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Identifying the Phillips Curve in Georgia[*]

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Abstract

There is an ongoing debate around the flattening of the Phillips Curve throughout the world. One of the most important challenges in looking at the statistical relationship between inflation and cyclical position of the economy is the endogenous nature of monetary policy. If monetary policy is successful in insulating the economy from demand shocks, all we are left with in the data is the effects of supply shocks. This makes the link between inflation and aggregate demand look negative, even if the underlying positively-sloped Phillips Curve relationship is alive and well. That's why it is important to take the endogeneity of monetary policy into account when estimating the Phillips Curve econometrically. In this paper we attempt to do that on the Georgian data using two econometric approaches: GMM and ARDL. Our results indicate that the slope of the Phillips Curve in Georgia is positive but relatively flat (despite the fact that it is still steeper than in the developed world). The resulting high sacrifice ratio makes it all the more important for the National Bank of Georgia to remain vigilant and proactive in anchoring inflation expectations. In addition, we show that half of economic agents' inflation expectations in Georgia are backward-looking (with the other half being forward-looking). This, despite important improvements during the last decade, implies still significant room for monetary policy to further anchor inflation expectations to its target.

JEL Codes: C13, E3, E52

Keywords: Phillips Curve; Inflation; Monetary policy; GMM; ARDL

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1 Introduction

There is an ongoing debate on whether the Phillips Curve (PC) relationship still exists or not – is it dead or just hidden in the data. For example, Cecchetti and Schoenholtz (2017)[5] argue that the PC is dead as the inflation and output data clearly seem disconnected. On the other hand, McLeay et al. (2018)[24] show that successful monetary policy frameworks, with the objective to minimize welfare losses from price and output instability, implies negative correlation between output gap and inflation in the data, which at the surface may seem at odds with the PC theory, even if it's not. This is so because, as successful monetary policies largely neutralize the demand shocks, all we are left with are supply shocks, which is nothing else but a combination of inflation and output gap going into opposite directions. Yet this does not mean that the PC does not exist; it means that if the aggregate demand were allowed to fluctuate with demand shocks, then inflation would, indeed, move in line with the PC. Therefore, the relationship could be just hidden and we need appropriate methods to uncover the underlying PC from the data. For example, Abdih et al. (2018)[1] analyze euro area inflation dynamics and, after adjusting inflation for other factors not related to the output gap, they come up with the positively sloped PC during the estimation period. Hence, sometimes in raw data the PC is invisible, but appropriate econometric procedure may successfully uncover it, i.e. deal with the issues related to identification. Moreover, Hooper et al. (2019)[15] suggest that, among other factors, the flatter PC can be explained by insufficient number of tight labor market episodes (i.e. economic upswing) in data, since the PC would have been steeper during that time taking into account non-linearity of the PC (see also Laxton et al. (1998)[21] and Mkhatrishvili et al. 2019[25]).

With this question in mind, in this paper we apply a couple of econometric approaches to identify the PC relationship in the Georgian economy data. One of the approaches that we use here, generalized method of moments (GMM) was first applied to estimate the PC relationship for the US data by Gali and Gertler (1999)[10]. From that period on there was a boost in the literature around this topic. Gali and Gertler (1999)[10] estimated the PC using the share of labor income in GDP as a forcing variable (i.e. the main driver of the variable in question), which is a proxy of marginal costs in the PC. However, there still is an ongoing debate that evidence of Gali and Gertler (1999)[10] on positive relationship between unit labor costs and inflation, on the one hand, and negative relationship between output gap and inflation, on the other hand, results from model misspecification (see, for example, Zhang and Clovis, 2010 [32]). Yet, as recent research shows, we can also come up with a positively sloped PC even in terms of output gap, if we base our approach on appropriate instrumental variables. Moreover, there is some evidence that the coefficient on output gap in the PC tends be insignificant in small open economies because firms' monopolistic power is smaller there (Vasilev, 2015)[31]. However, based on the PC estimation for the EU, Abdih et al. (2018)[1] show that global factors cannot explain significant part of the core inflation dynamics as well as the puzzle of coexistence of positive output gaps and low inflation. One part of the reason why global factors fail to do the job is that they are already reflected in domestic factors: in the output gap and inflation expectations.

In addition, there has been suggestions in the literature that we can improve the estimates of the PC by including more lags of inflation in the model. Based on this insight, we use auto regressive distributed lag (ARDL) model to test the importance of including the lags of inflation and other key variables which can affect inflation directly in the structural model. As in Lanau et al. (2018)[20], we used the disaggregated PC approach to identify the PC relationship for headline, core, tradable and non-tradable inflations separately.

In our case we estimate the PC by using both the output gap and unit labor costs (ULC). However, since we faced non-stationarity of ULC in case of Georgian data, we have used a gap of ULC estimated based on the HP filter. Short sample is an additional obstacle as the sample size is from 2005Q1 to 2019Q1 in our case. However, the results still seem in line with other empirical estimates as well as economic theory. The coefficients estimated by the GMM approach suggest that the estimates of the PC for core inflation with ULC and output gap as forcing variables are more in line with the theory relative to the PC for headline inflation. In addition, as coefficients from the reduced form model and structural parameters of the core inflation specification are more robust across estimation methods, the above evidence seems stronger in case of core inflation model. However, the slope coefficients of the models are around 0.1. This suggests rather flatter PC in case of Georgia,even if it is still steeper than the corresponding estimates for the developed economies. In addition, estimation of structural parameters shows that the share of backward looking price setters is approximately 56%, and also, price stickiness parameter implies that prices are changed every 2-3 quarters. This combination of some backward-lookingness and flat PC imply that undue changes in long-term inflation expectations will be more costly to undo (Clarida, 2019)[6]. This underlines the importance of monetary policy being much more proactive in maintaining inflation expectations close to its target level. Finally, open economy PC also show some importance of final imported goods and imported intermediates in the production function of the domestic firms.

The paper is organized as follows: the next section summarizes the main takeaways from the recent research on the topic. In section three, we describe the theoretical basis and our econometric approaches. The results of the empirical exercises for the Georgian economy are discussed in section four, while the fifth section concludes.

2 Literture review

There is an ongoing debate on flattening of the PC in advanced economies, while the literature on this topic is more limited on developing economies. Thus, here we summarize the main findings on flatter PC in developed economies together with a limited existing evidence in developing countries. The most robust explanations of flatter PC are well-anchored inflation expectations (mostly, after countries adopting the inflation targeting (IT) framework), overestimation of economic slack and global factors. For example, according to IMF (2013 April)[17], flatter PC has appeared since the late 1970s after which inflation expectations became much better anchored and there is evidence that the dependence of inflation expectations on current inflation dynamics is negligible and close to zero. The latter implies a strong forward-lookingness in inflation expectations.

The debate around the PC has become much more active since the Global Financial Crisis (GFC), as we observed vanished relationship between economic slack and inflation data (Cunliffe, 2017)[7] or at least the muted link that has appeared during the last few decades - something different from the previous dynamics in developed economies (IMF, 2013 April)[17]. It is a stylized fact from empirical estimation of the PC that the curve is flatter nowadays (Kuttner and Robinson, 2010)[19] than it was previously. Underlying causes why it happens are not very well understood, but introduction of inflation targeting framework seems one of the most intuitive as well as empirically justified explanation. For example, Kuttner and Robinson (2010)[19] estimated the reduced form time-varying coefficients of output gap in the PC for Australia and the US and they have come up with the slope coefficient of the PC that has been getting smaller and insignificant over time, especially after adopting the IT framework. In the case of Australia, while it was around 0.04 at the beginning of 90s, it has reduced to 0.02 afterwards and is now insignificant. In other words, it can be argued that central banks by achieving lower trend inflation created environment where firms reset prices less frequently. This means higher price stickiness parameter, which implies a flatter PC. Moreover, Del Negro et al. (2014)[9] show that marginal costs are more persistent which also implies a flatter PC. Another implication is that monetary policy has more effect on the real economy when price rigidity is higher. In addition, Blanchard et al. (2015)[4], with the example of 21 advanced economies, show that the slope coefficient of the PC has been declining since the mid-70s to 90s (but after that the coefficient is stable), while, at the same time, simultaneously increasing weight of inflation expectations in inflation dynamics is also observed. Hooper et al. (2019)[15], motivated with the empirical evidence on the PC in the US, suggest three key reasons for explaining a flatter PC. These are insufficient number of observations of up-cycles at the national level (i.e. muted cyclical movements), endogenous monetary policy (the argument in line with McLeay and Tenreyro (2018)[24]) and anchoring of inflation expectations. As long as monetary policy plays a key role in explaining a flatter PC, this does not rule out the possibility of inflation moving in a non-stationary state, where shocks, including overly accommodative monetary policy, have persistent effects on inflation (Hooper et al. 2019[15]).

As shown by other studies, besides anchoring of inflation expectations, a flatter PC can be explained by global factors and trade openness, such as outsourcing and supply chain integration throughout the world, high investment and overcapacity in manufacturing sector in China, and also increasing labor force mobility. All of these make the estimation of the PC more difficult as production capacity tends to be underestimated. In addition, higher labor mobility implies muted response of wages to demand shocks, even in non-tradable sector (Spencer, 2017)[28].

A flatter PC has implications for monetary policy. On the one hand, central bankers have the flexibility of being less responsive to the output gap without much changes in inflation, other things equal. But, on the other hand, they have to have stronger reaction to any undue changes in inflation, which implies higher volatility of output (Iakova, 2007)[16]. For this reason, IMF (2013 April)[17] emphasizes that a flatter PC makes it more important to understand how monetary policy "can best contribute to general economic welfare under the circumstances now facing advanced economies". Relatedly, Blanchard et al.(2015)[4] indicate that a flatter slope coefficient has an implication for monetary policy in terms of weighting output gap relatively more in its reaction function. It should be mentioned that "flexible inflation-targeting" which additionally weights output gap has already been put in place by many central banks. However, the above authors suggest to lengthen the horizon for achieving inflation target under even more "flexible" inflation-targeting (see, also Gillitzer, 2016[13]). This means responding less to imported inflation shocks, but still trying to maintain inflation expectations anchored (especially under a flatter Phillips curve). The higher sacrifice ratio implied by a flatter PC is not challenging for central banks as long as inflation expectations remain well anchored.

In addition to the developed world, there is also some empirical studies for developing and emerging economies trying to identify the PC and main drivers of inflation dynamics. For example, Bems et al. (2019)[3] identifies PC based on a panel regression for 19 emerging economies. According to their estimation, the slope coefficients of PC is up to 0.2 for those economies; also, mostly domestic factors account for inflation dynamics there, while only 11% of variation in inflation can be explained by external factors. Their last finding makes them to conclude that "inflation remains largely under the control of policymakers". However, we need to be careful before we directly apply those findings to a whole set of emerging markets, as their model is estimated mostly based on large emerging economies.

Methodological difficulties to identify PC lead to ambiguity about the estimated slope coefficients as well. First of all, the question is whether we correctly identify measure of economic slack (Kuttner and Robinson, 2010[19]); is the share of wage bill in GDP a correct measure of marginal costs? On the one hand, there are structural changes in the wage bill data. Also, even if labor income share is accurately estimated, the condition under which labor income share is proportional to marginal cost is derived from standard Cobb-Douglas production function which is free from labor market frictions.

In addition, there are empirical difficulties in identifying the PC with output gap as forcing variable and, sometimes, the wrong specification implies incorrect PC in empirical analysis. It is especially difficult to identify PC with output gap under the IT framework, as successful monetary policy in this case implies an increase in inflation whenever the economy experiences a negative output gap and a decrease in inflation whenever there is a positive gap. This is the stabilizing role of inflation expectations and monetary policy. This point is also stressed by McLeay and Tenreyro (2018)[24], according to which, the PC can very well exist and be alive in non-policy block of the model, but as we introduce policy rule with welfare objective of minimizing deviations of inflation and output gap from their steady state, we end up with negative correlation between output gap and inflation in the data, and inflation is seeming to be determined only by exogenous (cost-push) forces. This is a clear illustration why an estimation strategy based on a single equation bears simultaneity bias problem when trying to identify the PC. The main issue here is a potentially negative correlation between the output gap and an error term in the PC equation.

GMM procedure is assumed to address the problem of endogeneity in a single equation PC model. For example, Gali and Gertler (1999)[10] (GG) show that a new estimate of the PC with output gap as forcing variable is not identifiable in empirical analysis as we observe that inflation is lagged by the output gap (this property is in line with the old PC but not with the new one) in data, while output gap should lead inflation in the new PC. GG have introduced two methodological improvements in existing empirical models; firstly, they have applied labor income share as a measure of marginal costs in the PC. Also, hybrid PC was formulated in the nonlinear form of structural coefficients; the model is micro founded and involves Calvo pricing framework with partial backward looking expectations. The PC identified by GG shows that forward-looking component is dominant in inflation dynamics; only 0.23 part of agents have backward-looking expectations. However, Mavroeidis (2003)[23] point out that the dominance of forward-looking term in inflation dynamics results from weak identification of forward-looking model with the GMM approach.

More recent studies on the PC identified with the GMM are Karagedikli and McDermott (2016)[18], Malikane (2014)[22] and Ball and Mazumder (2011)[2]. Karagedikli and McDermott (2016)[18] have applied the GMM for New Zealand. According to the study, the slope coefficient, in case of output gap, is 0.09, while it is -0.18 in case of unemployment gap, though the share of backward-looking price setters varies from 0.55 to 0.64. This may show how challenging it can be to reduce backward-lookingness even for the economy with the longest history of inflation targeting (the parameter actually increased after 2009, possibly due to the GFC). However, the backward-looking behaviour may also have resulted from low and stable inflation environment. Ball and Mazumder (2011)[2] show that slope coefficient of the new Keynesian PC is 0.04 for the full sample (1960:Q1-2010:Q4), while it is only 0.012 from 1985:Q1 to 2010:Q4. This finding also shows a flatter PC in the last period. Malikane (2014)[22] has estimated triangle PCs for a group of developed and emerging markets. The specification formulated by them involves supply side factors directly and this modification helps to solve the negative sign problem of output gap in the PC estimation, except for Brazil. However, the results are still suffering from serial correlation and weak identification issues. Serial correlation is one of the main challenges in empirical identification, potentially resulting from insufficient lag structure of included variables in GMM. To address the problem and determine lag structure based on information criteria, ARDL model is also applied for estimating the PC. For example Lanau et al. (2018)[20] have estimated the PC for Columbia based on ARDL model. In particular, different PCs were estimated separately for headline, core, tradable and non-tradable inflations. As the evidence shows the PC for them is relatively steeper than for advanced economies, but is still low. In addition, supply-side drivers of inflation are more dominant if the price index in question contains more of tradable goods.

3 Methodology

3.1 Theoretical background

As empirical research shows pure forward-looking Phillips Curve is less likely to hold in the data while its extension with inflation inertia makes the curve empirically more plausible and easier to be identified with the data. Hence, our basic model in the paper is also a hybrid

Phillips Curve (for instance, similar to Smets and Wouters, 2003[27]), which can be expressed by the following equation:

$$\pi_t = b_1\pi_{t-1} + b_2\pi_{t+1}^{exp} + \gamma mc_t + \varepsilon_t \tag{1}$$

where π_t , π_{t-1} , π_{t+1}^{exp} are the measures of current, lagged, and expected inflations, respectively. mc_t stands for marginal cost (or it can be named as forcing variable) and ε_t measures supply side shocks.

The main challenge in the estimation is related to the forward-looking term in the equation. Regarding the expected inflation we have two options: either to use survey-based inflation expectations or to use proxy variables of expected inflation. The former, in our case, is a survey by the National Bank of Georgia (NBG), asking Georgian companies about the inflation they expect one year ahead; while the latter involves calculating a proxy based on the yields of the US and Georgian treasury bonds and the US inflation expectations, after accounting for a country risk premium[1] (Gerlach-Kristen et al., 2017)[12] ; also, we have applied ex-post realized inflation as a proxy of expected inflation as this is widely used in empirical literature. The problem with the survey-based inflation expectations is that it only starts from 2013 and also the sample doesn't include sufficiently many respondents (i.e. contains too much noise). For these reasons we couldn't use it for formal estimation. However, if we instead use proxies of expected inflation, then other econometric problems could also be raised if forecast (proxy) of ex-post inflation is biased. For example, by simple transformation of (1) we get:

$$\begin{aligned}\pi_t &= b_1\pi_{t-1} + b_2\pi_{t+1}^{exp} + \gamma mc_t + b_2\pi_{t+1}^{p} - b_2\pi_{t+1}^{p} + \varepsilon_t \\ &= b_1\pi_{t-1} + b_2\pi_{t+1}^{p} + \gamma mc_t + b_2\pi_{t+1}^{exp} - b_2\pi_{t+1}^{p} + \varepsilon_t \\ &= b_1\pi_{t-1} + b_2\pi_{t+1}^{p} + \gamma mc_t + \omega_t\end{aligned} \tag{2}$$

where π_{t+1}^{p} is a proxy variable we are applying instead of unobserved but true inflation expectation - π_{t+1}^{exp}. The issue here is that, now error term is ω_t=($b_2\pi_{t+1}^{exp}$-$b_2\pi_{t+1}^{p}$)+ε_t, which, in

[1]This approach assumes that Purchasing Power Parity (PPP) and Uncovered Interest Parity (UIP) hold. In this case it is straightforward to derive inflation expectations for Georgia based on the US inflation expectations taking into account the PPP and UIP relationships and the difference between the US and Georgian bonds yields which is further adjusted with risk premium in our case. Since, there are no inflation-indexed bonds in Georgia, we have to apply the above mentioned methodology for estimating market based inflation expectations.

addition to IID shock, contains the term in parentheses. The latter can, in turn, be a source of bias if there are systematic differences between the proxy and true inflation expectations. In that case estimates of the coefficients in the PC would be biased. As the test on rationality of market-based expectation is not satisfactory and also since the variable further reduces our sample size, we use ex-post future realized inflation as a measure of future expected inflation in our main models. The approach is widely used in GMM applications. In addition market-based expectations are used to estimate forward looking ARDL models due to endogeneity of ex-post inflation in this case (which cannot be instrumented in ARDL).

The above mentioned representation of the PC curve has not included terms relevant for open economies. This can also result in a biased estimation due to misspecification. To address this, we now derive open economy New-Keynesian hybrid Phillips curve.

Based on Calvo type (or similarly sticky) price setting on monopolistic competitive market and allowing partial backward-lookingness in prices, we can show that, domestic inflation can be described by the following equation:

$$\pi_t^h = b_1 \pi_{t-1}^h + b_2 \pi_{t+1}^{exp,h} + \gamma mc_t \tag{3}$$

where,π_t^h, π_{t-1}^h and $\pi_{t+1}^{e,h}$ are current domestic inflation, one period lag of domestic inflation and expected future domestic inflation, respectively. Also, from CES aggregator of imported and domestic price indexes we can show that the dynamic of headline inflation is given by the following equation:

$$\pi_t = (1-\alpha)\pi_t^h + \alpha(\Delta s_t + \pi_t^f) \tag{4}$$

With combining (3) and (4) we get:

$$\pi_t^h = \pi_t - \alpha \Delta q_t \tag{5}$$

Where Δs_t is the depreciation rate of domestic currency exchange rate, Δq_t is the real exchange rate depreciation and π_t^f is foreign inflation measured in foreign currency units, while α - can be interpreted as the share of imported consumption goods in total consumption basket. We can derive PC for overall inflation by using (2) and (3), however, in this case we will end up with two additional forward looking variables (Δs_{t+1} ,π^{f}_{t+1}). Instead, we refer to the fact that depreciation of real exchange rate (Δq_{t+1}) can be expressed as:

$$\Delta q_t = \Delta s_t + \pi^f_t - \pi^h_t \tag{6}$$

And finally putting (5) into (3) we end up with the following expression:

$$\pi_t = b_1\pi_{t-1} + b_2\pi^{exp}_{t+1} + \alpha\Delta q_t - \alpha(b_1\Delta q_{t-1} + b_2\Delta q^{exp}_{t+1}) + \gamma mc_t \tag{7}$$

With this we have derived an open economy New-Keynesian Phillips curve with two forward-looking variables (π^{exp}_{t+1} and Δq^{exp}_{t+1}). It should be mentioned that (7) is a representation of an open economy PC with exchange rate pass through to inflation through imported final consumption goods - a part of overall consumer basket. This assumption, however, may be too tight. Imported final consumption goods is not an only channel through which foreign sector may affect headline inflation. We should also allow for additional channel operating through imported intermediate goods in production, as domestic firms in small open economies use this kind of input in their businesses extensively.

For incorporating the above-mentioned additional channel in the simplest possible way, we assume the following production function:

$$y_{it} = l^{1-\sigma}_{it} m^{\sigma}_{it} \tag{8}$$

Where l_{it} is labor input in production and m_{it} – is imported intermediate goods, while σ is the share of imported intermediate inputs in total costs. From a standard cost minimization problem subject to (8) we can derive the following marginal cost function:

$$MC_{it} = \left(\left(\frac{\sigma}{1-\sigma}\right)^{1-\sigma} + \left(\frac{\sigma}{1-\sigma}\right)^{-\sigma}\right)\left(\frac{w_t l_{it}}{Y_{it}}\right)^{1-\sigma}\left(\frac{p_{m,t} m_{it}}{Y_{it}}\right)^{\sigma} \tag{9}$$

Where $p_{m,t}$ is a price index of imported intermediate inputs in real terms (i.e. something closely tied to real exchange rate), and w_t denotes real wages.

We can denote $\frac{w_t l_{it}}{Y_{it}} \equiv \mu_{lt}$ and $\frac{p_{m,t} m_{it}}{Y_{it}} \equiv \mu_{mt}$ where μ_{lt} is labor income share in output and μ_{mt} is the share of imported intermediate goods in overall output, both in period t. Then after log-linearizing the marginal cost function (9), we get $\widehat{mc_t}$:

$$\widehat{mc_t} = (1-\sigma)\widehat{\mu_{lt}} + \sigma\widehat{\mu_{mt}} \tag{10}$$

where hats above the variables indicate deviations from steady state. Finally, if we combine (10) and (7), then we get open economy PC with effects of exchange rate on inflation through not only imported final consumption goods, but also imported intermediaries inputs (i.e. part of marginal costs):

$$\pi_t = b_1\pi_{t-1} + b_2\pi_{t+1}^{exp} + \alpha\Delta q_t - b_1\alpha\Delta q_{t-1} - b_2\alpha\Delta q_{t+1}^{exp} + \gamma_{l\delta}\widehat{\mu_{lt}} + \gamma_{m\delta}\widehat{\mu_{mt}} \tag{11}$$

where $\gamma_{l\sigma}$=$\gamma(1-\sigma)$ and $\gamma_{m\sigma}$=$\gamma\sigma$.
This equation can now be used in our empirical strategy to estimate the reduced form coefficients[2]. It should be noted that estimation of the equation (11), where we have included imported intermediate input channel, would be more consistent in case where unit labor cost is used as measure of economic slack rather than output gap. In the former case interpretation would be that the unit labor cost measures domestic slack, while output gap would also reflect slack related to other inputs in the production, among them inflationary preasure from imported intermediate goods.

Hence, in empirical models where the output gap is used as a measure of economic slack there we estimate the open economy PC by accounting pass through only from imported final consumption goods, such as[3]:

$$\pi_t = b_1\pi_{t-1} + b_2\pi_{t+1}^{exp} + \alpha\Delta q_t - b_1\alpha\Delta q_{t-1} - b_2\alpha\Delta q_{t+1}^{exp} + \gamma\widehat{\mu_{lt}} \tag{12}$$

However, we still estimate the open economy PC with both specifications of (11) and (12) using unit labor cost as a forcing variable.

Key ("deep") structural parameters of the PC can be estimated by taking into account the

[2]Note, however, that there are 7 terms in the equation but we have only 5 free coefficients (b_1,b_2,α,γ,σ), i.e. there are some cross restrictions.

[3]In this case the term $\widehat{\mu}_{lt}$ defines general economic slack (either output gap or unit labor cost as a proxy).

following relationships[4]

$$b_1 = \frac{\omega}{\theta + \omega(1-\theta(1-\beta))} \tag{13}$$

$$b_2 = \frac{\beta\theta}{\theta + \omega(1-\theta(1-\beta))} \tag{14}$$

$$\gamma_l = \frac{(1-\omega)(1-\theta)(1-\beta\theta)}{\theta + \omega(1-\theta(1-\beta))} \tag{15}$$

where ω is a share of backward looking agents among price optimizers, θ – measures degree of price stickiness and β is subjective discount factor. Here we have three reduced form coefficients (that would be estimated from empirical exercise) and three (unknown) structural parameters, in other words, three unknowns with three equations.

3.2 Empirical strategy

To estimate the PC relationship we have applied two approaches. The first one uses our own estimates of market-based inflation expectations constructed using Georgian and the US treasury yields adjusted with country risk premium (as discussed in the previous sub-section). Here we treat inflation expectations as exogenous and use instrumental variables only for forcing variable and expected real exchange rate. However, inclusion of the estimated inflation expectations in our model causes a reduction of the dataset range available for estimation, as this time series (inflation expectations) is available only from 2009Q4 (while the dataset otherwise starts from 2005Q1). In the second specification we use one period ahead realized inflation as a proxy for inflation expectations in the PC equation (as it is in GG's paper, i.e. ex-post realization) as the forecast error related to market-based inflation expectations cannot satisfy formal test on unit root. The equation to be estimated is the following:

$$E_t((\pi_t - (b_1\pi_{t-1} + b_2\pi_{t+1}^{exp} + \alpha\Delta q_t - b_1\alpha\Delta q_{t-1} - b_2\alpha\Delta q_{t+1}^{exp} + \gamma_{l\delta}\widehat{\mu_{lt}} + \gamma_{m\delta}\widehat{\mu_{mt}}))|Z_t) = 0 \tag{16}$$

where Z_t is a set of instruments.

In the estimation we tried different forcing variables in the PC. In the first instance we tested whether unit labor cost gap (as a proxy of firms' marginal costs) contributes to higher inflation. But we also did the estimation of PC based on output gap estimated with the NBG's

[4] Derivation can easily be shown within a simple DSGE model.

core model as well as GDP gap estimated with HP filter as a robustness check of the results. Furthermore, PC relationships for core, headline and non-tradeable inflation were estimated separately – motivated by the literature showing that cyclical sensitivity of different indicators of inflations are not the same (see, Stock and Watson, 2019[29]).

Usually, in GMM estimation the main challenge is to select proper instrument set, which passes the test on orthogonality condition (empirically as well as theoretically). Moreover, instruments should not be weak and overidentification restriction should be satisfied. Even though the advantage of GMM over ordinary least squares is its consistency, if some of the above mentioned conditions are not met the cost can be enormous, especially when orthogonality condition fails or instruments are weak (ending up with bias in estimation). In the PC relationship there are three assumed endogenous variables: expected inflation, expected depreciation of REER and output gap (or labor income share), for which we may have to find instruments. In the case of market based inflation expectations as proxy of expected inflation we instead use the instruments only for REER and forcing variable, although we need to identify instruments for expected inflation where we use ex post realized inflation as the proxy of inflation expectations. Several alternative techniques are applied for instrument selection.

In the literature there are also some specifications of the PC that include supply side factors directly in PC equation. For example, Malikane (2014)[22] applied GMM for estimating PC where supply side factors (consumer prices for energy and food) are incorporated into the main equation (rather than applied them as instruments - so called triangle Phillips curve). Also, ARDL models are applied to deal with the problem of serial correlation (by including proper number of lags of explanatory variables), and, on the other hand, to determine proper lag structure. We estimate the PC with supply side factors using backward-looking ARDL method as ex post realized inflation used in GMM models cannot be instrumented in ARDL models and would leave biased estimations. However, estimation results from forward-looking ARDL model with market-based inflation expectation is also discussed in the empirical results. The application of the ARDL model is useful as a robustness check for GMM estimation as well as possible evidence on model misspecification. As noted above in our analysis we use disaggregated analysis of the PC similar to Lanau et al. (2018)[20], which have applied the approach for the case of Colombia.

4 Empirical results

4.1 Results from GMM

4.1.1 Instruments selection

To select proper set of instruments for estimating the PC several techniques are used. First, we have applied an approach proposed by Gali and Gertler (1999)[10] for selecting a set of instruments; actually, the ones used by them is widely accepted in the literature during the last years. Those are: four lags of inflation, labor income share, output gap, the long-short interest rate spread, wage inflation, and commodity price inflation. We also used boosting technique[5] to select instruments for endogenous variables, implementing this approach based on stepwise regression analysis; the method sequentially selects instrumental variables which contributes the most to partial explanation of endogenous variable at each stage of selection. In addition, general-to-specific approach was used for shortening the list of instruments - by discarding the instruments with low T-statistic step by step, until improvement of first stage regression is impossible. Then we check whether those instruments are not weak, and orthogonality condition is satisfied. Finally, to test endogeneity of output gap in the PC, Hausman test as well as the one based on "C statistic" is applied.

As we have long list of potential candidates, set of instruments for each of endogenous variables were selected based on their relevance. We have selected instruments for expected inflation (in the case when ex-post realized inflation is used as a proxy of inflation expectations), expected rate of appreciation of REER[6] , and the measure of marginal costs (output gap and unit labor cost). The set of all possible instruments contains lags of the following variables: headline inflation[7] (lags from -2 to -4), output gap[8] (from -1 to -4), rate of appreciation of NEER (from

[5]Boosting methodology sequentially selects instruments based on their partial significance to explain endogenous variable.

[6]REER – Real effective exchange rate; NEER – Nominal effective exchange rate; higher REER and NEER means appreciation of domestic currency.

[7]PCs estimated in the case of core, and non-tradable inflations include corresponding variables in instrument list.

[8]From the list all variables in terms of gaps are derived with HP filter, except output gap, which is NBG's model-based estimation of output gap. At the same time we tried HP filter to estimate real GDP gap and

-1 to -4) and rate of appreciation of REER (from -1 to -4), budget deficit (from –1 to -4), weighted growth rate of trading partners (from -1 to -4), depreciation rate of GEL against the USD (from -1 to -4), trade partners' weighted inflation (from -1 to -4), unit labor cost gap (from -1 to -4), HP gap of the share of imported intermediate goods in GDP (from -1 to -4), oil price inflation (from -1 to -4), FAO food price inflation (from -1 to -4) and credit gap (from -1 to -4). Selected instruments for each specifications are described in Appendix 3.

4.1.2 Estimated PC equations

We failed to obtain results where "market-based" inflation expectations measured as a difference between Georgian and US treasury bonds yields would had been unbiased[9]. Namely, forecast error is integrated process without intercept, but after subtracting constant term it is free from unit root; i.e. it seems that forecast error is not stationary zero mean process and our calculation of market-based inflation expectation overestimates future inflation systematically. For us this means that in the first approach where we intended to use market-based expected inflation (from our calculation) as exogenous variable we have little support to do this, as expectation does not seem to be rational. However, those test results are not against second approach (which uses ex-post inflation as proxy of inflation expectations), where rationality of expected inflation is necessary as well. Failure to meet rationality condition related to market-based expectations does not contradicts rationality of true but unobservable inflation expectations, while, the test result means that there are other factors which cause persistent deviation of market-based inflation expectation from true expectations (this can be the result of measurement error too). Hence, due to this problem and also to have longer dataset for estimating PC we use ex-post realized inflation in GMM application.

4.1.3 Estimation results for core inflation model

Core inflation PC is identifiable[10] with unit labor cost as a measure of economic slack (output gap helps identification too). This seems intuitive as labor cost mostly reflects domestic factors (change in wage bills) related to core inflation which is less affected by other supply side factors. There is negative contemporaneous correlation between unit labor cost and output gap,

obtained similar results.

[9]Measured based on our own calculation.

[10]Test results are satisfactory and coefficients are robust across different estimation methods.

but output gap leads unit labor cost 4 quarters ahead. It seems that firms, suffering negative demand shocks, use their profit as buffer during first few quarters (i.e. unit labor cost rises at the time as it is measured as a ratio between wage bills to output), and if demand shock is persistent enough then firms change wages accordingly, this can be interpreted as the evidence of wage stickiness too. To account possible negative contemporaneous relationship between wage bills and output gap, we also apply real wage gap as a measure of economic slack and unit labor cost adjusted with two lagged values of output gap. However, we ended up with qualitatively same results with those modifications of unit labor cost as in the case of applying unit labor cost directly in estimation.

Here we have estimated three specifications of the PC to account for characteristics of an open economy. The first specification incorporates exchange rate pass-through only based on imported final consumption goods (Table 1: Model 1C and Model 4C; parameter α) and the effect of imported intermediate goods is estimated in the second specification (without imported inflation channel from final consumption goods) (Model 2C and Model 5C; parameter σ), while the third specification (Model 3C and Model 6C) estimates the effects of both of those channels simultaneously. Firstly, we estimated reduced form parameters of the PCs, while estimation results of key structural parameters are reported in the Table 2. As the results show the core inflation PC is identifiable with unit labor cost and the slope coefficient (γ) varies from 0.025 to 0.044, indicating relatively flat PC, but the slope is still positive and steeper than in advanced economies. In case of output gap as a measure of economic slack, the coefficient varies from 0.065 to 0.11. The reduced form slope coefficients estimated with unit labor cost and output gap are not directly comparable as the scale of slacks are different. For instance, mean absolute value of the unit labor cost gap is 1.5 times larger than the same value for the output gap. While output gap has significant positive effect on core inflation according to our estimation, this is achieved using about 20 iterations of weighting matrixes until convergence, which can be problematic in case of small samples like in our case; while we come up with still positive but insignificant estimation of the slope coefficients in case of one step iterations. The last finding can be applied for the PC with unit labor cost with the first specification too, but robust and significant estimations are achieved in the second and third specifications of PC with unit labor cost even in case of small number of iterations of weighting matrixes. Those findings imply that on the one hand, estimation results depends on specifications (as we have little support of specification 1 even with unit labor cost, while unit labor cost combined with imported intermediates as a measure of marginal costs implies more plausible results), while on the other hand, unit labor cost (as opposed to the output gap) provides more robust estimates especially based on specifications 2 and 3 i.e by including costs of imported intermediates (σ) in the PC.[11] [12]

Apart from the estimate of the slope coefficient, the most significant part of the results is the estimate of backward (b_1) and forward lookingness (b_2) of the inflation process. In general, the more forward-looking the inflation process the more it reacts to monetary policy and, hence, the less the cost of maintaining price stability. In our estimates, in most specifications inflation is backward and forward-looking at about the same rate (roughly 0.5 coefficient for each of lag and lead). To estimate the key structural parameters of the PC across different specifications

Table 1: Estimation results of reduced form coefficients with GMM

	b_1^h	b_2^h	γ	α	σ	$J_{stat.}(P_{value})$
Model1C	0.429***	0.644***	0.110***	0.113***		0.769
Model2C	0.562***	0.478***	0.065***		0.207	0.690
Model3C	0.470***	0.565***	0.069***	0.170**	-0.155	0.784
Model4C	0.505***	0.530***	0.025***	0.194**		0.779
Model5C	0.493***	0.490***	0.042***		0.621***	0.452
Model6C	0.506***	0.486***	0.044^a	0.108	0.440***	0.876
Model1NT	0.479***	0.443***	0.050*		0.585***	0.315
Model1H	0.428***	0.584***	0.187***	0.301*		0.923
Model2H	0.599***	0.456***	0.078**	0.027		0.722
Model3H	0.608***	0.452***	0.011		0.839*	0.358

Note: Model 1C: core inflation model with output gap (specification 1); Model 2C: core inflation model with output gap (specification 2); Model 3C: core inflation model with output gap (specification 3); Model 4C: core inflation model with unit labor cost (specification 1); Model 5C: core inflation model with unit labor cost (specification 2); Model 6C: core inflation model with unit labor cost (specification 3); Model 1H: headline inflation model with GDP gap (specification 1); Model 2H: headline inflation model with output gap (specification 1); Model 3H: headline inflation model with unit labor cost (specification 2); Model 1NT: non-tradeable inflation model with unit labor cost (specification 2). a.P-value =0.13.

[11] List of instruments for each specifications are included in the Appendix 3.

[12] In case of specifications 2 and 3, the reduced form slope coefficients are not estimated directly in equation; they are implied by the following relationships $\gamma_{l\sigma}$=$\gamma(1-\sigma)$ and $\gamma_{m\sigma}$=$\gamma\sigma$. Hence, in those cases γ is the final reduced form slope coefficient of the PCs.

(see Table 2) in most cases we need to set restriction on the upper bound of β coefficient (subjective discount factor) in order to identify the rest of the parameters (in principle, we need the restriction to avoid counterintuitive estimation of β, as those specifications end with $\beta > 1$), except in Models 5C and 6C (i.e. the PC with unit labor cost with specifications 2 and 3). In the latter cases all parameters are estimated without any restrictions and are in line with the theory. In the Models 5C and 6C the sum of the coefficients of lagged and lead inflation is less than one which implies subjective discount factor less than one too, while in other cases subjective discount factor is above one, this is why we have to set restriction β=1.

Table 2: Estimation results of structural coefficients with GMM

	β	θ	ω	α	σ	γ^a
Model1C(with restriction $\beta = 1$)	1	0.617***	0.603***	0.062***		0.049
Model2C(with restriction $\beta = 1$)	1	0.567***	0.694***		0.367	0.029
Model3C(with restriction $\beta = 1$)	1	0.658***	0.528***	0.164**	0.087	0.042
Model4C(with restriction $\beta = 1$)	1	0.815***	0.546***	0.285**		0.011
Model5C	0.937***	0.535***	0.504***		0.622***	0.043
Model6C	0.971***	0.557***	0.563	0.109^b	0.441***	0.045
Model1NT	0.751***	0.585***	0.475***		0.585***	0.051
Model1H(with restriction $\beta = 1$)	1	0.474***	0.334***	0.317*		0.228
Model2H(with restriction $\beta = 1$)	1	0.609***	0.395**	0.334		0.092
Model2H(with restriction $\beta = 1$)	1	0.660***	0.558		0.661*	0.014

Note: a.Slope coefficient implied from the reduced form ones. b. P-value=0.19.

The price stickiness parameter (θ) implies that prices are changed approximately every 2-3 quarters (calculated by $\frac{1}{1-\theta}$) in case of core inflation, according to the results of Model 5C and 6C. At the same time about half of the firms change their prices in a backward-looking manner (ω). We cannot come up with a robust estimate of openness parameters (α and σ) across different specifications, but still we can exploit some findings from the estimation results: firstly, pass-through from imported final consumption goods (α) seems stronger in case of headline inflation (relative to core) as expected; in addition, the pass-through coefficient is lower in specifications where the cost of imported intermediates (σ) is included separately. As would be reasonable to expect, it seems in our estimates that real exchange rate affects inflation not only though final imported goods but also though the costs of imported intermediate goods.

4.1.4 Estimation results with headline inflation model

PC with headline inflation is identifiable with output gap, but only with specification 1. This seems intuitive too as the pass-through from imported final consumption goods is higher in case of headline inflation. However, as mentioned, the results are not stable across different estimation procedures. PC with specification 2 is identifiable with the unit labor cost; this further supports the finding that for empirical identification of PC with unit labor cost, imported intermediate cost matters too. The implied slope coefficient (γ) with unit labor cost is smaller (0.011) here than it was in the case of core inflation models. Hence, supply side factors seems more dominant in the case of headline inflation. GDP gap estimated with HP filter implies highest point estimation of PC slope (0.18), while it is only 0.078 in the case of model-consistent output gap in the PC with the same specification. We failed to get stable estimates of PC coefficients with the rest of the specifications of PC with headline inflation (i.e. the specifications which includes cost of imported intermediates as a component of marginal costs). This is why the results of only three equations are reported here, but the estimated slope coefficients significantly varies in those cases too.

There are several arguments why it is more difficult to identify headline inflation PC with output gap. For example, Mavroeidis (2004)[23] points that for empirical identifiability of the forward looking model, the forcing variable should be at least AR(2) process. We failed to get this condition in the case of output gap, even though we could reject unit labor cost not following at least AR(2) process. Moreover, it is harder to identify PC in case of headline inflation, as the analysis by Mavroeidis (2004)[23] shows the concentration parameter (the measure of the strength of identification of empirical forward looking model with GMM) is increasing with respect to variance of residual of forcing variable regressed on its first and second lags, and decreasing to variance of residuals from corresponding PC equation (the latter second moment can be interpreted as variability due to supply side shocks); in our case, ratio of standard deviation of residual of forcing variable regressed on its two lags to standard deviation of residuals from PC is more than 4 times larger in case of core inflation model with unit labor cost relative to headline inflation model with output gap. Due to higher variability of supply side shocks in case of headline inflation and insufficient dynamics of output gap relative to unit labor cost, possibility of empirical identification of PC is stronger in case of core inflation model with unit labor cost, relative to headline.

4.1.5 Test results

J-tests on overidentification of those models are acceptable (see Table 1), showing that moment conditions are fulfilled given the set of instruments. If instruments were weak, the test results would have been inconclusive; however, as AR (Anderson-Rubin) weak instrument robust test shows there is no evidence against the identification of PCs for each specification. Week instrument problem is a widespread issue in the literature for identification of PC with GMM and, hence, standard test results can be misleading. However, there still is a chance to test identification with arguably sufficient accuracy based on Anderson-Rubin test. The test checks whether residuals from the identified model is orthogonal to exogenous variables (excluding instruments and including exogenous variables; see, (Defour, 2005)[8]). Test results for all specifications are given in Appendix 2 (see, table B1). As is clear from those results all PC equations pass the formal test on identification based on AR test. Those results seem promising as AR test is a weak-instrument robust test procedure.

The instruments of the estimated equations presented in the previous section were selected though stepwise regression for each endogenous variables. F-test is applied as a rule of thumb approach for testing week instrument property (F statistics should be higher than 10, which is applied as the proxy of Stock and Yugo test on week instruments; however, the critical values of the latter test is not available for models with more than 3 variables). The requirement is satisfied for all endogenous variables but rate of expected appreciation of REER is an exception. However, when endogenous variables are more than one (for instance, in our case it is up to three depending on the specification), the high F statistic from the first stage regressions are not sufficient to test instrument relevance due to potential collinearity of instruments. To account for this problem we estimate Shea partial R-square for each endogenous variable. As the test results shows (see Table B2) partial R-square is satisfactory for all endogenous regressors, especially in the case of forcing variables, while it is lower in the case of ex-post realized real exchange rate.

GMM estimator is more consistent than OLS, but it's less efficient if explanatory variables (assumed to be endogenous) aren't really endogenous. The most important is to test whether ex-post inflation and output gap are endogenous in OLS estimation. We have applied formal test of endogeneity based on Durbin–Wu–Hausman test and in most cases we failed to reject no endogeneity assumption on assumed endogenous variables, but models 5C and 2H were close to rejection (P-value = 0.13 in both cases). In addition, assumed no endogeneity is more likely to be rejected in case of output gap in all specifications; probably inflation shocks and output gap shocks are more interrelated than in case of unit labor cost. However, those results are inconclusive. In GMM estimation we use four lags of weighting matrix, while critical values of the test is specified for one lag by default. We have applied the endogeneity test for models estimated with one lag of weighting matrix and based on this we strongly reject no enodogeneity assumption especially in the case of expected inflation and cyclical indicators; however, it was hard to reject the assumption in case of expected REER. But as we use its ex post realized values in our model we still consider it as enodgenous in our estimations too.

4.2 Results from ARDL model

ARDL model was also applied for estimating triangle PC for Georgia. The specification involves inflation inertia as well as forward looking term, in addition to demand side drivers (similar to GMM specifications, here we have used unit labor cost and output gap to proxy demand side drivers of inflation). Set of supply side factors are also directly included in the model (see, for instance, Lanau et al., 2018[20]), such as food price inflation, oil price inflation (as a proxy of energy price inflation) and, to account for possible balance sheet effects, USD/GEL nominal exchange rate (because of still high level of financial dollarization in Georgia). Finally, weighted CPIs of trading partners and REER are included as well, for capturing trade related drivers.

The empirical model estimated in this section is the following:

$$\pi_t = c + a(L)\pi_{t-1} + b\pi_{t+1}^{exp} + \alpha mc_t + \gamma(L)s_t + \epsilon_t \tag{17}$$

Where $a(L)$ is lag polynomial and captures the effect of inflation inertia. π_{t+1}^{exp} is expected inflation. Here we do not proxy it with ex-post inflation because of endogeneity, instead of this, we have estimated two alternative specifications: on the one hand, we used proxy of inflation expectations with market-based inflation expectations; on the other hand, we estimated equation (17) without expectation term. The latter is supposed to estimate the relation in case of PC being purely backward-looking (and sample is from 2005Q1 to 2019Q1), while the former strategy reduces our sample size to 38 observations (starts from 2009Q3) but incorporates forward-looking term as well. mc_t is a measure of economic slack, and s_t is set of supply side shocks. The lag structure is selected by estimating the ARDL model based on Akaike information criteria (AIC). However, in some cases we ended up with overfitting of the equations by using the criteria (especially in forward-looking PC where sample size is short and number of coefficients are many). In such cases we apply Schwarz criteria, which selects shorter lags structure. The equation (17) has been estimated for core, headline, tradable and non-tradeable inflations separately.

First, we estimated backward-looking models for the full sample (starting from 2005Q1). We estimate whether backward looking PC is alive in Georgia's case and in particular which inflation: headline, core, tradable, and non-tradable inflations are more sensitive to economic slack. As headline inflation is trend-stationary process for full sample we model it accordingly in a backward-looking specification. However, the series becomes stationary without a drift and a trend after 2009. Hence, the forward looking specification is modeled without a trend[13]. Core inflation is not stationary process neither with drift nor trend; hence, it is a candidate to be I(1) process. In this case ARDL bound test analysis suggests to write a model in an error correction form. But as all independent variables included in the model are stationary processes and serial correlation is not an issue, finally we decided to model the first difference of the dependent variable in ARDL specification. Inflation expectations is a stationary process with a drift. It is also worth noting that, as we have some evidence of the proxy variable being systematically deviated from true expectations, in a forward-looking specification we applied demeaned series or included a drift in the model. This strategy performs better in our case.

Similar to GMM applications, here we use three different forcing variables: model-consistent output gap, GDP gap estimated using HP filter and ULC. Hence, we have estimated 12 ARDL models for four different indicators of inflations (see Table A1 and A2 in Appendix 1). Our

[13]Since sample size in forward looking model is from 2009Q3 to 2018Q1, after inclusion of market based inflation expectation within the model.

first finding is that backward looking PCs are positively sloped in all cases, but the coefficients are small and indicate flatter PCs. Moreover, identification of PC is stronger using output gap and GDP gap. More specifically, the slopes of headline inflation PCs are 0.167 and 0.104 in the case of output gap and GDP gap, respectively. However, as the results show, identification of positively sloped PC is more difficult for the tradable inflation. In this case the PCs are positively sloped, but the coefficients are small and insignificantly different from zero in all the cases of tradable inflation PC (from 0.021 to 0.028). This seems intuitive as the tradable inflation is mostly driven by exogenous supply side shocks (external factors) and domestic demand has muted effect on its dynamics. As opposed to this, we observe more stable relationship in the case of core and non-tradable inflations. For example, the slope of core inflation PCs are 0.11, 0.076 and 0.028 in case of GDP gap, output gap and UCL, respectively. It should be pointed out that those coefficients are close to the estimates from headline inflation PCs, but here core inflation models show more robust results across variations of included variables and lag structure. Finally, we get the most robust estimate (0.086, 0.106, and 0.014) in the case of non-tradable PCs with satisfactory statistical properties (the results are free from AC and heteroscedasticity problems, and residuals are normally distributed).

Supply side factors, such as oil and food price indexes, play a role for inflation dynamics too in the cases of headline and tradable inflations. As the results show oil spot prices have lagged effect on inflation (the third and fourth lags are significant too). Hence, change in the current price of oil on international market affects headline and tradable inflations gradually. For example, on impact headline inflation increases by 0.023 pp after 1 pp oil price shock, but the long run effect is as much as 0.4 pp. While, food price index has more immediate impact on headline inflation. As oil price plays a role in production costs too, this can be an explanation of its delayed effect under sticky domestic price environment. Identification of forward looking PCs are less robust in the case of using market-based inflation expectations. By applying forward-looking specification we ended up with insignificant slope coefficients almost in all cases and the estimated coefficients are negative (see Tables A3 and A4). The reasons for this different results could include one or both of the following: (i) potential endogeneity of output gap in backward looking specifications; (ii) sample size being shorter in forward-looking specifications, which reduces d.f. of the models and induces many insignificant coefficients. As a cross check we have estimated backward looking specification for the restricted sample as well and the slope coefficients, indeed became smaller and insignificant too in these cases. Hence, smaller slope coefficient seems to be explained mostly by the second factor (sample size). In addition, from the literature we have evidence of relative flattening of PCs throughout the world. After introduction of inflation targeting (IT) framework inflation process becomes more anchored with the target and, hence, inflation reacting less to cyclical movements contributes to flatter PC. Indeed, in our case market based inflation expectations are available from 2009Q3 and this period coincides with the introduction of IT regime in Georgia.

The effect of forward looking terms are relatively high in the cases of headline and tradable inflations PCs (ranging from 0.31 for tradable inflation to 0.74 for headline inflation), while inflation expectations play smaller role in the cases of core and non-tradable inflations PCs (ranging from 0.05 to 0.18). Potentially, the relative dominance of inflation expectations in headline and tradable inflation dynamic contributes to less significant and unrobust estimates of the slope coefficients in the case of headline and tradeable inflations PCs.

5 Concluding remarks

Current debate on flatter Phillips Curve (broadly defined as the relation between inflation and cyclical position of the domestic economy) is focused on two main research topics: (i) to explain reasons behind flatter PC (for instance, anchoring of inflation expectations, global factors, etc.) and (ii) to improve analytical methods for identifying the PC taking endogenous response of monetary policy to demand side drivers of inflation into account. We have applied GMM as well as ARDL methods to identify the Phillips Curve in Georgia. This methods have recently been used by a number of authors to uncover the underlying relationship. Hence, the main contribution of our paper is more on empirical side: providing an estimate of the PC for Georgia – something that macroeconomic policy-makers as well as economic analyst should find useful[14].

To summarize our key findings, we came up with a positively sloped (yet somewhat flat) Phillips Curve in Georgia. Namely, the slope coefficients of core and headline inflation PC are in the vicinity of 0.1. It is worth mentioning that the PC may well be non-linear as well, rising

[14]The results should be a useful input for Georgian Economy Model discussed in Tvalodze et al. (2016).

proportionately more during upswing - something to be incorporated into empirical analysis in future work. In addition, another important part of the findings is the estimate of backward and forward lookingness of the inflation process. As mentioned above, the more forward-looking the inflation process is the less are the costs of maintaining price stability. In our estimates, in most specifications, inflation is backward and forward-looking at about the same rate (roughly 0.5 coefficient for each of lag and lead). This means that while inflation in Georgian is to some extent already forward-looking, there's still some room for monetary policy to anchor price setting process to its inflation target.

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A Appendix 1. ARDL model estimation results

Table A1: Backward-looking PCs for headline and tradeable inflations

	Headline inflation						Tradeable inflation					
	Coefficients	P-value	Coefficients	P-value	Coefficients	P-value	Coefficients	P-value	Coefficients	P-value	Coefficients	P-value
TRADEABLE_INF(-1)							0.638	0.000	0.625	0.000	0.672	0.0000
HEAD_INF(-1)	0,661	0,000	0,698	0,000	0,585	0,000						
HEAD_INF(-2)	-0,001	0,992	-0,120	0,266	0,152	0,267						
HEAD_INF(-3)	0,167	0,187	0,122	0,492	0,008	0,957						
HEAD_INF(-4)	-0,456	0,000	-0,458	0,000	-0,252	0,051						
HEAD_INF(-5)	0,426	0,000	0,514	0,000	0,442	0,000						
D(TRADE_INF)	0,573	0,166	0,075	0,851	0,567	0,106	0,439	0,255	0,417	0,284	0,774	0,069
D(TRADE_INF(-1))	0,497	0,091	-0,095	0,808	0,556	0,030	-0,008	0,982	-0,016	0,966		
D(TRADE_INF(-2))	1,157	0,008	0,866	0,068	1,373	0,001	1,339	0,001	1,328	0,001		
D(TRADE_INF(-3))	0,686	0,152	0,695	0,092	0,824	0,117						
D(TRADE_INF(-4))	0,564	0,033	0,768	0,012	0,714	0,009						
REER_DEP	0,162	0,031	0,224	0,000	0,080	0,313	0,141	0,004	0,142	0,004	0.112	0.045
REER_DEP(-1)	-0,118	0,032	-0,111	0,065	-0,069	0,480					-0.052	0.241
REER_DEP(-2)					-0,151	0,246						
REER_DEP(-3)					0,168	0,163						
REER_DEP(-4)					-0,243	0,039						
OIL_INDX	0,023	0,107	0,030	0,006	0,013	0,310	0,016	0,184	0,016	0,173	0,007	0,547
OIL_INDX(-1)	0,028	0,040	0,021	0,159	0,047	0,013	0,023	0,100	0,022	0,102	0,009	0,440
OIL_INDX(-2)	-0,010	0,309	-0,026	0,134	-0,037	0,050	-0,026	0,047	-0,025	0,049	-0,003	0,770
OIL_INDX(-3)	0,015	0,076	0,032	0,042	0,036	0,012	0,027	0,007	0,027	0,006	0,022	0,009
OIL_INDX(-4)	0,026	0,014	0,030	0,047								
FOOD_INF	0,120	0,000	0,111	0,000	0,133	0,000	0,053	0,081	0,052	0,093	0,028	0,162
FOOD_INF(-1)	-0,139	0,000	-0,124	0,044	-0,170	0,000	-0,060	0,050	-0,058	0,056		
FOOD_INF(-2)			0,077	0,134								
FOOD_INF(-3)			-0,063	0,307								
FOOD_INF(-4)			-0,042	0,449								
USD_DEP	0,166	0,000	0,192	0,000	0,130	0,021	0,090	0,063	0,092	0,060	0,117	0,002
USD_DEP(-1)					0,053	0,462	0,122	0,046	0,122	0,047		
USD_DEP(-2)					-0,157	0,058	-0,108	0,012	-0,104	0,021		
USD_DEP(-3)					0,185	0,030						
USD_DEP(-4)					-0,174	0,020						
GDP_GAP	0,104	0,204					0,022	0,750				
OUTPUT_GAP			0,167	0,007					0,028	0,659		
ULC_NGAP					-0,038	0,238					0,021	0,431

Table A2: Backward-looking PCs for core and non-tradeable inflations

	Core inflation						Non-tradable inflation					
	Coefficients	P-value	Coefficients	P-value	Coefficients	P-value	Coefficients	P-value	Coefficients	P-value	Coefficients	P-value
NON_TRADE_INF(-1)							1,098	0,000	1,036	0,000	1,079	0,000
NON_TRADE_INF(-2)							-0,275	0,015	-0,264	0,013	-0,245	0,043
D(CORE_FOOD_EN_INF(-1))	0,033	0,775	0,040	0,733	0,074	0,538						
D(CORE_FOOD_EN_INF(-2))	0,062	0,570	0,074	0,499	0,098	0,413						
D(CORE_FOOD_EN_INF(-3))	-0,114	0,288	-0,112	0,307	-0,115	0,311						
D(CORE_FOOD_EN_INF(-4))	-0,265	0,010	-0,283	0,006	-0,319	0,004						
D(TRADE_INF)	-0,012	0,958	-0,001	0,995	0,135	0,574						
D(TRADE_INF(-1))	0,319	0,191	0,327	0,187	0,362	0,160						
D(TRADE_INF(-2))	0,392	0,077	0,405	0,073	0,402	0,085						
REER_DEP	-0,033	0,263	-0,027	0,362	-0,020	0,527						
NEER							-0,045	0,011	-0,044	0,007	-0,055	0,005
NEER(-1)												
USD_DEP	0,085	0,002	0,089	0,001	0,082	0,004						
USD_DEP(-1)	-0,063	0,019	-0,062	0,024	-0,072	0,013						
GDP_GAP	0,111	0,039					0,086	0,025				
OUTPUT_GAP			0,076	0,084					0,106	0,001		
ULC_NGAP					0,028	0,320					0,014	0,423
INTERM_IMP_GAP					0,007	0,765					0,029	0,017

Table A3: Forward-looking PCs for headline and tradeable inflations

	Headline inflation						Tradeable inflation					
	Coefficients	P-value	Coefficients	P-value	Coefficients	P-value	Coefficients	P-value	Coefficients	P-value	Coefficients	P-value
TRADEABLE_INF(-1)							0,612	0,005	0,738	0,003	0,749	0,000
TRADEABLE_INF(-2)							0,169	0,464	0,177	0,488	0,384	0,142
TRADEABLE_INF(-3)							-0,405	0,014	-0,407	0,020	-0,467	0,006
HEAD_INF(-1)	0,527	0,002	0,849	0,003	0,425	0,000						
HEAD_INF(-2)			-0,245	0,069								
D(TRADE_INF)	1,039	0,052	1,166	0,046	0,632	0,228	0,527	0,247	0,653	0,118	1,348	0,043
D(TRADE_INF(-1))			0,026	0,947								
D(TRADE_INF(-2))			0,397	0,388								
D(TRADE_INF(-3))			-0,847	0,077								
REER_DEP	-0,009	0,874	-0,025	0,718	0,018	0,793	-0,015	0,709	-0,009	0,874	-0,040	0,340
REER_DEP(-1)	-0,178	0,003	-0,119	0,072	-0,161	0,005						
OIL_INDX	0,002	0,906	0,010	0,720	0,017	0,896	0,010	0,461	0,012	0,442	-0,008	0,632
OIL_INDX(-1)											0,028	0,023
FOOD_INF	0,062	0,130	0,074	0,035	0,040	0,110	-0,011	0,721	-0,030	0,410	0,022	0,586
FOOD_INF(-1)			-0,110	0,251							-0,080	0,077
FOOD_INF(-2)			0,086	0,086							-0,004	0,927
FOOD_INF(-3)											0,047	0,103
GDP_GAP	0,278	0,254					-0,049	0,804				
OUTPUT_GAP			0,114	0,480					-0,025	0,868		
ULC_NGAP					0,011	0,862					0,026	0,629
EXPECT_INF	0,743	0,000	0,608	0,001	0,834	0,000	0,506	0,000	0,411	0,004	0,316	0,007

Table A4: Forward-looking PCs for core and non-tradeable inflations

	Core inflation						Non-tradable					
	Coefficients	P-value	Coefficients	P-value	Coefficients	P-value	Coefficients	P-value	Coefficients	P-value	Coefficients	P-value
NON_TRADE_INF(-1)							0,930	0,000	0,925	0,000	1,051	0,000
NON_TRADE_INF(-2)							-0,085	0,445	-0,080	0,657	-0,372	0,009
NON_TRADE_INF(-3)							-0,202	0,037	-0,210	0,116		
D(CORE_FOOD_EN_INF(-1))	-0,086	0,607	-0,082	0,518	-0,241	0,108						
D(CORE_FOOD_EN_INF(-2))	-0,027	0,863	-0,017	0,844	0,002	0,985						
D(CORE_FOOD_EN_INF(-3))	-0,281	0,055	-0,274	0,009	-0,334	0,004						
D(CORE_FOOD_EN_INF(-4))	-0,413	0,010	-0,406	0,022	-0,450	0,001						
D(TRADE_INF)	-0,175	0,616	-0,210	0,692	-0,388	0,269						
REER_DEP	-0,069	0,077	-0,067	0,070	0,029	0,375						
NEER							-0,009	0,577	-0,011	0,575	-0,046	0,165
NEER(-1)											0,082	0,085
NEER(-2)											-0,097	0,039
NEER(-3)											0,050	0,154
USD_DEP					0,117	0,000						
USD_DEP(-1)					-0,043	0,099						
GDP_GAP	0,108	0,469					-0,062	0,087				
OUTPUT_GAP			0,088	0,642					-0,065	0,324		
ULC_NGAP					0,059	0,424					-0,029	0,380
INTERM_IMP_GAP											0,004	0,830
EXPECT_INF	0,166	0,150	0,149	0,180	0,114	0,179	0,065	0,007	0,052	0,098	0,050	0,083

B Appendix 2. Test statistics

Table B1: Anderson Rubin test results

	Model 1C	Model 2C	Model 3C	Model 4C	Model 5C	Model 6C	Model 1NT	Model 1H	Model 2H	Model 3H
P_value (Chi-square test statistics)	0,435	0,905	0,988	0,9286	0,656	0,8789	0,228	0,1929	0,697	0,245

Note: As the AR (Anderson Rubin test on joint significance of instrumental variable in explaining GMM residual) test results show, we fail to reject estimated models, even though instrumental variables were weak.

Table B2: Instrument relevance (Shea's partial R square) test:

	Model 1C	Model 2C	Model 3C	Model 4C	Model 5C	Model 6C	Model 1H	Model 2H	Model 3H	Model 1NT
Headline inflation (+1)							0,68	0,65	0,66	
Core inflation(+1)	0,43	0,43	0,59	0,62	0,48	0,65				
Reer dep(+1)	0,46		0,46	0,69		0,68	0,56	0,57		
GDP gap							0,62			
Output gap	0,89	0,89	0,68					0,75	0,76	
ULC gap				0,69	0,71	0,72				0.64
Non-tradeable inflation(+1)										0.59

C Appendix 3. Instrumental variables

Table C1: Set of instruments

Model 1C	Model 2C	Model 3C	Model 4C	Model 5C	Model 6C	Model 1NT	Model 1H	Model 2H	Model 3H
core_food_en_inf2	core_food_en_inf2	forg_growth1	core_food_en_inf2	core_food_en_inf2	core_food_en_inf2	credit_gap1	credit_gap1	food_inf4	forg_growth1
forg_growth1	forg_growth1	interm_imp_gap3	credit_gap1	food_inf3	credit_gap1	forg_growth1	food_inf4	credit_gap1	forg_growth1
output_gap1	interm_imp_gap3	neer2	credit_gap4	forg_growth3	credit_gap4	interm_imp_gap3	forg_growth1	forg_growth1	interm_imp_gap3
output_gap2	neer1	neer4	forg_growth1	neer1	food_inf1	neer3	gdp_gap1	interm_imp_gap3	interm_imp_gap4
output_gap3	oil_indx3	oil_indx4	interm_imp_gap1	oil_indx3	food_inf4	non_trade_inf4	interm_imp_gap3	neer2	oil_indx3
reer_dep3	output_gap1	output_gap1	interm_imp_gap2	output_gap4	forg_growth3	oil_indx2	neer2	neer4	output_gap4
trade_inf1	output_gap3	output_gap3	neer2	trade_inf1	interm_imp_gap1	oil_indx4	neer4	oil_indx4	real_bus_wage_gap4
trade_inf1	trade_inf1	trade_inf1	neer4	trade_inf2	interm_imp_gap2	real_bus_wage_gap1	oil_indx4	output_gap1	trade_inf2
ulc_ngap1	ulc_ngap4	ulc_ngap3	oil_indx3	usd_dep1	neer1		reer_dep3	output_gap3	usd_dep1
ulc_ngap3	usd_dep1	ulc_ngap4	real_bus_wage_gap3	forg_growth1	oil_indx3		ulc_ngap1	reer_dep3	usd_dep2
ulc_ngap4		usd_dep1	reer_dep2		output_gap4		ulc_ngap3	trade_inf2	
usd_dep1		usd_dep4	trade_inf1		reer_dep3		ulc_ngap4	ulc_ngap3	
			ulc_ngap_adj2		trade_inf1		usd_dep1	ulc_ngap4	
			usd_dep1		trade_inf2				

Note: Definitions: food_inf YoY food price inflation based on FAO price index; interm_imp_gap – HP filtered gap of the share of imported intermediates in GDP; neer - YoY change nominal effective exchange rate; output gap – deviation of real GDP from potential output based on NBG'S structural model estimation; reer_dep – YoY change real effective exchange rate; trade_inf - weighted average of trade partners' inflation; ulc_gapn – gap of unit labor cost (estimated as deviation from HP trend of share of wage bills in GDP); usd_dep – YoY depreciation of GEL/USD nominal exchange rate; core_food_en_inf – core inflation; forg_growth - weighted average of trade partners' growth; oil_indx – oil price YoY inflation based on WTI index; head_inf - headline inflation; real_bus_wage_gap –business real wage gap; credit gap – HP filtered credit to GDP gap (in line with the Basel recommendation).

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