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Oleg Zamulin
Konstantin Styrin

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Abstract

It has been noted in many papers that primary commodity exporting economies and developing countries frequently respond to movements in the real exchange rate as part of their monetary policies. For many central banks, this variable is the primary indicator of real activity. At the same time, smoothing the real exchange rate fluctuations has certain inflationary costs. In a way, this trade-off between inflation and the real exchange rate is identical to a standard Phillips curve. This paper derives an exact theoretical expression for this "real exchange rate based Phillips curve," and finds empirical support for its existence in the data for a number of primary commodity exporting economies such as Australia, Canada, New Zealand and others. It turns out that the correct right-hand-side variable in the Phillips curve is not the real exchange rate itself, but rather its deviation from the fundamental value, which is a function of the international price of exported commodities. The empirical counterpart of the fundamental real exchange rate is obtained from a cointegrating equation for the real exchange rate and the country-specific price index of exported commodities. As is frequently found in other Phillips curve studies, empirical tests point towards the accelerationist specification, which can be rationalized by dominance of adaptive expectations in price-setting behavior.

JEL Classification: E31, E32, F31

Key words: Real exchange rate; inflation; Phillips curve; commodity currencies.

*The authors thank Sergei Golovan for help with the earlier versions of this paper. Zamulin: National Research University – Higher School of Economics (NRU-HSE), Moscow; Styrin: New Economic School (NES), Moscow. The authors can be contacted at Nakhimovskiy prospekt, 47, Office 1721, Moscow 117418, Russia, or at ozamulin@hse.ru, and kstyrin@nes.ru

1 Introduction

The Phillips curve is one of the most interesting and important topics in modern macroeconomics. Since the rejection of the original curve in the 1970s (Lucas, 1975), economists have tried to explain the apparent presence of a trade-off between inflation and real activity, which still seems to be in the data (King and Watson, 1994; Stock and Watson, 1999). Alternative theories have ranged from the early New Classical Phillips Curve (Lucas, 1973), which seemed to be the primary model through the 1970s and 1980s, the New Keynesian version (Roberts, 1995; Galí and Gertler, 1999), which dominated in the 1990s and is still popular, as well as the more recent sticky information version (Mankiw and Reis, 2002 and 2003).

However, even within each of these theories, Phillips curve does not have to be treated narrowly as a trade-off between inflation and unemployment, as it was specified originally. Nowadays, economists look for a trade-off between inflation and any measure of real activity, be that unemployment, output gap, or real marginal costs. Thus, Stock and Watson (1999) estimate their curve with a large number of different real activity measures, while Galí and Gertler (1999) argue that a measure of real marginal cost is the appropriate variable by theory.

Here, we attempt to contribute to this literature by estimating a trade-off between inflation and the real exchange rate – a variable that is targeted by many central banks in commodity exporting economies and developing countries (Calvo, Reinhart, and Vegh, 1995), even though the wisdom of such policy choice has been questioned (Uribe, 2003). There has been some previous work on this issue (see, for example, Loungani, Razin, and Yuen, 2002), but a structural Phillips Curve relationship with real exchange rate, to our knowledge, has never been estimated.

We model and estimate the Phillips Curve within the New Keynesian sticky price paradigm. The idea is simple. A central bank can produce an unexpected devaluation of the domestic currency by increasing its supply in the foreign exchange market. Eventually, this expansion of money supply will lead to a rise in prices. However, due to sticky prices, the markets will clear only after some time, and in the meantime, there will be a combination of below-equilibrium real exchange rate and above average inflation.

Estimation of the Phillips curve is normally made more difficult by the fact that the fundamental value of the right-hand side variable is not observable. The most usual specification of a Phillips curve involves the output gap, which is the difference between output and its flexible price level. This flexible price level of output, however, is not known, and is normally estimated as simple log-linear or quadratic trend, or a trend obtained using the Hodrick-Prescott or a band-pass filter. These methods, obviously, can give only a rough approximation of the desired measure. Hence, Galí and Gertler (1999) prefer to use the real marginal cost as the right-hand side variable, which, of course, can also be measured only imperfectly.

We estimate the real exchange rate based Phillips Curve using data for a number of primary commodity exporting economies such as Australia, Canada, New Zealand and others and believe that we can avoid the problem with the fundamental value, to a large extent. Thus, it has been noted that the real exchange rate of the "commodity currencies" has been driven, to a substantial degree, by fluctuations in the international price of the respective country's commodity exports (Chen and Rogoff, 2003; Sosunov and Zamulin, 2006). We use the country-specific price index of commodity exports as the determinant of the fundamental real exchange rate value for the respective country.

The rest of the paper is organized as follows. Section 2 describes the theoretical derivation of the Phillips curve with the real exchange rate as the right-hand side variable. Then, in section 3, we estimate the equation derived from theory, and show that the theory is supported by data, although, as most of the literature does, we employ the accelerationist Phillips Curve specification, which could be rationalized by dominance of adaptive expectations in price-setting behavior. Finally, section 4 concludes.

2 The Model

The model presented here is highly stylized, which is done on purpose in order to derive an exact RER-inflation relationship. At the same time, the model tries to mimic a typical commodity exporting economy such as Australia or New Zealand, which will be used for the empirical exercise. These countries share a distinctive feature of being highly dependent on the exported commodities such as iron ore and coal in the case of Australia and lamb and milk products in the case of New Zealand. These commodities constitute a substantial part of all exports, while the contribution of the final goods produced within the country to its total exports is less important. This feature, as we shall see, will allow testing of the real exchange rate based Phillips curve.

The model suggests that the only good consumed in the economy is a composite of imperfectly substitutable nontradable goods, whose prices are sticky. These goods are produced using two inputs: labor and imported intermediate good. The economy also has a constant endowment of a natural resource, which is sold at a stochastic world price in the international market, in exchange for tradable intermediate goods.

Justification for having such a production function of the consumption good is that almost every good sold in an economy indeed has both domestic labor input and some sort of imported input. Even a perfectly internationally tradeable TV-set still has a big nontradable component, such as cost of domestic advertisement, transport and retail. Likewise, even an obvious non-tradable service, such as a hair cut, usually requires some sort of imported intermediate input, such as shampoo or styling gel. Therefore, it is reasonable to think of all final consumption goods as non-tradables produced using both imported inputs and domestic labor. The imported input, in turn, should not be thought as literary an input. Rather, it can be a final good, which requires additional work in order to be sold domestically. The real exchange rate is then the relative price of the domestic final good (the CPI) and the imported input. This line of reasoning is similar to that of Burtstein, Eichenbaum, and Rebelo (2005, 2006), who decompose the real exchange rate movements for a number of countries into these two components: changes in relative price of tradables versus changes in the sticky prices of nontradables, including the nontradable component of the seemingly tradable goods. They find, however, that these two effects are equally important in normal times; it is only at the time of large devaluations when the nontradable good prices dominate the movements in the RER.

When we assume that the exported good is a constant endowment of natural resource, we again are thinking of a typical primary commodity exporting economy, which we use below for empirical analysis. Since exports of such a country are mostly natural resources sold at world prices, export revenues are largely exogenous to internal economic conditions, and hence are best modeled as endowment. However, in principle, this assumption is not necessary: the Phillips curve should be possible to derive with a production export sector.

2.1 Setup

Within one period, consumers at time t solve the problem

$$\max_{C_t, L_t} \ln C_t - \frac{L_t^{1+\kappa}}{1+\kappa},$$

where C is the composite of the imperfectly substitutable final goods and L is the labor input. The intratemporal choice is needed only to derive the labor supply schedule.

Production of the domestic good is given by

$$C = Y_T^{\alpha} L^{1-\alpha}. \tag{1}$$

For expositional purposes, we will assume that the country exports oil. The amount of tradable inputs available for production purposes then depends on the degree of capital mobility. In the extreme case that such mobility is blocked completely, the imported input is simply equal to the endowment of exports in each period:

$$P_{oil,t} X = Y_{T,t}, \tag{2}$$

where P_{oil} is the world price of the natural resource (oil), and X is the constant endowment of oil.

In the case when capital is mobile, the households do not need to spend all of their export revenues on import; rather, they can accumulate international assets B_t, which yield a real rate of return r determined in the rest of the world:

$$B_{t+1} = (1+r)B_t + P_{oil,t}X - Y_{T,t}. \tag{3}$$

Note that the equation (3) is not a budget constraint facing households, but is rather a material balance condition for the whole economy.

2.2 Equilibrium real exchange rate

In this set-up the real exchange rate is best defined as the price of the domestic good (the CPI) over the price of the foreign good, that is $Q \equiv P/P_T$. Here, P is the CPI, defined as the minimal price of a consumption basket $C = 1$, and P_T is the domestic price of the foreign intermediate good. Assuming the law of one price, P_T is also the nominal exchange rate.

When prices are flexible, real exchange rate is fully determined by Y_T, which, in the case of no capital mobility and no reserve accumulation, is exogenously determined by the world price of the exported good. To see this, note that the first-order conditions of utility and profit maximization are, dropping time subscripts,

$$\frac{W}{P}\frac{1}{C} = L^{\kappa}, \tag{4}$$

$$(1-\alpha)\frac{C}{L} = \frac{W}{P}, \tag{5}$$

$$\alpha Q\frac{C}{Y_T} = 1, \tag{6}$$

where W is the nominal wage. These three equations, together with the production function (1) give the following relationship between Q and Y_T:

$$Q = Y_T^{(1-\alpha)}\frac{(1-\alpha)^{\frac{\alpha-1}{1+\kappa}}}{\alpha} \tag{7}$$

We see that an exogenous rise in the amount of imported good raises the equilibrium real exchange rate. The mechanism is simple: as economy receives a windfall gain and can afford more imports, the general wealth increases. This pushes up the price of domestic good and the wages in the economy. Hence, domestic price level rises relative to the world level.

The equation (7) is also important from a technical standpoint, in the sense that this equation allows log-linearization around a steady-state. In principle, variables Q and Y_T do not need to be stationary, and hence their direct linearization does not make sense. For example, if the oil prices follow a random walk and export volume is fixed, then imports will follow a random walk as well, and, according to (7), will be co-integrated with the real exchange rate, which by itself will also be non-stationary.

Even if they are stationary, the observed swings in these variables seem too large to be treated with a first-order approximation. Thus, in the empirical applications to Australia and Canada below, the real appreciation of the Australian dollar for the period 2000-2007, which is a part of our sample, has been in excess of 80%, while the real appreciation of the Canadian dollar for the same period was about 50%.

Hence, it may make sense to work with an imports-adjusted real exchange rate, that is,

$$\tilde{Q} \equiv \frac{Q}{Y_T^{1-\alpha}}. \tag{8}$$

This variable is a constant in the flexible price equilibrium independently of the stochastic properties of the oil price, imports, and the real exchange rate series. With sticky prices, this variable is no longer constant but is stationary, and its log-linearization around the steady state is fully warranted. In fact, we will see that it is precisely a version of this variable that will enter the Phillips curve formula.

The log-linearized version of (7) is remarkably simple:

$$q = (1-\alpha)y_T, \tag{9}$$

where small letters denote logarithmic deviations of the corresponding variables from the steady state. Note that we needed the labor market equilibrium to obtain this equation, but the Frisch elasticity of labor supply κ cancels out and does not appear in the expression. This is because the income and substitution effects exactly cancel each other out with this form of utility function, and changes in the world price of the exported good do not affect the labor supply, and only affect the real wage.

Note once again that even though q and y_T do not need to be stationary, the variable $\tilde{q} = q - (1-\alpha)y_T$ is stationary.

Alternatively, we can express the fundamental value of the real exchange rate in terms of the price of oil. Log-linearizing the balanced trade condition $Y_T = P_{oil}X$ and plugging it into (9) yields

$$q = (1-\alpha)(x + p_{oil}). \tag{10}$$

In the data, the supply of primary commodities with respect to price tends to be very inelastic, especially in the short run. This translates in their production volumes being much less volatile than their prices. Therefore, if one treats x roughly as a constant, then percentage deviation of the real exchange rate from its fundamental value is given, up to a constant, by $\tilde{q} = q - (1-\alpha)p_{oil}$.

2.3 The RER-based Phillips Curve

The intuition obtained above already suggests the nature for the RER-based Phillips curve. Suppose the terms of trade change, that is, world price of exported commodity increases. Then, in equilibrium, the real exchange rate must appreciate, normally via a nominal appreciation. However, the central bank can intervene and hold the nominal exchange rate constant, thus preventing the immediate real appreciation. In turn, however, the now wealthier consumers will want to exchange the extra foreign currency for the domestic currency, to purchase the final good. This means that the central bank will need to issue extra domestic currency to satisfy such desires, thus stimulating inflation. The real appreciation will thus occur later, via growth of domestic prices, instead of immediately through nominal rate adjustment. During the time of price adjustment, the central bank achieves below-equilibrium exchange rate at the cost of positive inflation.

In order to derive this Phillips Curve relationship formally, we need to introduce the behavior of sticky prices of the final goods as in Calvo (1983), or using modification of the model with adaptive expectations. Thus, we now model the final good C as a composite of a continuum of goods, and assume that each producer adjusts his price at a certain stochastic rate. We need to express the instantaneously desired price of the ith producer $p(i)^{\#}$ or simply $p^{\#}$ through the real exchange rate.

For that, consider the problem of the ith producer given that the nontradable composite is CES (the exact form of the composite is actually not necessary, see Kimball (1995) for the general form, which can be useful to increase the degree of real rigidity):

$$\max_{P(i)} \frac{P(i)}{P}\left(\frac{P(i)}{P}\right)^{-\epsilon} C - \frac{W}{P}L(i) - \frac{P_T}{P}Y_T(i), \tag{11}$$

where the first element is the relative price of the ith good times the demand for it, which depends on the relative price with the elasticity ϵ and the whole consumption aggregate. The second and the third elements are the cost.

The solution to this problem is standard, and the optimal price is simply a constant mark-up over marginal cost:

$$\frac{P(i)^{\#}}{P} = \frac{\epsilon}{\epsilon-1}\frac{{P_T}^{\alpha}W^{1-\alpha}}{P} = \frac{\epsilon}{\epsilon-1}\left(\frac{1}{Q}\right)^{\alpha}\left(\frac{W}{P}\right)^{(1-\alpha)}, \tag{12}$$

where the first fraction is the mark-up followed by the marginal cost. Thus, it appears that the desired price depends on the real exchange rate $Q = P/P_T$ and the real wage rate through obvious channels: these values are the real costs of the two inputs. Now we need to express the wage rate through the real exchange rate.

For that, we first note that there is no profit maximization in the case of sticky prices; however, firms can still minimize costs and select optimal expenditure shares for the two inputs. Cost minimization dictates

$$Q\frac{W}{P}\frac{L}{Y_T} = \frac{1-\alpha}{\alpha}. \tag{13}$$

combining this expression with the equations (1) and (4), we derive the expression for the real wage:

$$\frac{W}{P} = \left(\frac{1-\alpha}{\alpha}\right)^{\frac{1-\alpha+\kappa}{(1-\alpha)+(1+\kappa)}} Y_T^{\frac{1+\kappa}{(1-\alpha)+(1+\kappa)}} Q^{\frac{\alpha-1-\kappa}{(1-\alpha)+(1+\kappa)}}. \tag{14}$$

Plugging this equation into the formula for the desired price (12) and linearizing, we get

$$p^{\#} - p = -\frac{(1+\kappa)}{(1-\alpha)+(1+\kappa)}\tilde{q}, \tag{15}$$

where, once again, we use the variable $\tilde{q} = q - (1-\alpha)y_T$, since q and y_T are potentially non-stationary but co-integrated variables.

Then, the derivation of the rational expectations Phillips Curve is standard and follows, for example, Roberts (1995). The expression for this curve with time subscripts is:

$$\pi_t = E_t \pi_{t+1} - \lambda \tilde{q}_t, \tag{16}$$

where $\lambda = \frac{(1-\theta)^2}{\theta}\frac{(1+\kappa)}{(1-\alpha)+(1+\kappa)}$ and inflation is defined as $\pi_t \equiv p_t - p_{t-1}$. This expression will be referred to as the "RER-based Phillips curve." Once again, given the nature of the variable $\tilde{q}$, the expression involves not only the real exchange rate, but also the amount of imports, which in itself is determined by the amount of exports the country sells to the rest of the world, or, alternatively, the international price of exported oil. Hence, variable y_T or, respectively, p_{oil} is the shifter of the curve. Thus, if oil prices increase, then consumption of imports increases, and the trade-off between inflation and the RER worsens: greater inflation will be needed to support the same RER. Ultimately, if the increase in exported commodity prices is permanent, a corresponding permanent increase in the real rate is inevitable as in (9) or (10).

The variable $\tilde{q}$ is thus a measure of the deviation of the real exchange rate from its equilibrium level, much as in the standard Phillips curve, the right-hand side variable is deviation of GDP from flexible-price equilibrium. Hence, inflation is determined by the deviation of the real exchange rate from the equilibrium value. This equilibrium value is then determined by the terms of trade, so that such a Phillips curve is best suited for a commodity-exporting country, for which the terms of trade are largely exogenous. If the real exchange rate is too low in comparison to the price of exports, this means that the economy is strained - high demand due to large amount of export revenues contradicts low domestic prices (perhaps caused by central bank interventions). We thus should be expecting domestic prices to increase to bring the real exchange rate in line with the terms of trade. Hence, we are expecting inflation.

2.4 Adaptive expectations

So far, we derived a Phillips curve with forward-looking agents rational expectations. However, it is frequently noted that expectations may be backward looking, so that producers index their prices using observations of past inflation. In this case, the Phillips curve is

$$\pi_t = \psi \pi_{t-1} - \lambda \tilde{q}_t. \tag{17}$$

Basically, in this specification, current inflation is driven by a combination of the inflation observed previously and the current real exchange rate undervaluation.

Similar equations with a standard right-hand side variables were estimated, for example, by Rudebusch and Svensson (1999), and are sometimes referred to as "traditional Phillips curves" or "accelerationist Phillips curves." Sometimes the coefficients in front of lagged terms are restricted to sum to unity, as to produce a vertical long-run curve, but we do not make such a restriction in our estimation and use only one lag (as discussed below, further lags do not turn out to be statistically significant).

3 Empirical estimations

The theoretical model developed in Section 2 yields a dynamic relationship (16) between inflation and the real exchange deviation from its long-run equilibrium level. We refer to the deviation as the real exchange rate (RER) gap. This relationship looks similar to the New Keynesian Phillips Curve with the output gap replaced by the RER gap. In a sense, RER gap serves as an alternative proxy of economic activity. More broadly, our theoretical model implies the existence of a short-term tradeoff between inflation and real exchange rate.

To test implications of the theoretical model, we proceed in two steps. First, we estimate the RER gap. Second, we estimate an empirical equivalent of the dynamic relationship (16) or its backward looking equivalent (17), between the RER gap and inflation. We take a standard Phillips curve specification from the literature and substitute the real exchange rate gap for the activity variable. We deliberately employ a reduced-form accelerationist specification of the Phillips curve rather than the structural New Keynesian Phillips curve (NKPC), given that the former is more appealing empirically than the latter. Indeed, despite early successful attempts to estimate the forward-looking NKPC in Galì and Gertler (1999) and others, later research uncovered important flaws of their GMM estimation procedure caused by weak instruments (e.g., Mavroeidis, 2005; Dufour, Khalaf, and Kichian, 2006; Nason and Smith, 2008).

The fact that it is very difficult to find strong instruments for inflation implies that a standard GMM method cannot be applied. The estimation needs to be done in a different and more careful way (Kleibergen and Mavroedis, 2009). Once the parameters of the NKPC are estimated using appropriate methods, the coefficient on the output gap (proxied by the labor share in GDP) turns out to be significant only for the US but insignificant for other countries such as Canada (Dufour, Khalaf, and Kichian, 2006). Our reading of this literature is such that it seems premature to claim that good reliable instrumental variable estimates of NKPC are available. That is why it makes sense to play with old-fashioned accelerationist Phillips curve to test the theory, which suggests the existence of a short-run tradeoff between inflation and the real exchange rate.

Real exchange rates are notoriously known for the lack of a stable link with other macroeconomic variables that are considered, in theory, as their fundamentals, especially, in the short to medium term. Examples of such candidate fundamental variables include Home/Foreign productivity differential, interest rate differential, etc. This implies that, from the empirical perspective, it is not straightforward to build and estimate a reliable model of exchange rate for the long to medium term. At the same time, such a model is an essential building block of our empirical test. Indeed, its purpose is to determine/estimate the equilibrium level of the real exchange rate, which is unobserved directly. Estimates of the output gap, which is understood as output deviation from the unobserved potential, encounter exactly the same difficulty.

Luckily enough, there is a special class of currencies that show a relatively more tight relationship with their fundamentals compared with the rest of currencies. These are so-called *commodity currencies*, or currencies of those countries, for which primary commodities constitute a significant fraction of their exports (Chen and Rogoff, 2003). We have six major commodity exporters in our sample: Australia, Canada, New Zealand, Norway, Russia, and South Africa. The price of commodity exports of those countries is an important fundamental for their currencies. Unlike bilateral productivity differentials, for example, this fundamental is directly observed. When the price of crude oil, which Norway exports, rises on the international market, an increased supply of US dollars or euros on the FX market creates an upward pressure on the Norwegian exchange rate. As a result, the Norwegian kronor appreciates.

The above reasoning suggests that the international price of crude oil and the rate of Norwegian kronor should co-move in the medium to the long term. Even if the nominal rate of the kronor is not entirely flexible in the short term, the co-movement will be achieved in the longer term via nominal price adjustment. For example, following an increase in the price of crude oil, domestic price level in Norway will have a tendency to grow if the nominal rate of the kronor is kept fixed. As a result, the kronor will appreciate in real terms.

Our model spelled out above demonstrates exactly this logic. The real exchange rate in the long run should be linked to the volume of imports, which, in turn, is linked to the terms of trade. For commodity-exporting countries, the terms of trade are dictated by the price of the exported commodity. Even though the proper fundamental for the RER in the model seems to be the volume of imports, we nevertheless follow the literature and use the exported commodity price as the fundamental. If trade is balanced, as in equation (2), then the two measures should be the same. If the trade is not balanced, as in (3), the two measures should be the same if the commodity price is non-stationary. Finally, the volume of imports may simply be contaminated by too many endogenous fluctuations not captured in our stylized model.

Furthermore, our model suggests that a linear combination of the RER and the fundamental should be stationary, so that these two variables are either both stationary or are cointegrated. From the theoretical perspective, the real prices of commodities are more likely to be stationary. Indeed, a permanent upward shift in the demand for crude oil will drive up its price to the extent the short-run supply of oil is inelastic. The higher price of oil will stimulate search for and exploration of new oil fields and investments into drilling and extraction technology. The resulting long-term response of oil supply will produce a mean-reverting effect on the real price of oil. Two subsequent oil price increases in the 1970s induced a substantial amount of investments into oil exploration and production outside OPEC. The consequence was a remarkable increase in the non-OPEC supply of petroleum by the mid-1980 with the market share of OPEC eroding from above one half in the 1970s to roughly one a decade later.

Empirically, however, real prices of many commodities behave more like non-stationary time series. From practical perspective, given the final lengths of real-life data samples, it is often more appealing to assume that the data generating process for a real commodity price is better approximated by a non-stationary stochastic process. If so, it makes sense to model the long-run relationship between the real exchange rate and the respective commodity price index as a cointegration between the two series. Such an approach was undertaken, along with other alternatives, in Chen and Rogoff (2003). This is the strategy that we employ in our empirical exercise.

Table 1 describes data that we use in our analysis. We follow the empirical Phillips curve literature and use two proxies for the price level to compute the rate of inflation. These are GDP deflator and the consumer price index. We use two indicators for the real exchange rate. One is the bilateral real exchange rate against the US dollar, the other real effective exchange rate, both CPI-based. We employ two price indices for commodity price exports, one reported as such in the OECD Economic Outlook, and the other constructed by Chen, Rogoff, and Rossi (2010), or CRR hereafter, from individual prices of commodities with country-specific weights proportional to the composition of exports basket of a given country. For Russia and Norway, we roughly approximate the prices of their commodity exports by the average (over three brands, WTI, Dubai, and Brent) price of crude oil, since oil is the dominating exported commodity in these countries. The nominal price indices for commodity exports are deflated by the US CPI or the country-specific price indices for imports of goods and services as reported in the OECD Economic Outlook. All data are at quarterly frequencies.

Although we assume cointegration between the the RER and the fundamental on theoretical grounds, we still report the results of formal tests for cointegration. Tables 2, 10, 18, 26, 34, and 39 show the results of the Engle-Granger Augmented Dickey-Fuller (EG-ADF) test for cointegration between real exchange rate and real commodity price index. The test is run as follows (e.g., Hayashi, 2000, pp. 644-648). First, an OLS regression of the real exchange rate on the real commodity price index and time trend is estimated. The time trend is included to take into account such long-run effects as growth in the productivity differential between the country of interest and the rest of the world. Second, the OLS residuals obtained on the first stage are tested for unit roots by the Augmented Dickey-Fuller (ADF) test. It is the second-stage ADF regressions that are shown in the above-mentioned tables. The relevant critical values for the ADF t-statistics are -3.80 for 5% significance level and -3.52 for 10% (e.g., the second line of Table 10.1b in Hayashi, 2000, p. 646, which reproduces Table IIc in Phillips and Ouliaris, 1990).

Unfortunately, there are only two instances where the cointegration between the real exchange rate and real commodity prices is not rejected by the data at 10% level of significance. The first one is specification (6) in Table 1 for Australia that involves the real effective exchange rate and the CRR index deflated by the US CPI. The second one is specification (3) in Table 9 for New Zealand that involves the real effective exchange rate and the OECD proxy for the price of commodity exports deflated by the US CPI. The failure of the EG-ADF test for cointegration comes from the failure to reject the unit root in the OLS residuals at the second stage, and is likely to be a consequence of a notoriously low power of unit root tests in the final samples.

Another important consideration specific for real exchange rates is their well known property to demonstrate a remarkable slow rate of mean-reversion, the finding known as the Purchasing Power Parity puzzle (Rogoff, 1996). If the country-specific commodity price index and linear time trend capture the long-run influence of fundamental factors so that the cointegrating equation approximates the time-varying equilibrium real exchange rate, then the slow mean-reversion is equivalent to the residuals being near-unit root process.

Being aware of limited power of conventional cointegration tests and the presence of still unresolved PPP puzzle, we follow the literature (e.g., Chen and Rogoff, 2003) by *assuming* cointegration between the real exchnage rate and the real commodity price index. Our justification is that such an assumption cannot be excluded on the theoretical grounds.

Tables 3, 11, 19, 27, 35, and 40 report estimated cointegrating equations for real exchange rates and respective real commodity price indices. As for the previous set of results, each column in a table corresponds to a particular choice of proxies for real exchange rate, commodity price index, and deflator for the consumer price index. For example, specification (6) in Table 3 for Australia involves real effective exchange rate against and the CRR index deflated by the US CPI. Cointegrating equations are estimated by the method of Dynamic OLS (DOLS; Stock and Watson, 1993). This method prescribes that lags and leads of the first-differenced real commodity price index are added to the right-hand side of an OLS regression of the real exchange rate on the real commodity price index. We also include the linear time trend as a regressor to take into account such long-term effects as growth in the productivity differential between the country of interest and the rate of the world.

Overall, our estimates of the long-run elasticity of the real exchange rate with respect to the real price of commodity exports lie in the interval between 0.1 and 0.9, depending on what proxies are used for the price level, real exchange rate, the price index for commodity exports and its deflator. This interval covers cointegration-based estimates of the elasticity reported in Chen and Rogoff (2003; the second to the last column of Table 1 in their paper). Section 5 of that paper offers a structural interpretation of the parameters of the cointegrating equation, and so does our own model, see equation (9). This is not, however, a primary focus of our paper. One likely reason why the elasticity for Canada tends to be smaller than for New Zealand is lower share of primary commodities in the basket of Canada's exports compared with New Zealand's. Estimated elasticities make sense quantitatively.

Once the long-run level of the real exchange rate is estimated as predicted by the respective cointegrating equation, the real exchange rate gap is computed as the difference between the actual real exchange rate and its long-run equilibrium level. The next step is to test the presence of the short-term tradeoff between real exchange rate and inflation.

The empirical specification of the Phillips curve that we employ is a rather standard accelerationist functional form. Roberts (2006) postulates that the year-on-year growth in the 4-quarter rate of inflation is positively related to the average rate of unemployment for the last four quarters, including the contemporaneous one (see formula (1) in the cited paper):

$$(p_t - p_{t-4}) - (p_{t-4} - p_{t-8}) = \gamma_0 + \gamma_1 \left(\sum_{i=0}^{3} UR_{t-i} \right) /4, \tag{18}$$

where p_t is the log of the price level and UR_t is the rate of unemployment. As our baseline Phillips curve specification, we use equation (18) with UR replaced by a proxy of the real exchange rate gap:

$$\pi_t^4 - \pi_{t-4}^4 = \gamma_0 + \gamma_1 \left(\sum_{i=0}^{3} \text{RER gap}_{t-i} \right) /4, \tag{19}$$

where $\pi_t^4 \equiv p_t - p_{t-4}$ is the four-quarter rate of inflation.

The real exchange rate is defined so that greater values signal real appreciation of the currencies. The theoretical model laid out above implies that the sign of the relationship between the real exchange rate gap and the growth in the rate of inflation is negative. A positive value of the gap indicates that the currency is too strong (overvalued). This implies that in the longer term, goods prices should decline or rise with a slower rate and/or the nominal exchange rate will depreciate. It follows that the sign of γ_1 in (19) is negative.

Tables 4, 7, 12, 15, 20, 23, 28, 31, 36, and 41 show estimates of γ_1 for Phillips curve specification (19) and alternative proxies of the price level (GDP deflator or CPI), real exchange rate (bilateral real exchange rate with the US or real effective exchange rate), price index for commodity exports (OECD or Chen – Rogoff – Rossi), and deflator for commodity price index (US CPI or OECD country-specific price index for imports). For example, in Table 4 for Australia, model (1) uses GDP deflator (PGDP), real effective exchange rate (REER), OECD price index of commodity exports (PXNW), and US CPI (PCPUS). A detailed description of all variables and their mnemonics can be found in Table 1.

An inspection of Tables 4, 7, 12, 15, 20, 23, 28, 31, 36, and 41 suggests that the negative association between inflation and real exchange rate is present in a majority of specification, especially, for three industrialized countries in our sample, Australia, Canada, and New Zealand. For those three countries, the estimated coefficient is around 0.05-0.15. This suggests that a 10% deviation of the real exchange rate from its equilibrium value is associated with a decrease in the rate of inflation by 0.5-1.5%. The estimated effect is economically significant. Its absolute value is lower for Canada and higher for New Zealand, which is consistent with the notion that Canada has a more diversified economy, and hence its exports basket, than New Zealand.

For Norway (Tables 28 and 31) and Russia (Table 36) the effect is not statistically significant, and sometimes the estimated coefficient has a wrong (positive) sign. Remarkably, the effect is statistically and economically significant for South Africa (Table 41) despite a rather short time span of data.

We do two robustness checks. In both cases we move from four-quarter inflation rate π_t^4 defined above to more standard one-quarter rates $\pi_t \equiv 4(p_t - p_{t-1})$. Our first alternative specification is similar to equation (2) in Roberts (2006):

$$\Delta p_t = \gamma_0 + \gamma_1 UR_t + \gamma_2 \Delta p_{t-1} + \gamma_3 \Delta p_{t-2} + \gamma_4 \Delta p_{t-3} + (1 - \gamma_2 - \gamma_3 - \gamma_4)\Delta p_{t-4}. \qquad (20)$$

This equivalent to a regression of the rate of change in inflation $\Delta\pi_t$ on the rate of unemployment UR_t and three own lags.

$$\Delta\pi_t = \gamma_0 + \gamma_1 \text{RER gap}_t + \phi_1 \Delta\pi_{t-1} + \phi_2 \Delta\pi_{t-2} + \phi_3 \Delta\pi_{t-3}. \qquad (21)$$

Our second alternative is similar to (21) but contains lags of ΔRER gap as regressors. This is a common practice in forecasting models based on the Phillips curve (e.g., Stock and Watson, 2007).

The results of the two robustness checks are shown in Tables 5-6, 8-9, 13-14, 16-17, 21-23, 24-25, 29-30, 32-33, 37-38, and 42-43. It would be fair to claim that the pattern observed for baseline specification mostly survives. In general, the statistical association between real exchange rate and inflation remains quite stark for Australia, Canada, New Zealand, and South Africa. It is often insignificant for Norway and Russia, sometimes, with a wrong sign.

Our overall reading of empirical findings is strongly positive: the theory receives rather remarkable empirical support. As we already mentioned above, the task of establishing a short-term empirical link between the exchange rate and another variable is very challenging: exchange rates have been notorious for their short-term dynamics being disconnected from the behavior of other macro variables. Nevertheless, here we document a substantial degree of co-movement between estimated RER gap and inflation, which is significant both in statistical and economic sense.

4 Conclusions

We demonstrated that the standard New Keynesian Phillips curve can be represented as a trade-off between inflation and the real exchange rate. The intuition of such a trade-off is simple and not new: a central bank can achieve a temporary undervaluation of the domestic currency at the cost of spurring extra inflation.

In this paper, we modeled this trade-off and found empirical support for its existence using data for a number of primary commodity exporting economies such as Australia, Canada, New Zealand and others. The main trick in such estimation is to identify a good measure of the fundamental value of the real exchange rate, the value that would prevail under flexible prices. The dependency of the economies from our sample (and their real exchange rates) on exports of natural resources makes the international price of these resources a very good measure of this fundamental value. Deviation of the real exchange rate from this value is found to be a good predictor of inflation.

As in many previous studies, the data give support to the accelerationist Phillips curve in our empirical exercise. This specification could be rationalized by dominance of adaptive expectations in price-setting behavior.

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Table 1: Description of variables

Notation	Description	Source
Real exchange rate		
RER	CPI-based real exchange rate against USD	OECD Economic Outlook
REER	CPI-based real effective exchange rate	IMF International Financial Statistics
Commodity price index		
PXNW	Domestic currency price of commodity exports	OECD Economic Outlook
CRR	USD price of commodity exports	Chen, Rogoff, and Rossi (2010)
IMF	Average crude oil price	IMF International Financial Statistics
Deflator for commodity price index		
PMGS	Domestic currency price index for imports of goods and services	OECD Economic Outlook
PCPUS	US consumer price index	OECD Economic Outlook
Price level		
PGDP	GDP deflator	OECD Economic Outlook
PCP	Consumer price index	OECD Economic Outlook

Table 2: EG-ADF test for cointegration: Australia

	(1)	(2)	(3)	(4)	(5)	(6)
Real exchange rate	RER	RER	REER	REER	RER	REER
Commodity price index	PXNW	PXNW	PXNW	PXNW	CRR	CRR
Deflator for CP index	PCPUS	PMGS	PCPUS	PMGS	PCPUS	PCPUS
e(-1)	-0.0868	-0.0765	-0.241	-0.230	-0.135	-0.237
	(-2.389)	(-2.273)	(-3.457)	(-3.299)	(-2.609)	(-3.630)
Observations	130	130	130	130	93	93
R-squared	0.133	0.131	0.129	0.130	0.078	0.158

t-statistics in parentheses
Dependent variable: Δe where *e* is residual from OLS regression of log RER/REER on log real CP index and linear trend
4 lags of Δe added as regressors

Table 3: Cointegrating equation: Australia

	(1)	(2)	(3)	(4)	(5)	(6)
Real exchange rate	RER	RER	REER	REER	RER	REER
Commodity price index	PXNW	PXNW	PXNW	PXNW	CRR	CRR
Deflator for CP index	PCPUS	PMGS	PCPUS	PMGS	PCPUS	PCPUS
Log real commodity price index	0.277***	0.114*	0.494***	0.455***	0.517***	0.474***
	(0.0524)	(0.0591)	(0.0344)	(0.0387)	(0.0684)	(0.0447)
Observations	126	126	126	126	91	91
R-squared	0.471	0.351	0.818	0.778	0.467	0.600

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: log RER/REER
Linear trend and 4 lags/leads of $\Delta \log$ real CP index added as regressors

Table 4: RER-based Phillips curve: Australia, 1974Q2-2007Q4

VARIABLES	(1) PGDP REER PXNW PCPUS	(2) PCP REER PXNW PCPUS	(3) PGDP REER PXNW PMGS	(4) PCP REER PXNW PMGS	(5) PGDP RER PXNW PCPUS	(6) PCP RER PXNW PCPUS	(7) PGDP RER PXNW PMGS	(8) PCP RER PXNW PMGS
RER gap	-0.117***	-0.120***	-0.0832**	-0.100***	-0.0224	-0.0440*	-0.00818	-0.0195
	(0.0350)	(0.0324)	(0.0420)	(0.0372)	(0.0267)	(0.0246)	(0.0224)	(0.0199)
Observations	132	132	132	132	132	132	132	132

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\pi_t^4 - \pi_{t-4}^4$ where $\pi_t^4 = \log P_t - \log P_{t-4}$
4 lags/leads in Newey-West formula for standard errors

Table 5: RER-based Phillips curve: Australia, 1974Q2-2007Q4

VARIABLES	(1) PGDP REER PXNW PCPUS	(2) PCP REER PXNW PCPUS	(3) PGDP REER PXNW PMGS	(4) PCP REER PXNW PMGS	(5) PGDP RER PXNW PCPUS	(6) PCP RER PXNW PCPUS	(7) PGDP RER PXNW PMGS	(8) PCP RER PXNW PMGS
RER gap	-0.0550*	-0.0624**	-0.0514	-0.0618**	-0.0177	-0.0279	-0.00974	-0.0115
	(0.0325)	(0.0242)	(0.0362)	(0.0277)	(0.0208)	(0.0196)	(0.0166)	(0.0143)
Observations	135	135	135	135	135	135	135	135

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\Delta\pi_t$ where $\pi_t = 4\Delta \log P_t$
3 lags of $\Delta\pi$ added as regressors
4 lags/leads in Newey-West formula for standard errors

Table 6: RER-based Phillips curve: Australia, 1974Q2-2007Q4

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Price level	PGDP	PCP	PGDP	PCP	PGDP	PCP	PGDP	PCP
Real exchange rate	REER	REER	REER	REER	RER	RER	RER	RER
Commodity price index	PXNW	PXNW	PXNW	PXNW	PXNW	PXNW	PXNW	PXNW
Deflator for CP index	PCPUS	PCPUS	PMGS	PMGS	PCPUS	PCPUS	PMGS	PMGS
RER gap	-0.0870**	-0.0591**	-0.109**	-0.0627*	-0.0339	-0.0350*	-0.0214	-0.0151
	(0.0417)	(0.0276)	(0.0531)	(0.0325)	(0.0261)	(0.0199)	(0.0210)	(0.0163)
Observations	135	135	135	135	135	135	135	135

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\Delta\pi_t$ where $\pi_t = 4\Delta \log P_t$
4 lags of $\Delta\pi$ and $\Delta \log$ RER added as regressors
4 lags/leads in Newey-West formula for standard errors

Table 7: RER-based Phillips curve: Australia, 1984Q1-2007Q4

	(1)	(2)	(3)	(4)
	PGDP	PCP	PGDP	PCP
	REER	REER	RER	RER
	CRR	CRR	CRR	CRR
VARIABLES	PCPUS	PCPUS	PCPUS	PCPUS
RER gap	-0.0595*	-0.0503*	-0.00790	-0.0398**
	(0.0335)	(0.0293)	(0.0257)	(0.0192)
Observations	93	93	93	93

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\pi_t^4 - \pi_{t-1}^4$ where $\pi_t^4 = \log P_t - \log P_{t-4}$
3 lags/leads in Newey-West formula for standard errors

Table 8: RER-based Phillips curve: Australia, 1984Q1-2007Q4

VARIABLES	(1) PGDP REER CRR PCPUS	(2) PCP REER CRR PCPUS	(3) PGDP RER CRR PCPUS	(4) PCP RER CRR PCPUS
RER gap	-0.0142	-0.0270	-0.00878	-0.0187
	(0.0377)	(0.0240)	(0.0207)	(0.0174)
Observations	96	96	96	96

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\Delta\pi_t$ where $\pi_t = 4\log P_t$
3 lags of $\Delta\pi$ added as regressors
3 lags/leads in Newey-West formula for standard errors

Table 9: RER-based Phillips curve: Australia, 1984Q1-2007Q4

	(1)	(2)	(3)	(4)
Price level	PGDP	PCP	PGDP	PCP
Real exchange rate	REER	REER	RER	RER
Commodity price index	CRR	CRR	CRR	CRR
Deflator for CP index	PCPUS	PCPUS	PCPUS	PCPUS
RER gap	-0.0112	-0.0201	-0.0105	-0.00744
	(0.0384)	(0.0202)	(0.0200)	(0.0157)
Observations	96	96	96	96

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\Delta\pi_t$ where $\pi_t = 4\Delta\log P_t$
2 lags of $\Delta\pi$ and $\Delta\log$ RER added as regressors
3 lags/leads in Newey-West formula for standard errors

Table 10: EG-ADF test for cointegration: Canada

	(1)	(2)	(3)	(4)	(5)	(6)
Real exchange rate	RER	RER	REER	REER	RER	REER
Commodity price index	PXNW	PXNW	PXNW	PXNW	CRR	CRR
Deflator for CP index	PCPUS	PMGS	PCPUS	PMGS	PCPUS	PCPUS
e(-1)	-0.0368	-0.0340	-0.0575	-0.0537	-0.0416	-0.0436
	(-1.467)	(-1.334)	(-1.899)	(-1.768)	(-1.410)	(-1.461)
Observations	130	130	130	130	137	137
R-squared	0.092	0.083	0.064	0.059	0.032	0.023

t-statistics in parentheses

Dependent variable: Δe where e is residual from OLS regression of log RER/REER on log real CP index and linear trend

4 lags of Δe added as regressors

Table 11: Cointegrating equation: Canada

	(1)	(2)	(3)	(4)	(5)	(6)
Real exchange rate	RER	RER	REER	REER	RER	REER
Commodity price index	PXNW	PXNW	PXNW	PXNW	CRR	CRR
Deflator for CP index	PCPUS	PMGS	PCPUS	PMGS	PCPUS	PCPUS
Log real commodity price index	0.138***	0.122**	0.196***	0.189***	0.189***	0.240***
	(0.0443)	(0.0510)	(0.0458)	(0.0529)	(0.0413)	(0.0409)
Observations	126	126	126	126	135	135
R-squared	0.306	0.276	0.565	0.543	0.289	0.618

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Dependent variable: log RER/REER

Linear trend and 4 lags/leads of $\Delta \log$ real CP index added as regressors

Table 12: RER-based Phillips curve: Canada, 1974Q2-2007Q4

VARIABLES	(1) PGDP REER PXNW PCPUS	(2) PCP REER PXNW PCPUS	(3) PGDP REER PXNW PMGS	(4) PCP REER PXNW PMGS	(5) PGDP RER PXNW PCPUS	(6) PCP RER PXNW PCPUS	(7) PGDP RER PXNW PMGS	(8) PCP RER PXNW PMGS
RER gap	-0.0625*	-0.0533**	-0.0576*	-0.0490**	-0.0435	-0.0334	-0.0392	-0.0295
	(0.0323)	(0.0244)	(0.0332)	(0.0235)	(0.0378)	(0.0258)	(0.0377)	(0.0239)
Observations	132	132	132	132	132	132	132	132

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Dependent variable: $\pi_t^4 - \pi_{t-4}^4$ where $\pi_t^4 = \log P_t - \log P_{t-4}$

4 lags/leads in Newey-West formula for standard errors

Table 13: RER-based Phillips curve: Canada, 1974Q2-2007Q4

VARIABLES	(1) PGDP REER PXNW PCPUS	(2) PCP REER PXNW PCPUS	(3) PGDP REER PXNW PMGS	(4) PCP REER PXNW PMGS	(5) PGDP RER PXNW PCPUS	(6) PCP RER PXNW PCPUS	(7) PGDP RER PXNW PMGS	(8) PCP RER PXNW PMGS
RER gap	-0.0337	-0.0369**	-0.0326	-0.0347**	-0.0293	-0.0252	-0.0277	-0.0226
	(0.0224)	(0.0172)	(0.0226)	(0.0165)	(0.0253)	(0.0186)	(0.0248)	(0.0173)
Observations	135	135	135	135	135	135	135	135

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Dependent variable: $\Delta\pi_t$ where $\pi_t = 4\Delta \log P_t$

3 lags of $\Delta\pi$ added as regressors

4 lags/leads in Newey-West formula for standard errors

Table 14: RER-based Phillips curve: Canada, 1974Q2-2007Q4

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Price level	PGDP	PCP	PGDP	PCP	PGDP	PCP	PGDP	PCP
Real exchange rate	REER	REER	REER	REER	RER	RER	RER	RER
Commodity price index	PXNW	PXNW	PXNW	PXNW	PXNW	PXNW	PXNW	PXNW
Deflator for CP index	PCPUS	PCPUS	PMGS	PMGS	PCPUS	PCPUS	PMGS	PMGS
RER gap	-0.0327	-0.0324*	-0.0316	-0.0299	-0.0255	-0.0233	-0.0234	-0.0206
	(0.0238)	(0.0190)	(0.0249)	(0.0187)	(0.0268)	(0.0215)	(0.0269)	(0.0208)
Observations	135	135	135	135	135	135	135	135

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\Delta\pi_t$ where $\pi_t = 4\Delta \log P_t$
4 lags of $\Delta\pi$ and $\Delta \log$ RER added as regressors
4 lags/leads in Newey-West formula for standard errors

Table 15: RER-based Phillips curve: Canada, 1973Q1-2007Q4

VARIABLES	(1) PGDP REER CRR PCPUS	(2) PCP REER CRR PCPUS	(3) PGDP RER CRR PCPUS	(4) PCP RER CRR PCPUS
RER gap	-0.0527	-0.0402	-0.0370	-0.0261
	(0.0343)	(0.0264)	(0.0408)	(0.0265)
Observations	136	136	136	136

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\pi_t^4 - \pi_{t-1}^4$ where $\pi_t^4 = \log P_t - \log P_{t-4}$
3 lags/leads in Newey-West formula for standard errors

Table 16: RER-based Phillips curve: Canada, 1973Q1-2007Q4

VARIABLES	(1) PGDP REER CRR PCPUS	(2) PCP REER CRR PCPUS	(3) PGDP RER CRR PCPUS	(4) PCP RER CRR PCPUS
RER gap	-0.0267	-0.0228	-0.0235	-0.0184
	(0.0237)	(0.0209)	(0.0266)	(0.0205)
Observations	139	139	139	139

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\Delta\pi_t$ where $\pi_t = 4\Delta \log P_t$
3 lags of $\Delta\pi$ added as regressors
3 lags/leads in Newey-West formula for standard errors

Table 17: RER-based Phillips curve: Canada, 1973Q1-2007Q4

	(1)	(2)	(3)	(4)
Price level	PGDP	PCP	PGDP	PCP
Real exchange rate	REER	REER	RER	RER
Commodity price level	CRR	CRR	CRR	CRR
Deflator for CP index	PCPUS	PCPUS	PCPUS	PCPUS
RER gap	-0.0129	-0.0111	-0.0182	-0.00677
	(0.0243)	(0.0208)	(0.0284)	(0.0216)
Observations	140	140	140	140

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\Delta\pi_t$ where $\pi_t = 4\Delta \log P_t$
2 lags of $\Delta\pi$ and $\Delta \log \text{RER}$ added as regressors
3 lags/leads in Newey-West formula for standard errors

Table 18: EG-ADF test for cointegration: New Zealand

	(1)	(2)	(3)	(4)	(5)	(6)
Real exchange rate	RER	RER	REER	REER	RER	REER
Commodity price index	PXNW	PXNW	PXNW	PXNW	CRR	CRR
Deflator for CP index	PCPUS	PMGS	PCPUS	PMGS	PCPUS	PCPUS
e(-1)	-0.0869	-0.0843	-0.216	-0.147	-0.146	-0.139
	(-2.782)	(-2.874)	(-3.588)	(-2.907)	(-2.645)	(-2.355)
Observations	130	130	130	130	81	81
R-squared	0.171	0.165	0.169	0.162	0.103	0.082

t-statistics in parentheses
Dependent variable: Δe where e is residual from OLS regression of log RER/REER on log real CP index and linear trend
4 lags of Δe added as regressors

Table 19: Cointegrating equations: New Zealand

	(1)	(2)	(3)	(4)	(5)	(6)
Real exchange rate	RER	RER	REER	REER	RER	REER
Commodity price index	PXNW	PXNW	PXNW	PXNW	CRR	CRR
Deflator for CP index	PCPUS	PMGS	PCPUS	PMGS	PCPUS	PCPUS
Log real commodity price index	0.524***	-0.0257	0.470***	0.231**	0.947***	0.708***
	(0.110)	(0.165)	(0.0587)	(0.0964)	(0.106)	(0.0701)
Observations	126	126	126	126	79	79
R-squared	0.279	0.093	0.405	0.113	0.556	0.603

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$
Dependent variable: log RER/REER
Linear trend and 4 lags/leads of $\Delta \log$ real CP index added as regressors

Table 20: RER-based Phillips curve: New Zealand, 1974Q2-2007Q4

VARIABLES	(1) PGDP REER PXNW PCPUS	(2) PCP REER PXNW PCPUS	(3) PGDP REER PXNW PMGS	(4) PCP REER PXNW PMGS	(5) PGDP RER PXNW PCPUS	(6) PCP RER PXNW PCPUS	(7) PGDP RER PXNW PMGS	(8) PCP RER PXNW PMGS
RER gap	-0.150**	-0.158**	-0.106	-0.0949	-0.0964**	-0.0855*	-0.0580	-0.0463
	(0.0753)	(0.0729)	(0.0646)	(0.0626)	(0.0477)	(0.0451)	(0.0396)	(0.0437)
Observations	132	132	132	132	132	132	132	132

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\pi_t^4 - \pi_{t-4}^4$ where $\pi_t^4 = \log P_t - \log P_{t-4}$
4 lags/leads in Newey-West formula for standard errors

Table 21: RER-based Phillips curve: New Zealand, 1974Q2-2007Q4

VARIABLES	(1) PGDP REER PXNW PCPUS	(2) PCP REER PXNW PCPUS	(3) PGDP REER PXNW PMGS	(4) PCP REER PXNW PMGS	(5) PGDP RER PXNW PCPUS	(6) PCP RER PXNW PCPUS	(7) PGDP RER PXNW PMGS	(8) PCP RER PXNW PMGS
RER gap	-0.0969	-0.0903**	-0.0695	-0.0492	-0.0646	-0.0479**	-0.0400	-0.0188
	(0.0783)	(0.0426)	(0.0664)	(0.0349)	(0.0415)	(0.0238)	(0.0370)	(0.0234)
Observations	135	135	135	135	135	135	135	135

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\Delta\pi_t$ where $\pi_t = 4\Delta \log P_t$
3 lags of $\Delta\pi$ added as regressors
4 lags/leads in Newey-West formula for standard errors

Table 22: RER-based Phillips curve: New Zealand, 1974Q2-2007Q4

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Price level	PGDP	PCP	PGDP	PCP	PGDP	PCP	PGDP	PCP
Real exchange rate	REER	REER	REER	REER	RER	RER	RER	RER
Commodity price index	PXNW	PXNW	PXNW	PXNW	PXNW	PXNW	PXNW	PXNW
Deflator for CP index	PCPUS	PCPUS	PMGS	PMGS	PCPUS	PCPUS	PMGS	PMGS
RER gap	-0.0154	-0.0608	0.0111	-0.0173	-0.0593*	-0.0518***	-0.0379	-0.0216
	(0.0917)	(0.0424)	(0.0769)	(0.0327)	(0.0328)	(0.0175)	(0.0386)	(0.0190)
Observations	135	135	135	135	135	135	135	135

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\Delta\pi_t$ where $\pi_t = 4\Delta P_t$
4 lags of $\Delta\pi$ and $\Delta \log$ RER added as regressors
4 lags/leads in Newey-West formula for standard errors

Table 23: RER-based Phillips curve: New Zealand, 1987Q1-2007Q4

	(1)	(2)	(3)	(4)
	PGDP	PCP	PGDP	PCP
	REER	REER	RER	RER
	CRR	CRR	CRR	CRR
VARIABLES	PCPUS	PCPUS	PCPUS	PCPUS
RER gap	-0.0975*	-0.0629*	0.0399	0.0333
	(0.0542)	(0.0374)	(0.0562)	(0.0411)
Observations	81	81	81	81

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\pi_t^4 - \pi_{t-1}^4$ where $\pi_t^4 = \log P_t - \log P_{t-4}$
3 lags/leads in Newey-West formula for standard errors

Table 24: RER-based Phillips curve: New Zealand, 1987Q1-2007Q4

VARIABLES	(1) PGDP REER CRR PCPUS	(2) PCP REER CRR PCPUS	(3) PGDP RER CRR PCPUS	(4) PCP RER CRR PCPUS
RER gap	0.00490	-0.0134	0.0515	0.0307
	(0.0515)	(0.0229)	(0.0447)	(0.0266)
Observations	84	84	84	84

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Dependent variable: $\Delta\pi_t$ where $\pi_t 4\Delta \log P_t$

3 lags of $\Delta\pi$ added as regressors

3 lags/leads in Newey-West formula for standard errors

Table 25: RER-based Phillips curve: New Zealand, 1987Q1-2007Q4

	(1)	(2)	(3)	(4)
Price level	PGDP	PCP	PGDP	PCP
Real exchange rate	REER	REER	RER	RER
Commodity price index	CRR	CRR	CRR	CRR
Deflator for CP index	PCPUS	PCPUS	PCPUS	PCPUS
RER gap	0.0134	0.00451	0.0611	0.0398
	(0.0508)	(0.0273)	(0.0408)	(0.0245)
Observations	84	84	84	84

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Dependent variable: $\Delta\pi_t$ where $\pi_t = 4\Delta \log P_t$

2 lags of $\Delta\pi$ and $\Delta \log$ RER added as regressors

3 lags/leads in Newey-West formula for standard errors

Table 26: EG-ADF test for cointegration: Norway

	(1)	(2)	(3)	(4)	(5)	(6)
Real exchange rate	RER	RER	REER	REER	RER	REER
Commodity price index	PXNW	PXNW	PXNW	PXNW	IMF	IMF
Deflator for CP index	PCPUS	PMGS	PCPUS	PMGS	PCPUS	PCPUS
e(-1)	-0.0738	-0.0631	-0.150	-0.147	-0.0804	-0.150
	(-2.297)	(-1.847)	(-3.049)	(-2.920)	(-2.637)	(-3.329)
Observations	130	130	130	130	137	137
R-squared	0.072	0.065	0.073	0.070	0.079	0.102

t-statistics in parentheses
Dependent variable: Δe where e is residual from OLS regression of log RER/REER on log real CP index and linear trend
4 lags of Δe added as regressors

Table 27: Cointegrating equation: Norway

	(1)	(2)	(3)	(4)	(5)	(6)
Real exchange rate	RER	RER	REER	REER	RER	REER
Commodity price index	PXNW	PXNW	PXNW	PXNW	IMF	IMF
Deflator for CP index	PCPUS	PMGS	PCPUS	PMGS	PCPUS	PCPUS
Log real commodity price index	-0.0832**	-0.166***	0.0538***	0.0504***	0.00405	0.0270***
	(0.0364)	(0.0334)	(0.0133)	(0.0128)	(0.0257)	(0.00876)
Observations	126	126	126	126	135	135
R-squared	0.219	0.303	0.273	0.287	0.031	0.186

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: log RER/REER
Linear trend and 4 lags/leads of $\Delta \log$ real CP index added as regressors

Table 28: RER-based Phillips curve: Norway, 1974Q2-2007Q4

VARIABLES	(1) PGDP REER PXNW PCPUS	(2) PCP REER PXNW PCPUS	(3) PGDP REER PXNW PMGS	(4) PCP REER PXNW PMGS	(5) PGDP RER PXNW PCPUS	(6) PCP RER PXNW PCPUS	(7) PGDP RER PXNW PMGS	(8) PCP RER PXNW PMGS
RER gap	-0.134	-0.131	-0.103	-0.120	0.0797	0.0153	0.0708	0.0164
	(0.188)	(0.0825)	(0.204)	(0.0772)	(0.0688)	(0.0199)	(0.0796)	(0.0224)
Observations	132	132	132	132	132	132	132	132

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\pi_t^4 - \pi_{t-4}^4$ where $\pi_t^4 = \log P_t - \log P_{t-4}$
4 lags/leads in Newey-West formula for standard errors

Table 29: RER-based Phillips curve: Norway, 1974Q2-2007Q4

VARIABLES	(1) PGDP REER PXNW PCPUS	(2) PCP REER PXNW PCPUS	(3) PGDP REER PXNW PMGS	(4) PCP REER PXNW PMGS	(5) PGDP RER PXNW PCPUS	(6) PCP RER PXNW PCPUS	(7) PGDP RER PXNW PMGS	(8) PCP RER PXNW PMGS
RER gap	-0.0837	-0.0576	-0.0641	-0.0438	0.0494	0.0276	0.0482	0.0301
	(0.154)	(0.0739)	(0.158)	(0.0703)	(0.0500)	(0.0194)	(0.0580)	(0.0220)
Observations	135	135	135	135	135	135	135	135

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\Delta\pi_t$ where $\pi_t = 4\Delta \log P_t$
3 lags of $\Delta\pi$ added as regressors
4 lags/leads in Newey-West formula for standard errors

Table 30: RER-based Phillips curve: Norway, 1974Q2-2007Q4

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Price level	PGDP	PCP	PGDP	PCP	PGDP	PCP	PGDP	PCP
Real exchange rate	REER	REER	REER	REER	RER	RER	RER	RER
Commodity price index	PXNW	PXNW	PXNW	PXNW	PXNW	PXNW	PXNW	PXNW
Deflator for CP index	PCPUS	PCPUS	PMGS	PMGS	PCPUS	PCPUS	PMGS	PMGS
RER gap	-0.0836	-0.179**	-0.0644	-0.157*	0.0320	0.0122	0.0318	0.0153
	(0.182)	(0.0870)	(0.199)	(0.0839)	(0.0581)	(0.0234)	(0.0638)	(0.0258)
Observations	135	135	135	135	135	135	135	135

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\Delta\pi_t$ where $\pi_t = 4\Delta \log P_t$
4 lags of $\Delta\pi$ and $\Delta \log$ RER added as regressors
4 lags/leads in Newey-West formula for standard errors

Table 31: RER-based Phillips curve: Norway, 1972Q1-2007Q4

	(1)	(2)	(3)	(4)
	PGDP	PCP	PGDP	PCP
	REER	REER	RER	RER
	CRR	CRR	CRR	CRR
VARIABLES	PCPUS	PCPUS	PCPUS	PCPUS
RER gap	-0.130	-0.127	0.111	0.0153
	(0.187)	(0.0804)	(0.0672)	(0.0202)
Observations	132	132	132	132

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\pi_t^4 - \pi_{t-1}^4$ where $\pi_t^4 = \log P_t - \log P_{t-4}$
3 lags/leads in Newey-West formula for standard errors

Table 32: RER-based Phillips curve: Norway, 1972Q1-2007Q4

VARIABLES	(1) PGDP REER CRR PCPUS	(2) PCP REER CRR PCPUS	(3) PGDP RER CRR PCPUS	(4) PCP RER CRR PCPUS
RER gap	-0.117	-0.0254	0.0488	0.0257
	(0.162)	(0.0836)	(0.0556)	(0.0195)
Observations	135	135	135	135

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\Delta\pi_t$ where $\pi_t = 4\Delta \log P_t$
3 lags of $\Delta\pi$ added as regressors
3 lags/leads in Newey-West formula for standard errors

Table 33: RER-based Phillips curve: Norway, 1972Q1-2007Q4

	(1)	(2)	(3)	(4)
Price level	PGDP	PCP	PGDP	PCP
Real exchange rate	REER	REER	RER	RER
Commodity price index	IMF	IMF	IMF	IMF
Deflator for CP index	PCPUS	PCPUS	PCPUS	PCPUS
RER gap	-0.117	-0.0718	0.0252	0.00714
	(0.161)	(0.0652)	(0.0555)	(0.0191)
Observations	136	136	136	136

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\Delta\pi_t$ where $\pi_t = 4\Delta \log P_t$
2 lags of $\Delta\pi$ and $\Delta \log$ RER added as regressors
3 lags/leads in Newey-West formula for standard errors

Table 34: EG-ADF test for cointegration: Russia

	(1)	(2)
Real exchange rate	RER	REER
Commodity price index	IMF	IMF
Deflator for CP index	PCPUS	PCPUS
e(-1)	-0.137	-0.169
	(-2.329)	(-2.395)
Observations	49	49
R-squared	0.188	0.169

t-statistics in parentheses
Dependent variable: Δe where *e* is residual from OLS regression of log RER/REER on log real CP index and linear trend
2 lags of Δe added as regressors

Table 35: Cointegrating equation: Russia

	(1)	(2)
Real exchange rate	RER	REER
Commodity price index	IMF	IMF
Deflator for CP index	PCPUS	PCPUS
Log real commodity price index	1.173***	0.500***
	(0.271)	(0.0970)
Observations	47	47
R-squared	0.821	0.627

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: log RER/REER
Linear trend and 2 lags/leads of $\Delta \log$ real CP index added as regressors

Table 36: RER-based Phillips curve: Russia, 1999Q1-2007Q4

VARIABLES	(1) PGDP REER CRR PCPUS	(2) PCP REER CRR PCPUS	(3) PGDP RER CRR PCPUS	(4) PCP RER CRR PCPUS
RER gap	0.317	0.266	0.0171	0.0302
	(0.199)	(0.274)	(0.0529)	(0.0237)
Observations	44	44	44	44

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\pi_t^4 - \pi_{t-1}^4$ where $\pi_t^4 = \log P_t - \log P_{t-4}$
3 lags/leads in Newey-West formula for standard errors

Table 37: RER-based Phillips curve: Russia, 1999Q1-2007Q4

VARIABLES	(1) PGDP REER CRR PCPUS	(2) PCP REER CRR PCPUS	(3) PGDP RER CRR PCPUS	(4) PCP RER CRR PCPUS
RER gap	0.192**	0.235	0.00907	0.0253
	(0.0774)	(0.385)	(0.0268)	(0.0432)
Observations	47	47	47	47

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\Delta\pi_t$ where $\pi_t = 4\Delta \log P_t$
3 lags of $\Delta\pi$ added as regressors
3 lags/leads in Newey-West formula for standard errors

Table 38: RER-based Phillips curve: Russia, 1999Q1-2007Q4

	(1)	(2)	(3)	(4)
Price level	PGDP	PCP	PGDP	PCP
Real exchange rate	REER	REER	RER	RER
Commodity price index	IMF	IMF	IMF	IMF
Deflator for CP index	PCPUS	PCPUS	PCPUS	PCPUS
RER gap	0.314**	-0.152**	-0.0196	0.0323
	(0.124)	(0.0636)	(0.0488)	(0.0307)
Observations	36	36	36	36

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\Delta\pi_t$ where $\pi_t = 4\Delta \log P_t$
2 lags of $\Delta\pi$ and $\Delta \log$ RER added as regressors
3 lags/leads in Newey-West formula for standard errors

Table 39: EG-ADF test for cointegration: South Africa

	(1)	(2)
Real exchange rate	RER	REER
Commodity price index	CRR	CRR
Deflator for CP index	PCPUS	PCPUS
e(-1)	-0.198	-0.235
	(-2.222)	(-2.624)
Observations	53	53
R-squared	0.096	0.127

t-statistics in parentheses
Dependent variable: Δe where e is residual from OLS regression of log RER/REER on log real CP index and linear trend
2 lags of Δe added as regressors

Table 40: Cointegrating equation: South Africa

	(1)	(2)
Real exchange rate	RER	REER
Commodity price index	CRR	CRR
Deflator for CP index	PCPUS	PCPUS
Log real commodity price index	0.861***	0.439***
	(0.118)	(0.0817)
Observations	51	51
R-squared	0.605	0.542

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: log RER/REER
Linear trend and 2 lags/leads of $\Delta \log$ real CP index added as regressors

Table 41: RER-based Phillips curve: South Africa, 1994Q1-2007Q4

	(1)	(2)	(3)	(4)
	PGDP	PCP	PGDP	PCP
	REER	REER	RER	RER
	CRR	CRR	CRR	CRR
VARIABLES	PCPUS	PCPUS	PCPUS	PCPUS
RER gap	-0.0498	-0.154***	-0.0275	-0.0451**
	(0.0478)	(0.0575)	(0.0177)	(0.0202)
Observations	53	53	53	53

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\pi_t^4 - \pi_{t-1}^4$ where $\pi_t^4 = \log P_t - \log P_{t-4}$ is 4-quarter rate of inflation
3 lags/leads in Newey-West formula for standard errors

Table 42: RER-based Phillips curve: South Africa, 1994Q1-2007Q4

VARIABLES	(1) PGDP REER CRR PCPUS	(2) PCP REER CRR PCPUS	(3) PGDP RER CRR PCPUS	(4) PCP RER CRR PCPUS
RER gap	-0.0882*	-0.125***	-0.0344	-0.0294*
	(0.0496)	(0.0418)	(0.0214)	(0.0159)
Observations	56	56	56	56

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\Delta\pi_t$ where $\pi_t = 4\Delta \log P_t$
3 lags of $\Delta\pi$ added as regressors
3 lags/leads in Newey-West formula for standard errors

Table 43: RER-based Phillips curve: South Africa, 1994Q1-2007Q4

	(1)	(2)	(3)	(4)
Price level	PGDP	PCP	PGDP	PCP
Real exchange rate	REER	REER	RER	RER
Commodity price index	CRR	CRR	CRR	CRR
Deflator for CP index	PCPUS	PCPUS	PCPUS	PCPUS
RER gap	-0.0493	-0.0787**	-0.0300	-0.0262**
	(0.0473)	(0.0391)	(0.0193)	(0.0121)
Observations	56	56	56	56

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: $\Delta\pi_t$ where $\pi_t = 4\Delta \log P_t$
2 lags of $\Delta\pi$ and $\Delta \log$ RER added as regressors
3 lags/leads in Newey-West formula for standard errors