift in the curve. A positive coefficient would mean an upward shift in the curve, showing that for the same levels of economic activity, inflation is now higher in that period.

[6] Refer to Jordà (2005) for a detailed argument of this approach over a VAR approach.

Next, I run a two-step error correction model within the Phillips curve to evaluate the change in the pass-through of producer price inflation to consumer inflation.

The two-step model involves estimating a long-term model to obtain an error correction term that is then put into a short-term model, following the likes of De Gregorio et al., 2007, Chen (2009), and C. J. Williams (2023) to estimate the relationship of interest: pass-through of producer price inflation to consumer inflation. The two-step model estimates what can be called an augmented Phillips curve, and allows the model to account for the long-term relationship and co-variation between consumer and producer inflation - something that a simple bivariate equation would fail to do.

The long-term model can be estimated as follows:

$$\pi_{it}^{CPI} = a_i + b_1 y_{it} + b_2 \pi_{it}^{PPI} + \varepsilon_{it} \tag{5}$$

Where:

π_{it}^{PPI} : producer price inflation, annualized based on log PPI
ε_{it} : the error correction term

The error correction term ε_{it} goes into the short-term model below, allowing for changes in the pass-through rate of PPI inflation while controlling for the output gap. Here we consider one structural break in the time periods: before and after the Global Financial Crisis of 2007.

$$\begin{aligned} \pi_{it}^{CPI} = \alpha_i + \beta_1 y_{it} + \Sigma_{j=1}^{2} \rho_{1j} \pi_{it}^{PPI} + \Sigma_{j=1}^{2} \rho_{2j} D_t * \pi_{i,t-j}^{PPI} \\ + \Sigma_{n=4}^{4} \lambda_n \pi_{i,t-n}^{CPI} + \delta REER_{it} + \omega \varepsilon_{i,t-1} + \epsilon_{it} \end{aligned} \tag{6}$$

Where:

D_t : dummy variable for the quarter being after the Global Financial Crisis, e.g., $D_t = 1$ if the quarter is after 2007Q2, else it is zero
$\varepsilon_{i,t-1}$: The error correction term from the long-run model

From this specification, the set of coefficients ρ_{2j} indicates the change in the pass-through rate of producer price inflation before and after the GFC. We take four periods of lagged PPI inflation, to match the lags taken of CPI inflation.

4.2 Results

Table 1: Phillips curve changes over decades

	(1) Aggregate	(2) High income	(3) Other income
Output gap	0.184	-0.0125	0.574*
	(0.0981)	(0.0303)	(0.219)
2000s=1	-0.00307	-0.00130	-0.0155
	(0.00180)	(0.000660)	(0.0109)
2000s=1 × Output gap	-0.158	0.0308	-0.602*
	(0.0997)	(0.0325)	(0.232)
2010s=1	-0.00354	-0.00191*	-0.0140
	(0.00220)	(0.000863)	(0.0113)
2010s=1 × Output gap	-0.179	0.0170	-0.580*
	(0.100)	(0.0318)	(0.222)
2020s=1	0.00767*	0.00258***	-0.00333
	(0.00382)	(0.000448)	(0.0128)
2020s=1 × Output gap	-0.124	0.0582	-0.537*
	(0.0885)	(0.0344)	(0.231)
Real effective exchange rate	-0.000259**	-0.0000448*	-0.000510***
	(0.0000815)	(0.0000167)	(0.000139)
Constant	0.0352***	0.00824***	0.0768***
	(0.00932)	(0.00233)	(0.0190)
Observations	7063	4489	2574
Countries	94	46	48
Inflation lags	4	4	4

Standard errors in parentheses

The dependent variable is quarterly core CPI inflation (taken in logs), annualized. All regressions above include country fixed effects. Errors are clustered at country-level.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Using equation 4, I test for changes in the general Phillips curve across the four time periods in Table 1. Alongside the aggregate of all the countries, I separate the 94 countries into two buckets: high-income and other-income, which includes middle-income and low-income economies. There are 46 countries in the high-income bucket, and 48 for other-income. Notably, there are almost twice more observations for the high-income group, as advanced economies are more likely to have quarterly data spanning well into the previous century. Additionally, the other-income group is likely to be highly heterogeneous, as it contains countries of various income categories. This highlights the data challenge in research for developing nations.

The results show that at the aggregate level, the curve shifted slightly downwards in the periods before 2020 and decreased in slope. The changes in the slope indicate a smaller increase in inflation for every percentage increase in the output gap, and the downward shifts indicate less inflation for every level of the output gap. Notably, the standard errors are very high at the aggregate level, likely due to the high level of heterogeneity among the countries being considered. At an aggregate level, the results are only significant for a shift in the 2020s.

Turning next to the high-income and other-income sub-groups, the difference is quite stark in how the Phillips curve is changing in various countries. Firstly, the low and statistically insignificant coefficient of the output gap in high-income countries corroborates the theory that the relationship between output and inflation has become very weak. This relationship is much stronger for developing nations. We also see that "base" inflation in the constant or intercept is much higher for developing countries than for advanced economies. With regards to the changes in the curve, it appears to be making a comeback in developed countries with a statistically significant upward shift since 2020 - consistent with what recent literature has found. On the other hand, the Phillips curve's slope is becoming less steep in developing countries and shifting downwards, indicating both lower inflation and a weaker output-inflation relationship. These flattenings are both large economically and statistically significant at the 5% level.

It is worth noting that the coefficients in table 1 for high-income countries, while close in value to those seen in similar literature such as Gudmundsson, Jackson, & Portillo (2024), are not exactly the same and appear as statistically insignificant. This may be due to a number of reasons, such as the inflation or output gap measure used, and the variations in specification such as the number of lags and inclusion/ exclusion of inflation expectations.

Next, I turn to the two-part model[7] to see if PPI pass-through has changed by considering a singular structural break during the time of the GFC. The results of the long-term regression in equation 5 are in table 2[8]

The second stage estimates changes in pass-through rates of production price inflation using equation 6. In table 3, the results show that the pass-through of producer price inflation in one quarter to consumer inflation in the immediate

[7]Twelve countries are not included in this part of the analysis as they do not have quarterly PPI data published, which consists of 4 high-income countries and 8 other-income countries.

[8]Appendix B contain the results of an Im-Pesaran-Shin unit-root test to see if the error terms for all panels contain a unit root, which rejects the hypothesis that all panels have unit roots. I proceed with the hypothesis that PPI and CPI inflation belong to a cointegrated model, and PPI inflation leads CPI inflation.

next quarter has increased since the GFC. Importantly, this result at the aggregate level is mainly driven by other-income countries, which see a much higher increase in the pass-through rate.

Table 2: Long-run model

	(1) Aggregate	(2) High income	(3) Other income
Output gap	0.0105	0.0212	-0.00895
	(0.0192)	(0.0108)	(0.0250)
PPI inflation	0.0694	0.124**	0.0460
	(0.0973)	(0.0366)	(0.125)
Constant	0.0249***	0.0198***	0.0338***
	(0.00365)	(0.000985)	(0.00739)
Observations	6300	4248	2052
Countries	82	42	40

Standard errors in parentheses

The dependent variable is quarterly core CPI inflation (taken in logs), annualized. All regressions above include country fixed effects. Errors are clustered at country-level.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

It is worth noting that the coefficient for PPI inflation lagged by one quarter in the reference period before the GFC is negative. This does not match most studies for PPI pass-through, but the coefficient for PPI inflation is positive in the long-run model in table 2, which ensures the correct direction of the relationship. Additionally, the output gap coefficient is negative for other-income countries in both tables 2 and 3, with high standard errors - a sign of the heterogeneity issue when lumping together such a group of countries. I consider this issue more closely in Appendix C.

Table 3: Short-run model with time-varying PPI pass-through

	(1) Aggregate	(2) High income	(3) Other income
Output gap	0.0202**	0.00870*	-0.00266
	(0.00693)	(0.00371)	(0.0252)
L.PPI inflation	-0.963*	-0.00924	-0.802***
	(0.452)	(0.0308)	(0.0810)
L2.PPI inflation	1.095**	-0.00828	1.654***
	(0.390)	(0.0198)	(0.124)
L3.PPI inflation	-0.514**	-0.0506	-0.882***
	(0.181)	(0.0609)	(0.0557)
L4.PPI inflation	0.0668	0.0680	0.152***
	(0.0404)	(0.0557)	(0.0122)
GFC dummy=1 × L.PPI inflation	0.823*	0.00908	1.209***
	(0.323)	(0.0149)	(0.193)
GFC dummy=1 × L2.PPI inflation	-1.108**	-0.00606	-1.684***
	(0.376)	(0.0193)	(0.118)
GFC dummy=1 × L3.PPI inflation	0.504**	0.0519	0.840***
	(0.185)	(0.0570)	(0.0662)
GFC dummy=1 × L4.PPI inflation	-0.0881	-0.0706	-0.201***
	(0.0593)	(0.0524)	(0.0512)
Real effective exchange rate	-0.000278*	-0.0000330*	-0.000525*
	(0.000130)	(0.0000147)	(0.000218)
L.ε_it - Aggregate	-3.754		
	(2.254)		
L.ε_it - High income		-0.358	
		(0.246)	
L.ε_it - Other income			4.953
			(3.956)
Constant	-0.0638	-0.00144	0.241
	(0.0475)	(0.00494)	(0.164)
Observations	6017	4183	1834
Countries	79	42	37
Inflation_lags	4	4	4

Standard errors in parentheses

The dependent variable is quarterly core CPI inflation (taken in logs), annualized. All regressions above include country fixed effects. Errors are clustered at country-level.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

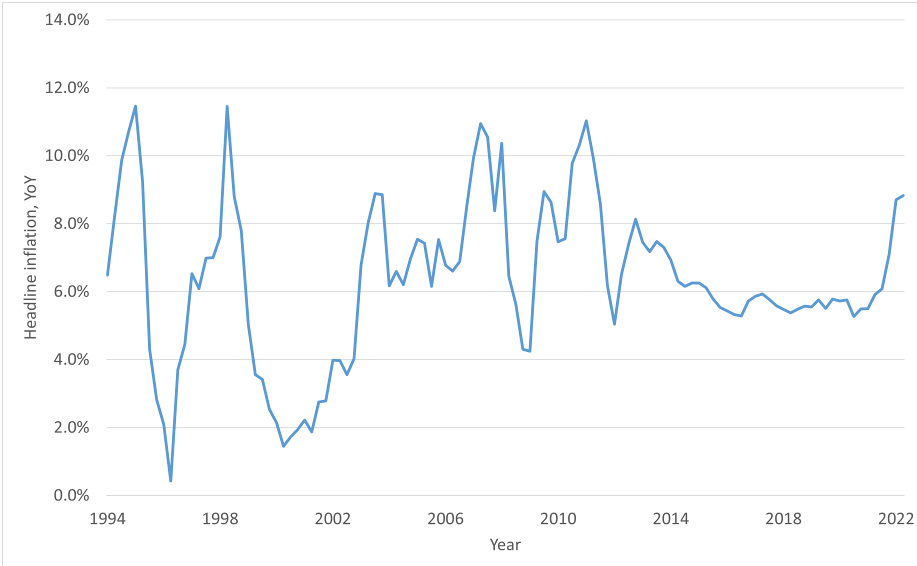

Figure 1: Quarterly headline inflation, year-on-year, in Bangladesh

5 Microeconomic Analysis

5.1 Overview

The macro-level analysis, as mentioned, looks at 94 countries, of which 46 are classified as "high income" by the World Bank, and 48 as middle income or low income. However, when it comes to the number of observations, the high-income countries have nearly twice as many observations as the other-income countries. Quarterly time series for the macroeconomic indicators of interest have been maintained for far longer in advanced economies than in countries like Bangladesh, which only started publishing quarterly GDP statistics in 2015.

Keeping this in mind, as well as the limitations of estimating the Phillips curve and pass-through shifts as documented in the literature, taking a micro-data approach may be more appropriate for developing nations.

Bangladesh is a lower-middle-income country that has seen considerable economic growth over the past few decades, with real GDP growth rates exceeding 5% nearly every year this century, except during the pandemic (The World Bank, 2022d). However, this has been coupled with persistent increases in consumer price levels, as visible in figure 1, with headline inflation consistently exceeding the previous inflation target of 6% - a target that Bangladesh Bank recently raised to 7.5% for the current financial year (Bangladesh Bank, 2024).

Located on the fertile Ganges delta, Bangladesh is a highly agricultural nation; over 77% of its land was being used for agriculture in 2021, a share exceeded by only 7 other countries (The World Bank, 2022a). While the sector's contribution to the economy shrunk from 51% in 1971, Bangladesh's year of independence, to just over 11% in 2022 (The World Bank, 2022b), it remains a critical employer for 37% of the labour force, compared to 41% in services and 22% in industry (The World Bank, 2022c).

As such, not only is agriculture important to the Bangladeshi people, but it is also important to Bangladeshi policymakers and researchers – especially when it comes to inflation. The Ministry of Finance and Bangladesh Bank view the agriculture sector as pivotal for inflationary pressures from food products, providing producers and exporters with rebates, cash incentives, and input subsidies (TBS News, 2023). Bangladesh Bank in particular has focused on expanding the range of low-cost financing options available to producers in the sector, including micro and small enterprises (Bangladesh Bank, 2024). Providing sectoral liquidity support to ease supply-side constraints is a policy tool that the central bank clearly considers critical to control inflation – but are higher input costs really behind price level hikes? This warrants a closer look at the pass-through of costs to prices.

Notwithstanding the importance of the agricultural sector to Bangladesh's economy and monetary policy, agriculture is also a field for which microdata is more readily available in developing countries compared to other topics, as it is a well-researched field and sees a higher devotion of resources (as opposed to, for example, consumption surveys and price datasets).

I use the theoretical model developed in Section 3 to study the marginal cost Phillips curve in the small-scale agriculture industry in Bangladesh, where the curve will show how costs are passed on from agricultural producers to their buyers.

5.2 Methodology

5.2.1 Data

The process of going about estimating pass-through for agricultural producers in Bangladesh requires data about the inputs used by those producers, what costs they incur, and what prices they are eventually charging for the finished product.

The Bangladesh Integrated Household Survey (BIHS), conducted over 3 rounds from 2011-12 to 2018-19, covers a range of topics, including health, food security, and agricultural production. There are over 6,000 households in each round, covering all 64 districts in the country to form a nationally representative sample of rural Bangladesh.

For the agriculture production section of the survey, male enumerators asked the primary male decision-maker of each household to answer questions related to inputs and outputs at the plot and crop-level. The survey excludes plots leased or rented out, and includes any plots leased or rented in; in other words, the survey asks households to report on production for crops they are directly involved in the cultivation of. The recall period is for the past 12 months at the time the survey is conducted, which covers the three major harvest seasons.

Treating the households as small-scale agricultural producers, I use their input cost data and reported outputs to estimate costs. Using information reported on crops sold, I evaluate the subsequent relationship to prices in the form of a cost-based Phillips curve, and changes in the relationship over time.

Households report their usage of inputs such as fertilizer, machinery and draft animals, and labour across a range of tasks, such as land preparation, fertilizing, and harvesting[9]. Labour hours are reported for both family labour and hired labour – I only consider the latter as a paid input as one can assume (as does the survey) that family members work unpaid[10].

Table 4 provides some descriptive statistics for the smallhold farmers in the survey. Over 85% of the producers in each round hire external labour, but the split of the load between internal, i.e., family, labour and external labour is roughly equal. The high standard deviation for average hours and costs shows the necessity of a model that allows for heterogeneity among firms in the production technology.

The final panel across the three rounds contains 3,665 households, who produce multiple crops in each round (some across all rounds, some in only one).

Table 4: Descriptive statistics agriculture-cultivating households

	Round 1	Round 2	Round 3
Number of total households	6,503	6,715	6,011
Number of households cultivating on own or leased-in plots	3,409	3,384	2,937
Top crop group (share of total kilograms harvested)	Cereal (41.5%)	Cereal (51.8%)	Cereal (48.8%)
Average kilograms of crop harvested per household	485.23	537.03	590.13
Standard deviation	*938.32*	*1,082.81*	*1,457.79*
Labour usage			
Average hours worked per kilogram of crop harvested per household	5.26	7.34	4.42
Standard deviation	*20.19*	*26.60*	*11.12*

[9] The survey covers agricultural inputs and outputs under the following modules: (1) Agriculture Plot Utilization, (2) Irrigation Method and Harvest, (3) Usage of Agricultural Chemicals, Fertilizers, and Pesticides, (4) Rental Cost of Tools, Machinery, and Draft Animal, (5) Labour Usage by Gender for Crop Plantation and Harvesting, and (6) Post Harvest Labour, Animal, and Tools/ Machinery Usage.

[10] Refer to Appendix D for a complete list of production inputs.

Share of producers hiring external labour	89.1%	87.0%	85.2%
Share of total hours worked by hired labour	46.7%	46.9%	43.7%
Average costs and prices			
Average cost per kilogram of crop harvested (BDT)	11.82	12.80	11.21
Standard deviation	*40.58*	*26.82*	*24.13*
Average price per kilogram of crop sold (BDT)	23.69	24.25	23.70
Standard deviation	*21.58*	*21.07*	*26.99*

One USD is approximately 110 Bangladeshi taka (BDT).

5.2.2 Model Assumptions

In this section, I discuss the assumptions being taken in the theoretical model from Section 3.2 and their applicability to the small-scale agriculture industry in Bangladesh.

There are several assumptions taken in the model that are simplifications compared to more advanced models. Firstly, I assume that prices are not sticky, such that producers can adjust prices in any period, as opposed to an approach where only a fraction of firms can update their prices (as in Calvo, 1983). This is tied in with the assumption that producers do not face menu costs or nominal rigidities. Given the flexibility of agricultural prices (compared to products from other sectors), this applies to the environment I'll be applying the model to. Moreover, the procedure of crops being sold at the end of the harvest period means that producers are fully informed on costs incurred during production before setting a selling price, rather than requiring a model that bases prices on expected marginal costs where production is continuous.

Most of the producers in the panel sell their crops at semi-formal points such as village markets, as seen in figure 2. However, a significant portion also engage in farm gate sales, which means buyers (either local consumers or wholesale purchasers) collect the product directly from the farm. Due to transportation costs and other constraints, this may be a preferable option to resource-limited smallholder farms (Kyaw, Ahn, & Lee, 2018), but they are more likely to receive lower prices than they would from a market centre (Abu, Issahaku, & Nkegbe, 2016).

The elements of the pricing equation 3 are a common markup faced by all firms (which is time-varying depending on the demand function) and the marginal cost, which depends on input wages, received as given by firms, and the firm's production technology. This aligns with the view that small-scale agricultural producers respond to the demand for their crop. Naruetharadhol, Ketkaew, & Srisathan (2022) find that Thai farmers of cassava, rice, and sugarcane are price-setters who use tiered and mass customization tactics to deter-

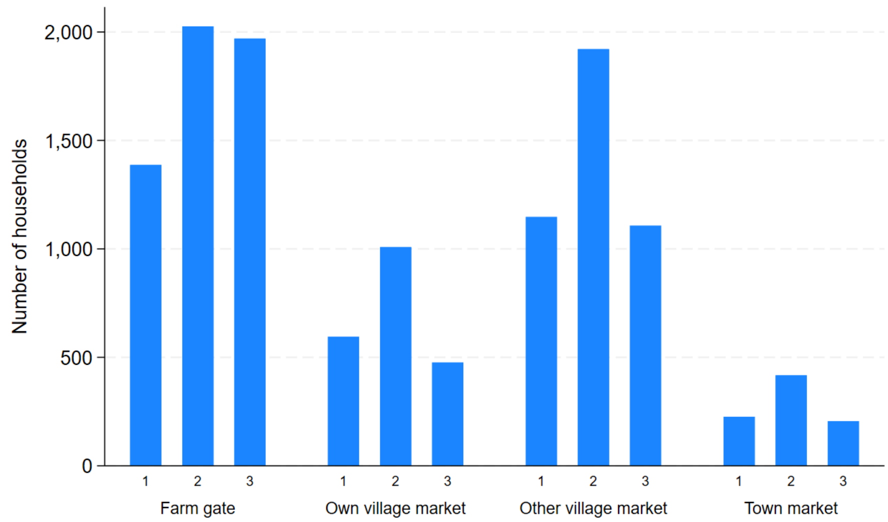

Figure 2: Point of sale for BIHS small-scale farmers, by round

mine selling price, even when global commodity prices are used as a reference, so I continue with the assumption that farmers can execute some decision-making power when determining prices.

Another key assumption is that firms are small, such that they take the price index (which can be considered an industry price index for all crops) as given, as the scale of the producers in question is small and most operate on land under 1 hectare.

The theoretical model allows for internally-sourced inputs, which is important as many households employ their own family members to work on the farm, as seen in table 4. However, this does not factor into the marginal cost term, shown in the derivations in Appendix A.

5.2.3 Empirical Specification

From equation 3, the model indicates that prices depend on a markup and marginal costs. Given that marginal costs and average costs are equal in the model[11], I estimate the primitive Phillips curve based on average costs of producing one unit of crop for each household's crops:

$$p_{fit} = \alpha_f + \alpha_i + \beta_1 AC_{fit} + \Sigma_{j=2}^{3} \beta_{2j} R_{jt} * AC_{fit} + \lambda_1 p_{fi,t-1} + \epsilon_{fit} \tag{7}$$

Where:

p_{fit} : selling price charged per kilogram by producer f for crop i at time t

AC_{fit} : average cost term, taken to be either average total costs or unit labour costs

R_{jt} : round dummy variable

The specification includes crop and producer fixed effects to absorb factors such as competitor's prices, past price benchmarks, and industry-level demand shocks. Producer fixed effects also capture the variation among households of family labour usage, as the availability of able-bodied workers by household will vary. The set of variables β_{2j} indicate the changes in the gradient of the curve, and are thus the variables of interest[12].

As rounds are conducted with gaps of 3 to 4 years in between, this allows the assumption that prices need to be perfectly flexible to be relaxed. Even if prices display some level of rigidity in the short-term, it can be assumed that producers will adjust them more flexibly over a longer time period[13].

[11] Sbordone (2002), Galí & Gambetti (2019), and Gagliardone et al. (2023)'s models find that average variable costs are proportional to marginal costs, also allowing average variable costs to act as a proxy for marginal costs.

[12] Notably, the specification takes into account absolute levels instead of percentage changes - this is to prevent data loss from the previous round and is offset by including the lagged price term to still allow a comparative.

[13] For example, Gagliardone et al. (2023) find that the prices are rigid for 3 or 4 quarters on average in the Belgian manufacturing sector.

5.3 Results

Table 5: Primitive Phillips curve

	(1) Average cost	(2) Unit labour cost
Average cost	0.227***	
	(0.0118)	
Unit labour costs		0.194***
		(0.0234)
L.Selling price	-0.125	-0.0887
	(0.114)	(0.118)
Constant	26.91***	27.65***
	(2.832)	(2.848)
Observations	2918	2918

Standard errors in parentheses

The dependent variable is selling price. All regressions above include household and crop fixed effects. Errors are clustered at household crop-level.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Before moving to the case considering variation in the curve gradient among rounds, I start by observing the marginal cost curve across all rounds in table 5. The strong coefficient here, especially compared to the coefficient for the traditional Phillips curve in Bangladesh[14], already provides an important finding by corroborating the results in Gagliardone et al. (2023). The primitive Phillips curve is well and alive, even where the traditional curve appears to be weak and declining.

[14] Refer to Appendix E.

Table 6: Change in the primitive Phillips curve

	(1) Average cost	(2) Unit labour cost
Average cost	0.0905	
	(0.0580)	
Unit labour costs		0.0128
		(0.107)
Round=3 × Average cost	0.134*	
	(0.0581)	
Round=3 × Unit labour costs		0.169
		(0.102)
L.Selling price	-0.167	-0.110
	(0.118)	(0.125)
Constant	28.75***	28.67***
	(2.965)	(3.136)
Observations	2918	2918

Standard errors in parentheses

The dependent variable is selling price. All regressions above include household and crop fixed effects. Errors are clustered at household crop-level.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In table 6, the results of the micro-level analysis indicate that the relationship between the prices charged by small-scale farmers in Bangladesh on their crops and the costs they faced in growing those crops has strengthened on average across households. This means that these producers are, on average, more likely now to adjust their prices upwards in the face of rising costs than before.

6 Discussion

In this section, I discuss the implications of the results found, sources of bias or misspecification, and possible mechanisms for the results.

There are three important conclusions to reach from the macroeconomic analysis: firstly, the Phillips curve has been weakening in developing countries. The flattening of the curve reversed for advanced economies during the COVID-19 pandemic, but the trend continued for developing countries. Secondly, the pass-through of input prices to consumer prices has increased – meaning that increases in prices at the producer or wholesaler level are more likely to lead to increases in final product prices down the line. This result is chiefly driven by other-income countries, which see a much higher change than high-income nations. In Appendix C, I show that this result is in turn driven by upper-middle-income countries, due to data challenges for lower-middle-income and low-income countries.

As a result, the third key conclusion to reach from the macroeconomic analysis is that the behaviour of the Phillips curve and its underlying elements are not homogenous across countries of various income classifications. This paper is a small attempt to study a developing country's inflation dynamics more closely, but more attention needs to be given to monetary-policy-informing research in such economies.

Data challenges undoubtedly make this task difficult. Using agriculture surveys and microdata for Bangladesh may help avoid some of the identification issues faced at the aggregate level, but the fact that there are only three rounds of BIHS survey data, and only a subset of households which have harmonized responses across the three rounds, mean that the paper works with a much more limited dataset than similar studies that leverage decades-worth of firm-level data. The lack of a suitable survey also means that the model used in the paper is very simplistic, unable to incorporate the more advanced elements of pricing models. Regardless, the panel format and crop-level data of the BIHS surveys lend statistical power to the tests conducted.

Moving on to the results of the microeconomic analysis, it is clear that a strong relationship exists between the sale price charged by small-scale agricultural producers and the marginal cost they face in the production of those goods. This is consistent with similar studies of the primitive Phillips curve, showing that prices are not as exogenous to real activity variables as the aggregate Phillips curve may suggest. Moreover, the strengthening of the relationship in latter rounds opposes what was seen in the macroeconomic analysis, where a weakening was evident in the relationship between CPI inflation and the output gap. This dichotomy is concerning, as aggregate-level models that are more likely to be used in policy decisions do not align with what is being seen at the microeconomic level.

The analysis in Section 5 does not take into account the asymmetry of cost movements and the related price adjustments. According to the model of asymmetric price adjustments in Ball & Mankiw (1994), firms will adjust prices upwards when costs increase to prevent a decrease in their profit margin but will not do the same for downward shocks to costs. As such, the cost-push theory may only hold true, or hold truer, for periods of positive supply shocks. To test this, I remove observations for all households that see a drop in the average costs to evaluate the impact on the curve gradient. Indeed, the gradient is steeper for households that see increasing average costs or unit labour costs in Appendix F. This indicates that the pass-through of input prices is especially relevant during periods of positive shocks, when producers face rising costs. This asymmetry may explain both why the Phillips curve and producer price pass-through have appeared weaker in papers considering time periods prior to the pandemic, when global commodity prices were falling and many countries were seeing disinflation (Jongwanich, Park, & Wongcharoen, 2019).

It is worth noting that despite having information on individual outputs, it is not possible to calculate marginal costs for the producers in the dataset using the Cobb-Douglas function due to such few rounds of data. Moreover, not all the inputs reported in the survey have an associated quantity – many are simply provided at the total cost level. With a longer time series and the appropriate data format, it would be prudent to use real marginal cost instead of average cost to relax the assumptions taken in the model. However, as mentioned previously, it is a common finding of price-setting models that average cost is proportional to marginal costs.

Next, I consider variation in the curve by point of sale. As shown in figure 2, producers primarily rely on village markets and farm gate selling. Appendix G shows the impact on the primitive Phillips curve gradient of the point of sale. The impact of moving from farmgate to village markets is inconclusive depending on the independent variable used, but shifting to town markets increases the gradient, allowing producers to pass on more of the cost increases to buyers than in farm gate sales. This aligns with the literature, as smallhold agricultural producers can negotiate prices and receive more information when they can access market centers - improving their welfare (Hoq et al., 2021). As such, as policymakers focus on increasing market access and improving infrastructure for small-scale producers to alleviate poverty, they must also keep an eye on the possibility of increasing the pass-through of supply shocks.

This paper only considers one step in the value chain for agricultural or food products. Intermediate firms such as wholesalers and processers are more likely to leverage market power (Rahman et al., 2021), and thus the cost pass-through for these agents should also be studied.

7 Conclusion

Studies focusing on issues related to the Bangladeshi economy beyond poverty and agriculture are limited, and even more so when it comes to the field of monetary economics. This paper brings to light a few critical comments about the relationship between output and inflation. Firstly, the macroeconomic analysis looking at over 90 countries clearly shows that the inflation story being told in advanced economies will not align with what is true for developing countries. This warrants researchers and policymakers in those countries to pay closer attention to the changes relevant to their economies, rather than extrapolate trends in Western nations to represent global movements.

Secondly, the pass-through of prices from producers to buyers appears to have increased. This increases the importance of producer prices as a target variable for monetary policymakers to control consumer inflation and indicates the vulnerability of the economy to supply-side shocks. Indeed, both the results of the macroeconomic and microeconomic analysis corroborate this for nations like Bangladesh. This indicates that Bangladesh Bank should continue to implement supply-side policy tools, as opposed to relying solely on aggregate demand-side tools such as the policy interest rate.

This paper only considers the very specific case of Bangladeshi small-scale farming – a critical sector in Bangladesh, but still not representative of the economy. Studies considering manufacturing firms, such as the export-critical ready-made garments sector, or the services sector, would be useful to guide optimal policy. Moreover, the model makes use of certain assumptions in order to leverage the data available, but a more suitable dataset could allow the incorporation of more advanced price-setting elements, such as price rigidities and information asymmetry.

Policymakers in developing nations face different economic conditions and challenges compared to those in developed countries. The importance of the agriculture sector both from the production and consumption sides means that the impact of supply-side policies for the sector must be carefully evaluated for unintended effects, especially when intended to improve the welfare of the recipients.

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Appendix A Theoretical Framework Derivations

For simplification, we remove the time operator from the derivations in this section. The economy consists of m firms producing heterogenous products that are imperfect substitutes. They engage in monopolistic competition, setting prices to maximize profits given the demand level for the product and their production function. Each firm f thus has following Cobb-Douglas production function using a total of J external inputs x_{fj} and internal inputs n_{fj} which are combined in the production process:

$$Y_{ft} = \prod_{j=1}^{J} (x_{fjt} + n_{fjt})^{\alpha_{jt}} \tag{A.1}$$

Where $\sum_{j=1}^{J} a_{fj} = 1$. Firms first solve the cost minimization problem for a given level of output Y_f:

$$\min_{x_{fj}} \sum_{j=1}^{J} w_j x_{fj}$$

s.t.:

$$Y_f = \prod_{j=1}^{J} x_{fj}^{\alpha_{fj}}$$

$$n_{fj} \leq \bar{n}_{fj}$$

Where $\bar{n}_{fj}$ refers to the constraint firms face on the amount of internal input available to them. Firms do not pay for internally sourced inputs. Solving this problem leads to the following cost function:

$$C(Y_f) = \sum_{j=1}^{J} w_j x_{fj} = \frac{Y_f W}{A_f} - N_f \tag{A.2}$$

$$MC = \frac{\partial C(Y_f)}{\partial Y_f} = \frac{W}{A_f}$$

Where the wage index is defined as $W = \prod_{J}^{j=1} w_j^{\alpha_j}$ the factor share index is defined as $A_f = \prod_{J}^{j=1} \alpha_{fj}^{\alpha_{fj}}$, and the internal input index is $N_f = \prod_{J}^{j=1} \bar{n}_{fj}^{\alpha_{fj}}$. Thus, average costs and marginal costs are equal at cost minimization and depend on the production technology of the firm. Note that internal inputs do not factor into the marginal cost term as they do not have a wage.

Firms face the following demand curve[15] :

[15] Refer to Blanchard & Kiyotaki (1987) for the derivation of the demand function by solving the household's utility maximization problem.

$$Y_f = \left(\frac{P_f}{P}\right)^{-\theta} \frac{Y}{m}$$

Where $\theta < 1$ is the elasticity of substitution among goods and Y is the aggregate demand of the economy. The aggregate price index $P = (\frac{1}{m}\sum_{f=1}^{m} P_f^{1-\theta})^{\frac{1}{1-\theta}}$ is taken by firms as given. Firms thus aim to maximize profits as follows, subject to the constraints in equations A.2 and A.1:

$$\max_{P_f} P_f Y_f - \sum_{j=1}^{J} w_j x_{fj}$$

Placing the constraints in the profit function, the following profit function needs to be maximized:

$$\max_{P_f} P_f \left(\frac{P_f}{P}\right)^{-\theta} \frac{Y}{m} - \left[\frac{W}{A_f}\left(\frac{P_f}{P}\right)^{-\theta} \frac{Y}{m} - N_f\right]$$

Solving this gives the following price rule:

$$P_f = \frac{\theta}{\theta - 1}\frac{W}{A_f}$$

Thus, the optimal pricing policy for firms is a markup, $\frac{\theta}{\theta-1}$, on the marginal cost.

Appendix B Im-Pesaran-Shin Test

I conduct a unit root test on the error terms from the three models considered in section 4 - a necessary step as it is an input in the short-run regression. The Im-Pesaran-Shin (IPS) test checks for unit roots in panel data, allowing for unbalanced panels and heterogeneous autoregressive parameters.

The hypothesis that the ε_{it} error term has a unit root for all panels is rejected.

Table 7: Im–Pesaran–Shin unit-root test for ε_{it}

Model	Average lags	IPS statistic	p-value
Aggregate	0.78	-13.88	0.00
High income	0.71	-15.56	0.00

Continued on next page

Table 7: Im–Pesaran–Shin unit-root test for ε_{it} (Continued)

Other income	0.79	-12.51	0.00

Note: There are 82 panels in the test, with 76.83 periods in each on average. ADF regression lags are selected using AIC.

Appendix C PPI Pass-through for Other Income Nations

In this section, I re-do the regressions in equation 5 and 6, but this time separating the groups by the categories within the other income category into upper-middle-income, lower-middle-income, and low-income nations.

The cause for concern in the results from table 2 was the negative relationship between the output gap and consumer inflation in the long-run analysis. In table 8, one issue becomes clear: the observations are clearly much higher for upper-middle-income countries than the two other sub-groups, which also have much fewer countries. This reinforces the data challenge mentioned in the paper, also visible in table 9 where many of the lower-middle-income and low-income economies do not have sufficient observations for PPI inflation prior to the GFC.

Table 8: Long-run model: Other-income nations

	(1) Upper middle	(2) Lower middle	(3) Low income
Output gap	0.0118	-0.0440	-0.0359
	(0.0276)	(0.0535)	(0.125)
PPI inflation	0.0149	0.256*	0.106
	(0.125)	(0.0842)	(0.0227)
Constant	0.0357***	0.0228**	0.0120*
	(0.00729)	(0.00547)	(0.000939)
Observations	1574	408	70
Countries	26	12	2

Standard errors in parentheses

The dependent variable is quarterly core CPI inflation (taken in logs), annualized. All regressions above include country fixed effects. Errors are clustered at country-level.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 9: Short-run model with PPI pass-through: Other-income nations

	(1) Upper middle	(2) Lower middle	(3) Low income
Output gap	-0.00904	-0.0117	-0.0105
	(0.0395)	(0.00866)	(0.0610)
L.PPI inflation	-1.104***	0.0106	-0.0405
	(0.227)	(0.164)	(0.0285)
L2.PPI inflation	1.587***	-0.0626**	-0.0107
	(0.130)	(0.0189)	(0.0168)
L3.PPI inflation	-0.825***		-0.00628
	(0.0356)		(0.00863)
L4.PPI inflation	0.145***		0.0510
	(0.0163)		(0.0188)
GFC dummy=1 × L.PPI inflation	1.085***	0.0913	
	(0.165)	(0.128)	
GFC dummy=1 × L2.PPI inflation	-1.555***		
	(0.112)		
GFC dummy=1 × L3.PPI inflation	0.816***	0.0273	
	(0.0443)	(0.0211)	
GFC dummy=1 × L4.PPI inflation	-0.196***	0.0140	
	(0.0372)	(0.0206)	
oL3.PPI inflation		0	
		(.)	
oL4.PPI inflation		0	
		(.)	
Real effective exchange rate	-0.000589*	-0.000229	0.000494
	(0.000239)	(0.000147)	(0.000174)
L.ε_it - Upper middle	-5.994		
	(4.186)		
L.ε_it - Lower middle		0.249	
		(0.330)	
L.ε_it - Low income			-0.767
			(0.0891)
Constant	-0.173	0.0405	-0.0609
	(0.146)	(0.0185)	(0.0255)
Observations	1388	380	66
Countries	23	12	2
Inflation_lags	4	4	4

Standard errors in parentheses

The dependent variable is quarterly core CPI inflation (taken in logs), annualized. All regressions above include country fixed effects. Errors are clustered at country-level.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix D Production Inputs

Table 10: Input categories and average shares

Category	Average share	Item	Share of category
Labour	28.2%	Carrying crops from farm to home	10.0%
		Threshing crop	5.2%
		Drying crop	0.6%
		Sorting crop	1.2%
		Packaging crop	0.4%
		Land preparation	7.4%
		Planting (seeding/ transplanting)	19.2%
		Fertilizer application	0.2%
		Pesticide application	0.6%
		Weeding	25.0%
		Maintaining irrigation channels	0.6%
		Harvesting	27.6%
Machinery, tools, and animals	24.8%	Animal used for land preparation	20.3%
		Animal used for crop threshing	0.7%
		Tools/ machinery used for land preparation	74.8%
		Tools/ machinery used for harvesting	0.2%
		Tools/ machinery used for pesticide application	1.1%
		Tools/ machinery used for weeding	0.1%
		Tools/ machinery used for planting	0.1%
		Tools/ machinery used for fertilizer application	0.1%
Raw materials, other	47.0%	Seed and seedlings	65.4%
		Manure/ compost used	7.2%
		Irrigation	16.3%
		Pesticides/ insecticides/ herbicides	11.1%

Labour input items are split into male and female hired labour. Average shares of items are simple averages across the nine crop groups, not weighted. Average shares will not add up to 100%.

Appendix E The Phillips Curve in Bangladesh

Table 11: Bangladesh Phillips curve estimation

	(1) Core CPI inflation
Output gap	0.0436
	(0.0445)
Real effective exchange rate	0.000289
	(0.000248)
Constant	-0.0512
	(0.0420)
Observations	30
Countries	
Inflation_lags	4

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix F Assymetric Price Adjustments

Table 12: Primitive Phillips curve with assymetric price adjustments

	(1) Average cost	(2) Unit labour cost
Average cost	0.509**	
	(0.170)	
Unit labour costs		0.202***
		(0.0508)
L.Selling price	-0.138	-0.00175
	(0.173)	(0.267)
Constant	21.12***	24.79***
	(5.548)	(6.132)
Observations	1686	1858

Standard errors in parentheses

All regressions above include household and crop fixed effects. Errors are clustered at household crop-level. The observations only include rounds 2 and 3, where households saw an increase in average costs or average unit labour costs from the previous round.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix G Point of Sale Variation

Table 13: Primitive Phillips curve, varying by point of sale

	(1) Average cost	(2) Unit labour cost
Average cost	0.180***	
	(0.0374)	
Unit labour costs		0.201***
		(0.0294)
L.Selling price	-0.0899	-0.0747
	(0.122)	(0.132)
Own village market × Average cost	-0.0886	
	(0.0712)	
Other village market × Average cost	0.0550	
	(0.0411)	
Town market × Average cost	0.214	
	(0.202)	
Own village market × Unit labour costs		0.0763
		(0.149)
Other village market × Unit labour costs		-0.0356
		(0.0935)
Town market × Unit labour costs		0.167
		(0.464)
Constant	26.29***	27.14***
	(3.041)	(3.355)
Observations	2914	2914

Standard errors in parentheses

All regressions above include household and crop fixed effects. Errors are clustered at household crop-level.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$