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A new Keynesian triangle Phillips curve

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ABSTRACT

We propose a solution to address the observed negative sign on the marginal cost variable in new Keynesian Phillips curve estimations. Our solution is based on an elaborate specification of the cost function faced by firms and the formulation of a reduced-form production function which is characterised by non-linear input–output relations. The resultant Phillips curve features the standard hybrid expectational term, labour share, output gap, speed-limit effects and supply shock variables. In general, GMM estimations of the model for developed and emerging markets yield a positive and significant coefficient on the labour share and the output gap. We conclude that supply shock variables are essential to the empirical validity of the cost-based Phillips curve.

1. Introduction

The new Keynesian Phillips curve is part of the core elements of modern dynamic macro-models. The strength of the new Keynesian Phillips curve is that it is derived from microfoundations. Therefore, the parameters that characterise it have a clear structural interpretation. However, the empirical performance of the new Keynesian Phillips is still a matter of debate. Gali et al. (2001, 2005) argue that the new Keynesian Phillips curve provides an adequate account of inflation dynamics, whereas Rudd and Whelan (2005a, 2007) argue that the backward-looking Phillips curve better explains inflation dynamics.

One of the problems with the new Keynesian Phillips curve is that the coefficient of the forcing variable, real marginal cost, tends to be insignificant and in some cases, carries a wrong sign when estimated. Rudd and Whelan (2007) find that the sign on the forcing variable is either not statistically significant or is negative in the case of the US. Mazumder (2010, 2011) proposes an alternative, procyclical measure of marginal cost, and still finds that the new Keynesian Phillips curve fails to explain inflation dynamics. Estimates of the new Keynesian Phillips curve for Australia by Abbas and Sgro (2011) produce similar findings. Similarly, Va šíček (2011) finds that alternative measures of real marginal cost tend to be insignificant and sometimes carry the wrong sign for some transitional economies.

The contribution of this paper is to present a more elaborate specification of marginal cost than has been used in the literature. In this sense, we build on the work by Petrella and Santoro (2012), who find evidence in support of the new Keynesian Phillips curve in the case of US manufacturing firms. These authors formulate a production function with raw material inputs and labour as factors of production. Their resultant real marginal cost is a linear combination of the firm-level labour share and relative input prices. They conclude that this measure of real marginal cost produces dynamic properties that are in line with a new Keynesian theory.

This paper also provides the theoretical basis for the new Keynesian Phillips curve formulation that is proposed by Mehra (2004). We exploit non-linear input–output relationships as suggested by Batini et al. (2005) to formulate a reduced-form production function. The non-linearity in input–output relations, coupled with adjustment costs, leads us to a new Keynesian Phillips curve that features the output gap, speed-limit effects, labour share and "supply shock" variables. This formulation can be interpreted as the "new Keynesian Triangle Phillips curve" because it features an expectational element, excess demand pressure and "supply shock" variables, as in Gordon (2011).

Our formulation achieves three objectives. Firstly, it directly constructs a procyclical measure of real marginal cost, thereby addressing part of the empirical problems of the new Keynesian Phillips curve as pointed out by Mazumder (2010, 2011). Secondly, at the empirical level, it bridges the gap between the "left fork" and the "right fork", i.e. between the triangle Phillips curve literature and the new Keynesian approach (see Gordon, 2011) by formulating a Phillips curve that has baseline new-Keynesian features whilst at the same time exhibiting variables that are found in the triangle Phillips curve approach. Thirdly we show that Gali et al.'s (2001) statement about the redundancy of supply shocks may be unjustified, because the empirical validity of the new Keynesian Phillips curve depends critically on the significance of supply shock variables.

The paper is structured as follows: Section 2 derives the new Keynesian Triangle Phillips curve. Section 3 presents the empirical results and Section 4 is the conclusion.

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2. Theoretical framework

As pointed out by Fuhrer et al. (2009) and Ascari et al. (2011), there are two ways to derive the new Keynesian Phillips curve. One way, due to Rotemberg (1982), is based on quadratic price adjustment costs. The other way, due to Calvo (1983), assumes that at each point in time a fraction of firms re-sets prices with a constant, exogenously determined probability. In this paper, we use the hybrid, Calvo-style, new Keynesian Phillips curve that is proposed by Gali and Gertler (1999) and Gali et al. (2001) of the following form:

$$\pi_t = \gamma_f E_t \pi_{t+1} + \gamma_b \pi_{t-1} + \lambda \widehat{mc}_t \tag{1}$$

where γ_f, γ_b and λ are non-linear combinations of the discount factor, the fraction of firms that re-sets prices and the fraction of firms that optimise. Gali and Gertler (1999) and subsequent authors assumed procyclicality of marginal cost so that $\widehat{mc}_t = \kappa \widehat{y}_t$, where $\kappa > 0$. However the output gap was soon found to be a poor proxy of marginal cost (see Gali et al., 2001). Consequently, by assuming a simple production function with labour as the only input, Gali et al. (2001) found that the labour share is a better proxy of marginal cost. However the findings by Rudd and Whelan (2005a, 2007) cast serious doubt on the usefulness of the labour share as a proxy of real marginal cost, and thus put the new Keynesian approach into question.

Our contribution is to provide an elaborate specification of marginal cost by building on the work by Petrella and Santoro (2012). To do so we assume, along the lines of Batini et al. (2005), that firms exhibit non-linear input requirements in production such that: $X_{it} = Y_t^{\delta_i}$, where X_{it} is the amount of non-labour input i required in production and $\delta_i > 0$ is the input requirement coefficient. The motivation for this technology is that, in the short run, firms cannot substitute between labour and non-labour inputs. If firms use capital equipment whose efficiency varies with output, at the margin as output rises, less efficient machines are employed into the production process. These less efficient machines in turn require increasing amounts of non-labour inputs for a unit of output to be produced. With fixed capital normalised to 1, we can write the production function as:

$$Y_t = A_t L_t^{\alpha} \left[\prod_{i=1}^{n} Y_t^{\theta_i \delta_i} \right]^{\varphi}, \tag{2}$$

where A_t is the state of technology, L_t is the level of employment and, $0 < \alpha < 1$, and θ_i is the elasticity of output with respect to input i. The reduced-form expression for Eq. (2) is given by:

$$Y_t = A_t^{'} L_t^{\sigma}, \tag{3}$$

where $\phi = \sum_{i=1}^{n} \theta_i \delta_i, \sigma = \frac{\alpha}{1-\phi}$ and $A_t^{'} = A_t^{\frac{1}{1-\phi}}$. Using Eq. (3), real total cost faced by the firm can be written as follows:

$$TC_t = \frac{W_t Y_t^{\frac{1}{\sigma}}}{A_t^{'\frac{1}{\sigma}} P_t} + \sum_{i=1}^{n} \frac{P_{it}}{P_t} Y_t^{\delta_i}, \tag{4}$$

where P_{it} is the price of non-labour input i, P_t is the aggregate price level and W_t is the nominal wage. Let p_{it} denote the real price of non-labour input i. We can write real marginal cost as:

$$MC_t = \frac{W_t Y_t^{\frac{1-\sigma}{\sigma}}}{\sigma A_t^{'\frac{1}{\sigma}} P_t} + \sum_{i=1}^{n} \delta_i p_{it} Y_t^{\delta_i - 1}. \tag{5}$$

Linearising Eq. (5) around the steady state we get the following relationship:

$$\widehat{mc}_t = \frac{S_0}{MC_0 \sigma} \widehat{s}_t + \sum_{i=1}^{n} \frac{\delta_i p_{i0} Y_0^{\delta_i - 1} (\delta_i - 1)}{MC_0} \widehat{y}_t + \sum_{i=1}^{n} \frac{\delta_i p_{i0} Y_0^{\delta_i - 1}}{MC_0} \widehat{p}_{it}. \tag{6}$$

We can then insert Eq. (6) into Eq. (1) to get the following extended version of the new Keynesian Phillips curve:

$$\pi_t = \gamma_f E_t \pi_{t+1} + \gamma_b \pi_{t-1} + \lambda \vartheta_s \widehat{s}_t + \lambda \vartheta_y \widehat{y}_t + \lambda \sum_{i=1}^{n} \vartheta_{ip} \widehat{p}_{it}, \tag{7}$$

where:

$$\vartheta_s = \frac{S_0}{MC_0 \sigma}, \vartheta_y = \sum_{i=1}^{n} \vartheta_{ip} (\delta_i - 1) \text{ and } \vartheta_{ip} = \frac{\delta_i p_{i0} Y_0^{\delta_i - 1}}{MC_0}.$$

Eq. (7) can be viewed as an extension of the baseline framework of Gali and Gertler (1999). It builds on Petrella and Santoro (2012) in the sense that, besides the labour share and relative input prices, the output gap enters the Phillips curve as well. Because of the presence of the expectations, excess demand pressure and "supply shock" variables, we refer to Eq. (7) as the "new Keynesian Triangle Phillips curve". The significance of the output gap in driving inflation depends entirely on the relevance of relative input prices in the determination of production costs. Thus, we are able to provide a structural interpretation of the finding by Mehra (2004), that the omission of supply shocks makes the output gap statistically insignificant in new Keynesian Phillips curve estimations.

Based on Eq. (7), we are able to provide a structural interpretation of the sign of the output gap. Batini et al. (2005) assume that $\delta_i > 1$. They justify the convexity of the non-linear input–output relation on the grounds that at high levels of output, inefficiencies in production increase at an increasing rate because firms tend to draft old machines into the production line, which use more inputs than new machines. However it is possible, especially if production technology exhibits significant economies of scale, for inefficiencies to increase at a decreasing rate at high levels of output. In this case $\delta_i < 1$, which delivers a negative sign on the output gap. Furthermore, if the input–output relation is linear, i.e. $\delta_i = 1$, then the output gap parameter would be zero.

If the assumption that input–output relations are convex holds, Eq. (7) provides a straightforward way in which a procyclical measure of real marginal cost can be constructed. In this sense, Eq. (7) also extends the work by Mazumder (2010), although in a different direction. Mazumder proposes a procyclical measure based on Bils (1987). However, when this measure is used, the new Keynesian Phillips curve collapses. The measure that we propose in Eq. (7) explicitly features the output gap which, by definition is procyclical. If our assumptions about production technology are correct, then it means that the sign problem in new Keynesian Phillips curve estimations may reflect misspecification. Secondly, our theoretical formulation suggests that supply shocks and the level output gap have to be jointly significant if our assumptions hold empirically.

Some scholars, e.g. Mehra (2004) and Fuhrer et al. (2009), find that speed-limit effects play a significant role in driving inflation over and above the level effects of excess demand pressure. In the framework presented above, we can introduce speed-limit effects in the basic new Keynesian model by assuming that firms face output adjustment costs in addition to production costs. This assumption is analogous to the standard investment adjustment cost found in DSGE literature, e.g. Smets and Wouters (2003) and Christiano et al. (2005). Therefore we specify output adjustment costs as follows:

$$AdjC_t = \left(\frac{Y_t}{Y_{t-1}} \right)^{\omega} Y_{t-1}, \tag{8}$$