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Commodity Price Effects on Currencies

Abstract

Using quarterly data on four commodity exporting countries, we study the explanatory power of real commodity prices for predicting real effective exchange rates, with special attention to the separate roles of different sectoral commodity prices during alternative time periods. We find that the commodity price effect is non-uniform across countries and commodity sectors, and moreover varies over time. The use of fixed weight price indexes, or nominal exchange rates and commodity prices, also yields heterogeneous commodity price effects. Further, the pattern of commodity price effects is influenced by the presence of macroeconomic conditions, the effects of crises, and the exchange rates of top trading partners. These empirical results highlight the challenges of explaining a wide range of currency behaviors across different time periods with a single commodity-price-based exchange rate model. These findings also complicate the tasks facing policymakers who assume stable commodity price effects.

JEL-Codes: F310, F410.

Keywords: commodity currencies, sectoral commodity prices, The US Dollar Effect, The Global Financial Crisis, macro variables.

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1. Introduction

The seminal studies Meese and Rogoff (1983a, b) forcefully illustrate the difficulty of modeling and forecasting exchange rate movements. Subsequent analyses usually affirm the general conclusion of the seminal studies; especially, it is challenging to find a model that explains and predicts all currencies for all historical periods (Cheung, *et al.*, 2005; Cheung, *et al.*, 2019; Engel, *et al.*, 2019; Rossi, 2013).

While a general specification is hard to establish, Chen and Rogoff (2003) and Cashin, *et al*. (2004) employ least squares or dynamic least squares regressions and report strong evidence of a positive relationship between commodity prices and exchange rates. They suggested the Balassa–Samuelson framework is in accordance with the empirical positive commodity price effect. A commodity currency is then referred to as the currency of a commodity exporting country that pro-cyclically moves with commodity prices. Subsequent studies report varying degrees of commodity price effects employing alternative estimation techniques and data samples. For instance, Chen, *et al*. (2010) and Clements and Fry (2008) adopt the Granger-causality technique and show that commodity prices only weakly affect exchange rates. [1]

The current paper studies the explanatory performance of real commodity prices for real effective exchange rates in a systematic manner, and with special attention given to differential roles of different sectoral commodity prices in alternative historical time periods. We anticipate that, because of their different industrial structures and different mixes of commodity exports, the commodity currencies of different commodity exporting countries can respond non-uniformly to different sectoral commodity prices.[2] Dis-similar productivity differentials between commodity and non-commodity sectors in different countries can further contribute to non-uniform responses.

The US dollar is the predominant global currency and the main pricing currency in the global commodity market. The market usually perceives a strong correlation between the US dollar

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[1] Studies on commodity exchange rates and commodity prices have evolved to include a) both developed and developing countries (Bodart, *et al*., 2012, 2015; Cashin, *et al*., 2004; Coudert, *et al*., 2015), b) country-specific aggregate commodity price indexes to commodity specific price indexes (Bodart, *et al*., 2012; Ferraro, *et al*., 2015; Zhang, *et al*., 2016), c) the feedback between commodity currencies and commodity prices (Chen, *et al*., 2010; Clements and Fry, 2008, Zhang, *et al*., 2016), and d) the effects of structural determinants on the strength of commodity currency and commodity price relationship (Bodart, *et al*., 2012, 2015; Chen and Lee, 2018), and e) forecasting performance, links to carry trade, volatility, and equity returns (Ayres, *et al*., 2020; Byrne, *et al*., 2019; Chaban, 2009; Chen, *et al*., 2010; Ready, *et al*., 2017b).

[2] Bodart, *et al.* (2012, 2015), for example, study the effect of the price of a country's leading commodity export on its currency. However, studies on the differential effects of different sectoral commodity prices on a commodity currency are limited.

and commodity prices. Thus, the dollar valuation can be a common factor driving both commodity currencies and commodity prices – a strong US dollar, for instance, can be associated with a weak commodity currency and low commodity price. Anecdotal evidence suggests that the world's demand for the US dollar varies over the global financial cycle. The association between the US dollar, commodity currencies, and commodity prices, thus, can change over time. In this study, the US dollar real effective exchange rate is employed to account for the US dollar effect on the links between real commodity price indexes and real effective exchange rates of commodity currencies.[3]

We stipulate the association between commodity currencies and commodity prices has changed after the 2007-8 Global Financial Crisis (GFC). In the midst of the GFC and after, countries have altered their monetary policies and financial market regulations. These changes coupled with shifted economic conditions have triggered changes in the global financial market in general and the global commodity market in particular. Adams and Glück (2015), Ordu, *et al*. (2018), Ready, *et al*. (2017a), for example, note the different behaviours of commodity price indexes before and after the GFC. In the post-GFC era, commodity financialization has gained momentum and facilitated commodities to be a viable asset class for both institutional and individual investors (Adams and Glück, 2015; Baker, 2021; Basak and Pavlova, 2016; Henderson, *et al*., 2015; Ordu, *et al*., 2018). Different commodities have experienced different degrees of financialization, which can affect the link between prices of commodities, financial assets, and exchange rates. Against this backdrop, we compare the nexus between commodity currencies and commodity prices before and after GFC.

We find that commodity prices influence the currencies of Australia, Canada, Norway, and New Zealand. In general, the set of sectoral commodity price indexes offers better explanatory power than the aggregate commodity price index. The sectoral commodity price index effects differ across countries, sectors, and historical time periods and are stronger in the post-GFC than the pre-GFC period. The US dollar effect is not as strong as anticipated - it mainly shows up in some cases in the post-GFC period.

The heterogeneous sectoral commodity price effects qualitatively hold up with fixed weight price indexes and nominal exchange rates and commodity prices. They are also influenced

[3] Chen, *et al*. (2010) uses GBP-based exchange rates to assess if exchange rates forecasting performance is sensitive to the US dollar effect.

by the crisis effect, and the presence of macroeconomic variables and the exchange rates of top trading partners.

From a modeling viewpoint, the non-uniform sectoral commodity price effect does not contradict the Meese and Rogoff result that it is difficult to explain and forecast exchange rate movements. Heterogeneous and period-specific commodity price effects attenuate the usefulness of a single commodity price model of exchange rate determination for all currencies in all historical time periods. For policymaking, the heterogeneity of commodity price effect can have important implications for the conduct of monetary policy and inflation management based on the notion of a stable empirical link between commodity prices and exchange rates. [4]

The following section provides some basis information of the empirical exercise. Section 3 presents the basic commodity price and US dollar effects. Section 4 reports some additional analyses that involve fixed weight commodity price indexes, nominal (instead of real) effective exchange rates and commodity prices, the presence of macroeconomic variables, the role of the GFC period, and the inclusion of top trading partner's exchange rates. Some concluding remarks are offered in Section 5.

2. Basis Information

The positive response of commodity currencies to commodity price movements is usually illustrated in a setup incorporating the Balassa–Samuelson effect (Cashin, *et al*., 2004; Chen and Rogoff, 2003).[5] Following this perspective, we can modify the exchange rate model in Patel, *et al*. (2019) to illustrate the dependence of commodity price effect on "labor intensity" and "commodity productivity." In Appendix A.1, we outline a model that shows the impacts of labor intensity, commodity productivity, and sectoral wage weights on commodity price effects for readers interested in the basic theoretical setup.[6] Since these factors can vary across sectors and countries,

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[4] The exchange rate response to commodity price movements can lead to the so-called "Dutch disease," which affects macroeconomic performance (Frankel, 2010).

[5] Alternative explanations based on portfolio balance models and terms-of-trade shocks are offered by, for example, Ayres, *et al*. (2020), Chen (2004), and Coudert, *et al*. (2015). An improved commodity price enhances the terms of trade of a commodity exporting country and its currency. The effect and the corresponding increase in income can induce foreign direct investment (in the commodity sector) and push up nontradable prices that further strengthens the commodity currency.

[6] The relevance of the Balassa-Samuelson effect goes beyond emerging and developing economies. For instance, the seminal Balassa (1964) documents the effect using data from 12 developed countries. Cardi and Restout (2015), Cheung and Fujii (2014), Égert, *et al*. (2003), Hassan (2016), Lothian and Taylor (2008), and Wang, *et al*.

and change over time, heterogeneous commodity price effects can be a staple feature of empirical data.

2.1 Commodity Exporting Countries

We conduct a systematic assessment of the influence of commodity prices on real effective exchange rates of Australia, Canada, Norway and New Zealand, which are small open developed countries with a large commodity export sector. The seminal Chen and Rogoff (2003) study, for example, motivates the focus on Australia, Canada and New Zealand. Chen and Rogoff (2003) did not consider Norway because of its regulated exchange regime at that time. The current study includes the Norwegian economy because, since then, it has evolved towards a market economy with a floating rate arrangement.

Despite their differences, these four countries, compared with a large group of developed and developing countries, are relatively homogenous in terms of economic, social, and institutional structures. The heterogeneous commodity price effects presented below are unlikely due to different economic, social, and institutional structures.[7]

During our sample period, these four small open developed countries practice relatively little intervention in their domestic (capital) markets and, mainly adopt the inflation targeting monetary policy.[8] Their levels of openness as measured by the total trade to GDP ratio are between 34.75% (Australia) to 54.71% (Canada) in 2019 (Appendix A.2). They follow a flexible exchange rate arrangement, and their currencies are quite actively traded in the global foreign exchange (FX) market. The Australian dollar, Canadian dollar, New Zealand dollar and Norwegian krone are, respectively, the fifth, sixth, tenth, and fourteenth most globally traded currencies (Bank for International Settlements, 2019). The FX trading turnover is quite large relative to the size of their economies (Appendix A.2); for instance, the daily FX turnover to total trade ratios and to GDP ratios are, respectively, in the range of 35.66% (Canada) to 163.27% (New Zealand) and in the range of 19.51% (Canada) to 66.84% (New Zealand). ~~Given the relatively small size of their~~

(2016) present evidence of Balassa-Samuelson effects and the implied price–income relation for developed countries and within a developed country.

7 Besides Chen and Rogoff (2003), studies that focused on a small set of similar developed commodity exporting countries include Chaban (2009), Chen and Lee (2018), Chen, *et al.* (2010,), Ferraro, *et al*. (2015) and Zhang, *et al*. (2016).

8 The dates of adopting the inflation targeting strategy are Australia (1993M4), Canada (1991M2), New Zealand (1990Q1), and Norway (2001M3).

~~economies, these four countries are mostly price takers in the competitive global commodity market~~ (I suggest to take it out as some countries are a dominant supplier of some commodities).

Australia, Canada, Norway, and New Zealand are commodity exporters – commodity exports account for a large share of their total merchandise exports. Table 1 presents, for each country in three alternative sample periods, the average shares of exports from three main commodity sectors; namely the Agriculture sector (38 commodities), the Energy sector (3 commodities), and the Metals sector (13 commodities), and the aggregate commodity exports given by the sum of exports from these three sectors.[9] Individual commodities included in these three sectors are listed in Appendix A.3. The three sample periods are a) the full sample period 1990Q2 to 2019Q4, b) the pre-GFC period 1990Q2 to 2007Q2, and c) the post-GFC period 2009Q1 to 2019Q4. Note that the crisis period 2007Q3 to 2008Q4 is not included in the pre-GFC and post-GFC periods but will be considered in Section 4.

Commodity exports contribute to more than one half of the total exports of Australia, Norway and New Zealand, and about one-third of Canada. The aggregate commodity export shares have increased after the GFC – Canada's share experiences the largest increase to 40.12% from 29.35% while New Zealand's share shows only a marginal increase.

Norway's and New Zealand's sectoral commodity exports are led by, respectively, the Energy sector and the Agriculture sector. These two leading sectors hold up their positions before and after the GFC, and account for about one-half of the corresponding total exports. For Australia and Canada, their leading commodity export sectors were the Agriculture sector in the pre-GFC period. These leading sectors switched to the Metals sector and Energy sector, respectively, in the post-GFC period.

2.2 Data on Exchange Rates and Commodity Prices

Our main analysis is based on quarterly data on real effective exchange rates (REERs) and real commodity price indexes (RCPIs) from 1990Q2 to 2019Q4.[10] The data on REERs that

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[9] Similar to most other studies, we do not include the Fertilizers sector, which accounts for 0.04% (Australia), 1.08% (Canada), 0.03% (Norway), and 0.04% (New Zealand) of total exports. Further, "copra" under the Agriculture sector is not included as its price was not updated.

[10] Some data are available at the monthly frequency (commodity prices and effective exchange rates), and some at the annual frequency (the MUV index and commodity exports). The quarterly frequency is quite commonly considered; and adopted in, for example, Chen and Rogoff (2003), Chen, *et al*. (2010), Clements and Fry (2008), and Ferraro, *et al*. (2015).

measure the overall valuation of a currency (Chinn, 2006) are from the *International Financial Statistics* database. For RCPIs, we consider the country-specific real indexes derived from time-varying trade weights. For brevity, we label them RCPIs henceforth. The change in a sectoral RCPI (Δrcp) is calculated from:

$$\Delta rcp_{i,t} = \Sigma_j \omega_{ij,t} \Delta \ln(P_{ij,t} / MUV_t), \quad (1)$$

where *i* is the commodity group identifier; *i* = Agriculture sector, Energy sector, and Metals sector, *j* is the *j*-th commodity in the *i*-th commodity group, $\omega_{ij,t}$ is the time-varying weight of commodity *j* in group *i* given by its export value normalized by total export value at time *t*, $P_{ij,t}$ is the nominal price (index) of commodity *j* at time *t*, and MUV_t is the manufactures unit value index at time *t*.[11] The change in *aggregate* commodity price index is the sum of changes in the three sectoral commodity price indexes. Appendix A.4 contains information about the definitions and sources of these data and other data used in the empirical exercise.

Figure 1 presents the country-specific REERs and RCPIs; Australia in Figure 1a, Canada in 1b, Norway in 1c, and New Zealand in 1d. Visually speaking, for these individual countries, most of these series in accordance with the 2000s commodities boom exhibit a higher value and are more volatile in the latter part of the sample period. The GFC appears as a watershed for the properties of these REERs and RCPIs. Further, preliminary data analyses show that REERs and RCPIs are usually I(1) but not cointegrated. Similar non-cointegration results for these four countries are reported in, for example, Cashin, *et al.* (2004) and Chen and Lee (2018). Thus, we consider the first differences of these variables in the subsequent analyses.

Table 2 presents some basic descriptive statistics of the changes in REERs and RCPIs. There are a few observations. First, these four real exchange rate series display different appreciation and volatility patterns in these three sample periods (column labeled "REER"). Second, both the mean and the standard error of the changes in RCPIs can be quite different among commodity exporters and between sample periods. They suggest differential RCPI effects across commodity exporting countries over time.

[11] The 54 individual commodity price series are either US dollar-based nominal prices or indexes from the IMF *Primary Commodity Prices* database and the World Bank *Commodities Price Data* (The Pink Sheet). Also, we follow Bodart, *et al*. (2012, 2015), Cashin, *et al*. (2004), Chen and Lee (2018) and Collier and Goderies (2012) to deflate commodity prices using MUV, which is the index based on a trade-weighted average of US dollar export prices of manufactured goods from 15 major developed and emerging countries.

Third, there is a stark difference between descriptive statistics reported for the pre-GFC and post-GFC periods. For instance, the volatility of aggregate and sectoral RCPI changes is generally smaller in the pre-GFC period than the post-GFC period. The increase in volatility is in accordance with the growing popularity of commodity financialization in the post-GFC period (Basak and Pavlova, 2016; Henderson, *et al*., 2015).

On the correlation estimates between changes of a commodity exporter's REER and other variables presented under the rows labeled "*Corr*," their magnitudes in the post-GFC period are larger than those in the pre-GFC period; the only exception is the Norwegian Agriculture sector case. Technically, these correlation estimates give the association between the variables and carry no causal interpretation. Since the crisis period 2007Q3 to 2008Q4 is not included in the pre- and post-GFC subsamples, the increased correlation is unlikely due to contagion triggered by crisis effects. The strong correlation in the post-GFC period is likely due to the growing importance of commodity exports (Table 1) and commodity financialization that induce strong interdependence between commodity currencies and commodity prices.[12]

3. Empirical Results

The descriptive statistics presented in the previous section indicate the linkages between exchange rates and commodity prices. Here we analyze exchange rate responses to commodity price movements with regression equations:

$$\Delta reer_{c,t} = \alpha + \beta \Delta rcp_{aggregate,t} + \varepsilon_t \quad (2a)$$

$$\Delta reer_{c,t} = \alpha + \beta \Delta rcp_{aggregate,t} + \delta \Delta reer_{us,t} + \varepsilon_t \quad (2b)$$

and

$$\Delta reer_{c,t} = \alpha + \Sigma_{i\ =commodity\ sector} \beta_i \Delta rcp_{i,t} + \varepsilon_t \quad (3a)$$

$$\Delta reer_{c,t} = \alpha + \Sigma_{i\ =commodity\ sector} \beta_i \Delta rcp_{i,t} + \delta \Delta reer_{us,t} + \varepsilon_t \quad (3b)$$

where $reer_{c,t}$ is the logarithm of a commodity country's REER, $rcp_{aggregate,t}$ and $rcp_{i,t}$ are the country-specific aggregate and sectoral (*i* = Agriculture sector, Energy sector, Metals sector) RCPIs, $reer_{us,t}$ is the logarithm of the US dollar REER, and Δ is the first-difference operator.

12 Appendix A.5 shows the US dollar REER usually exhibits a stronger association with the RCPIs in the post-GFC than the pre-GFC period. The plots of these differenced series in Appendix A.5 depict their different behaviors before and after the GFC and the strong comovement during the GFC.

Equation (2a) is the canonical bivariate setup for assessing the exchange rate response to commodity price movements (Chaban, 2009; Chen and Rogoff, 2003; Coudert, *et al*., 2015). The US dollar effect is investigated using (2b). The inclusion of the US dollar REER index is motivated by its role in pricing global commodities and the bivariate correlation estimates in Table 2. The US dollar global prominence is re-affirmed by Gopinath, *et al*. (2020).

Equations (3a) and (3b) offer insights into the individual roles of sectoral commodity exports. The heterogeneous composition of commodity exports and non-uniform commodity price properties across sectors and over time suggest the aggregate commodity index may not be a good average measure that captures individual sectoral commodity price effects on exchange rates. Further, we will compare the exchange rate responses in the pre-GFC and post-GFC periods.

The results of estimating (2a), (2b), (3a) and (3b) for the whole sample period are presented in Table 3, the pre-GFC period in Table 4, and the post-GFC period in Table 5.[13] For brevity, we omitted the intercept estimates.

3.1 Results from the Full Sample

There are a few observations from Table 3. First, for all the four commodity currencies, the estimated coefficient on the change of aggregate RCPI, $\Delta rcp_{aggregate,t}$, is significantly positive (Column 2a); indicating real commodity prices and real effective exchange rates are positively correlated. The result is in accordance with most extant findings, though the coefficient estimates of $\Delta rcp_{aggregate,t}$ tend to be below the range of 0.5 to 1 reported by Chen and Rogoff (2003).[14] The New Zealand dollar specification garners the smallest adjusted R^2 estimate of 9.3% while the other three specifications yield an estimate of over 20%.

Second, for individual commodity sectors, the changes of RCPIs ($\Delta rcp_{i,t}$ s) mostly have a significantly positive coefficient estimate (Columns 3-i to 3-iii). Different sectoral RCPIs, however, have coefficient estimates of different magnitudes.

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13 Before conducting these regression analyses, we adopted the Durbin-Wu-Hausman test to assess the endogeneity of commodity prices. Nine of 12 cases (four countries and three sample periods) yield no significant evidence of endogeneity at the 5% level. The finding is in accordance with the price-taking behavior of these four countries stated in previous studies including Chen and Rogoff (2003) and Cashin, *et al*. (2004).

14 The range of our estimates is narrower than those presented in Chaban (2009), which has estimates between 0.37 and 1.9 for Australian dollar, 0.06 and 0.1 for Canadian dollar and 0.3 and 0.5 for New Zealand.

When the three sectoral RCPIs are included, the number of significant RCPIs is reduced to two or one (Column 3a). Some of the significant results reported under Columns 3-i to 3-iii are spurious, and not all the sectoral RCPIs contain independent information on commodity currencies. Further, the leading commodity export sector is not necessarily the dominant sector or the only sector determining commodity price effects. While the Australian dollar, Canadian dollar, and Norwegian krone respond to the price indexes of their respective leading commodity export sector (Metals, Energy, and Energy, respectively), they also respond to another sectoral commodity price index. For the New Zealand dollar, the leading commodity export sector – the Agriculture sector – yields no significant commodity price effect in the presence of other sectoral commodity prices (column 3a). The results cast doubt on focusing on *only* the role of the leading commodity export.

The results indicate that different commodity sectors display different effects, and the significance and magnitude of sectoral RCPI effects ~~including the leading commodity export sector~~(I suggest to take it our as we did not work on leading commodity export sector) are different across countries. The heterogeneous sectoral commodity price effects can be attributed to varying levels of labor intensity, commodity productivity, and sectoral wage weights in different sectors and in different countries as discussed in Section 2 and Appendix A.1.

Third, the group of sectoral RCPIs, compared with the corresponding aggregate RCPI, in general offers a better explanatory power in terms of adjusted R^2 estimates (Columns 2a and 3a). The use of aggregate RCPI may not fully reflect individual sectoral RCPI effects.

Fourth, the coefficient estimates on $reer_{us,t}$ – the variable that captures the US dollar effect – have the expected negative sign. While the inclusion of the US dollar variable reduces the estimates of aggregate RCPI effect, none of the US dollar coefficient estimates is statistically significant.[15]

In sum, while the full sample results are largely in line with the view that commodity currencies and commodity prices comove, they indicate potential gains in considering sectoral instead of aggregate RCPIs.

3.2 Pre-GFC and Post-GFC Periods

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15 In a bivariate regression setting, the estimated coefficient on $reer_{us,t}$ is significant with the expected negative sign for the full sample and the post-GFC sample.

Tables 4 and 5 present the results obtained from, respectively, the pre-GFC period (1990Q2-2007Q2) and post-GFC period (2009Q1-2019Q4). The GFC period is not included here – but considered in the next section – to avoid uncertainty effects caused by extraordinary crisis conditions.

For the pre-GFC sample period, the aggregate RCPI has a statistically significant effect on the Canadian dollar and Norwegian krone (Table 4, columns 2a and 2b). The Canadian dollar and the Norwegian krone regressions yield significant sectoral RCPI variables that are similar to those reported in the full sample (Tables 3 and 4, columns 3b). The New Zealand dollar regression, however, presents an extreme case in which neither the RCPI (aggregate and sectoral) varaibles nor the US dollar variable are statistically significant. Compared with the full sample results, there are a fewer number of significant (sectoral) RCPI variables. The US $reer_{us,t}$ variable again is insignificant for all the four cases (Table 4, columns 2b and 3b). The adjusted R^2 estimates are less than the corresponding ones from full sample regressions (Table 3).

The post-GFC sample, on the other hand, offers a few different observations. These commodity currencies significantly respond to the aggregate RCPI (Table 5, columns 2a and 2b); except the New Zealand dollar in the presence of the US dollar variable. When each individual sectoral RCPI variable enters the regression by itself, they are all statistically significant. However, the significance can vanish in the presence of other sectoral RCPI or the US dollar variables (Table 5, 3-i to 3-iii, 3a and 3b). Depending on the currency, the significant sectoral RCPI variables in the composite specification (3b) may or may not be comparable to those in the full sample presented in Table 3.

The RCPI effects are different in the pre- and post-GFC periods, and they tend to be stronger in the latter period. These results are in accordance with the growing of commodity financialization after GFC that enhances commodity price effects on financial assets and exchange rates (Adams and Glück, 2015; Baker, 2021; Basak and Pavlova, 2016; Henderson, *et al.*, 2015; Ordu, *et al.*, 2018; Ready, *et al.*, 2017a).

The result that RCPI price effects are sector- and currency-specific holds up in the subsample analyses. As noted earlier, the heterogeneous effects are consistent with a model that links the RCPI effect to labor intensity, commodity productivity, and sectoral wage weights. The sectoral RCPIs, compared with the aggregate RCPI, tend to offer a better way to describe commodity price effects on commodity currencies.[16]

The US dollar effect is statistically significant in the post-GFC Australian dollar and Canadian dollar regressions but not in the other two currency specifications. The presence of the US dollar improves the adjusted R^2 estimates by 22.5% (Australia) and 5.1% (Canada), respectively. As expected, the presence of a significant US dollar effect usually improves the absolute estimated errors. Consider the Australian dollar case in the post-GFC subsample, the omission of the US dollar effect worsens the mean and maximum absolute estimated errors by, respectively, 6.9% and 9.7%.

The significance of the US dollar can reflect the commodity financialization process and high correlation estimates between the US dollar and these two currencies in the post-GFC period. However, its statistically significance is mostly confined to two currencies in the post-GFC period. The presence of a significant US dollar variable in Table 5 in general reduces the estimated RCPI effect.[17] That is, one might over-state the commodity price effect by ignoring the role of the US dollar.

While the US dollar effect can be a factor in assessing commodity price effects, its significance is relevant only to specific commodity currencies in the post-GFC period. Does US dollar effect depend on the mix of commodity exports, the intensity of commodity financialization, and the trade with the US? Further investigation of the factors underlying the interactions between commodity currencies, commodity prices and the US dollar effect can shed additional light on commodity currency dynamics.

The adjusted R^2 estimates from the post-GFC sample (Table 3) are discernibly larger than the corresponding ones in both Tables 3 and 4.

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[16] In a formal test of the sectoral RCPIs having the same coefficient estimates, the Australian, Canadian and Norwegian regressions reject the hypothesis of coefficient equality 7 cases out of 12 cases considered, indicating strong statistically evidence in favor of differential sectoral RCPI effects. The New Zealand regression garners 3 rejections out of 12 cases, which is higher than the test size though the evidence is not as strong as others. A specification with sectoral RCPIs usually offers absolute estimated errors better than the corresponding specification with the aggregate index. Consider the New Zealand case in the post-GFC subsample, the specification with the aggregate index yields the mean and maximum absolute estimated errors that are, respectively, 11.5% and 23.8% larger than those from the specification with disaggregate indexes.

[17] It is noted that in the cases of the Australian dollar and the Norwegian krone, the insignificant sectoral RCPI effect under Column 3b may be caused by the relatively large correlation between $reer_{us,t}$ and the RCPI variables (Appendix A.5.iii). The Metals sector RCPI variable (Australia) and the Energy sector RCPI variable (Norway) are marginally significant under a one-sided test, which is appropriate with a strong prior of positive commodity price effect.

4. Additional Analysis

In this section, we evaluate the commodity price effect using alternative specifications. To economize the presentation, we focus on the performance of sectoral RCPIs derived from (3b) in Table 3 or variants of it for the full sample, the pre-GFC period, and the post-GFC period; other results are available from authors. Specifically, we consider a few specifications considered in some extant studies and a few others that have not been widely discussed.

4.1 Fixed Weights

First, we consider the commodity price indexes based on fixed weights that are commonly adopted in existing studies.[18] That is, $\omega_{ij,t}$'s in equation (1) are replaced with ω_{ij}'s, where ω_{ij}'s are the average (over time) shares of individual commodity exports, and are normalized to have a sum of one. Arguably, compared with the time-varying specification, the fixed weight specification can better capture effects of average shares, but not of time-varying shares.

The results based on RCPI data with fixed weights are summarized in Table 6. The *italic font* indicates a variable has a significance classification different from its counterpart under column 3b in Tables 3, 4, or 5.

The use of RCPI data with fixed weights, in general, does not much affect the pattern of significance of the sectoral RCPIs and the US dollar index. In the post-GFC period, one additional significant sectoral RCPI variable is reported for the Australia (Metals) and the Norway (Energy) case. One less significant sectoral RCPI (Energy) is found for the Canada case in the pre-GFC period. While there are variations in the magnitudes of coefficient estimates, the sectoral RCPI and the US dollar effects are qualitatively comparable to those in Tables 3 to 5.

In sum, the commodity price indexes derived from fixed weights also generate heterogeneous sectoral RCPI and US dollar effects.

4.2 Nominal Data

Some existing studies used nominal effective exchange rates and nominal commodity price indexes to examine the commodity price effect; nominal rates are not uncommonly discussed in

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18 See, for example, Cashin, *et al*. (2004), Chen and Rogoff (2003), Chen and Lee (2018), Chen, *et al*. (2010), Coudert, *et al*. (2015). Gruss and Kebhaj (2019) discusses the construction of commodity price indexes.

policymaking, forecasting, and financial markets.[19] We present our results based on nominal data in Table 7.[20]

Compared with results based on real data, the Australian dollar and New Zealand dollar do not respond to the Metals sector RCPI variable in all the three time periods, and the Norwegian krone does not respond to the Energy sector RCPI in the pre-GFC period but responds to it in the post-GFC period. The Canadian dollar specification shows no change in the pattern of significant variables. The New Zealand dollar specification under the nominal data setting has neither significant sectoral RCPI nor US dollar variable in all the three sample periods.

In general, the use of nominal, compared with real, data alters the inference on sectoral commodity price effects and yields weaker evidence of commodity price effects on exchange rates. Nevertheless, these nominal data display heterogeneous effects of commodity prices on exchange rates and of the US dollar.

4.3 Macroeconomic Fundamentals

Third, we evaluate the effect of augmenting (3b) with macroeconomic fundamentals

$$\Delta reer_{c,t} = \alpha + \Sigma_{i\ =commodity\ sector}\beta_i \Delta rcp_{i,t} + \delta \Delta reer_{us,t} + \Sigma_{i\ =macro}\gamma_i \Delta z_{i,t} + \varepsilon_t , \qquad (4)$$

where $z_{i,t}$ is *i*-th macro variable and γ_i is its coefficient. We consider variables from the monetary model, which is the workhorse of exchange rate model comparison studies. Specifically, $\Delta z_{i,t}$'s include money supply growth rates, GDP growth rates, interest rates and inflation rates.

The results of estimating (4) are summarized in Table 8. The row labeled "F test" presents the F test statistics for the null hypothesis of the coefficients on the macro variables are jointly zero. These four commodity currencies respond differently to these macro variables. The F test indicates that the macro variables are jointly significant for the three New Zealand dollar cases and the Australian dollar and Norwegian krone specifications in the post-GFC period. The Canadian dollar shows no significant response. The diverse response pattern echoes the finding that exchange rate models have differential performance across historical time periods and currencies (Cheung, *et al*., 2019; Rossi, 2013).

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[19] See, for example, Chaban (2009), Chen (2004), Chen, *et al.* (2010), Ferraro, *et al*. (2015), and Zhang, *et al*. (2016).

[20] The data on nominal commodity price indexes are constructed based on (1) but without the MUV normalization.

The presence of these macro variables has some implications for the reported sectoral RCPI and the US dollar effects. It is noted that, depending on the currency and the sample period, the significance of the RCPIs and the US dollar REER variables can reverse in the presence of the macro variables. The inclusion of these macro variables slightly favors the significant commodity price effect result in the post-GFC period.

In a sense, our results are in line with the remark that "incorporating commodity prices into standard monetary-type regressions only underscores the 'fickleness' of standard models in the literature, and provides little support for a commodity-price-augmented Dornbusch model" (Chen and Rogoff, 2003).[21] Further, there is still evidence of the "fickleness" of commodity price and US dollar effects.

4.4 The GFC Period

The GFC was characterized by extreme conditions that impose strains on normal economic interactions.[22] To illustrate the GFC effect, Table 9 presents results of incorporating the GFC period 2007Q3 to 2008Q4 to either the pre-GFC or the post-GFC period. The including of these 6 crisis period observations yields a noticeable increase in the model's explanatory power as measured by adjusted R^2 estimates; especially for the pre-GFC case – the adjusted R^2 estimates of the Australian dollar, Canadian dollar, and Norwegian krone specifications increased to above 20%, and the New Zealand dollar specification turned from negative to positive. The finding corroborates the common belief that asset prices including exchange rates and commodity prices exhibit strong comovement during market turmoil (Appendix A.5.v).

As indicated by the *italic* font in Table 9 that signifies a change in the classification of significance (compared with Tables 4 and 5), the inclusion of the six crisis period observations at least from an empirical perspective has modified the evidence on the commodity price effect.

The sensitivity to the duration of the sample period buttresses the difficulty of inferring the commodity price effect. The empirical commodity price effect depends on the way the crisis effect is accounted for.

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21 In our case, a good number of macro variable estimates are different from their theoretical predictions.

22 Cheung, *et al.* (2019), for example, consider differential macro news effects in pre-GFC, GFC, and post-GFC periods.

4.5 Top Commodity Export Destination

The third-country exchange rate effect beyond the US dollar effect is not commonly addressed in the literature. The US dollar is included to control for its primary roles in the global commodity and global foreign exchange markets. Some countries in practice may implicitly (soft-)peg to their major trading partners to alleviate exchange rate volatility, while some let the market forces work. Heller (1978) and Melvin (1985) discuss the implications of major trading partners for exchange rate arrangement choices. To illustrate the possible trading partner effect, we consider

$$\Delta reer_{c,t} = \alpha + \Sigma_{i\ =commodity\ sector} \beta_i \Delta rcp_{i,t} + \delta \Delta reer_{us,t} + \Sigma_{i\ =1,2} \lambda_i \Delta w_{i,t} + \varepsilon_t\,, \qquad (5)$$

where $\Delta w_{i,t}$ s are the changes of log REERs of the top two commodity export markets. If the US is one of its top two commodity export destinations, then $\Delta w_{i,t}$ contains only the REER of the other top export destination. For Australia, Canada, Norway, and New Zealand, their top two commodity export markets are, respectively, Japan and China, the US and Japan, the Euro area[23] and the UK, and Australia and the US. With the exception of Canada, these are also the top two trading partners of these commodity exporting countries. Canada's top two trading partners are the US and China.[24]

Table 10 summarizes the results of estimating the augmented equation (5). In general, (5) offers a better explanatory power than (3b) in Tables 3 to 5 – the adjusted R^2 estimates are all larger except for the pre-GFC Canadian dollar case.

There are two cases in which the effect of trading partner's exchange rates is positive – the euro REER on the Norwegian krone in the full and pre-GFC periods, and the Australian REER on the New Zealand dollar in the three sample periods. The results can attribute to the fact that the euro and the Australian dollar have been the anchor currency of the Norwegian krone and the New Zealand dollar, respectively (Ilzetzki, *et al.*, 2019; Munro, 2004). The other trading partner currency effects, if statistically significant, are negative. It is noted that both effects of trading partner's exchange rate and the US dollar are not uniform across these commodity currencies and sample periods.

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23 Country-wise, the top one is the UK, the second, third, and fourth are Germany, Netherlands, and France.

24 The correlation between the REER variables of the US and these trading partners is typically not larger – only four of 18 estimates are larger than 0.5 (in absolute value) with the largest one being -0.601 between Australian and US REERs in the post-GFC period (Appendix A.5.iv).

The presence of exchange rates of trading partners alters the empirical sectoral RCPI effect. For instance, the Metals sector RCPI variable becomes insignificant for the Australian dollar (full and pre-GFC samples), Canadian dollar (pre-GFC sample) and the New Zealand dollar (full and post-GFC samples) regressions, while the Energy sector RCPI variable is significant for the Norwegian krone (post-GFC sample) and the New Zealand dollar (pre-GFC sample, but with a negative sign) regressions.

Overall, these additional regressions indicate that the heterogeneous commodity price effects are unlikely attributed to our choices of time-varying weights and real series, do not consistently enhance the performance of a monetary exchange rate model, and display discernible dependence on crisis events and exchange rates of major trading partners. These results cast doubts about the generality of the empirical commodity price effect and the related policy implications.[25]

5. Concluding Remarks

Using quarterly data on four commodity exporting countries, we conduct an in-sample analysis of real commodity price index (RCPI) effects on real effective exchange rates (REERs). While REERs respond to RCPIs, the pattern of responses is country-specific, displays non-uniform sectoral commodity effects, and changes over time. The US dollar effect is not as strong as anticipated - it mainly shows up in some cases in the post-GFC period. The heterogeneous RCPI effects are unlikely an artifact of the choices of time-varying weights and real data. The inclusion of commodity prices does not consistently improve the performance of a monetary exchange rate model. Further, the GFC and the exchange rates of top trading partners alter the empirical commodity price effect.

Compared with a mix of developed and developing countries, the four commodity exporting countries considered in the current paper are relatively homogenous small open developed economies. The differences between developed and developing countries do not play a significant role in generating these heterogeneous RCPI effects.

Our empirical results do not contradict the presence of commodity price effects. Instead, they highlight the heterogeneity of commodity price effects. Given the heterogeneous commodity

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25 We did a few additional investigations that include a) the asymmetric commodity price effect, b) the effect of interacting the US dollar and commodity price effects, and c) the bounds test. It turns out that these results are in general weak and insignificant, and they are available upon request.

price effect, one must be wary of using a single price model of exchange rate determination to explain a wide range of currencies across different historical time periods. The empirical heterogeneity is likely to attenuate the usefulness of a general commodity price-based exchange rate model. The Balassa-Samuelson setup outlined in Appendix A.1 and discussed in Section 2 indicates the possible roles of labor intensity, commodity productivity, and sectoral wage weights in determining the heterogeneous RCPI effect thereby warrants further investigation.

For commodity exporting countries, commodity price movements can have significant implications for their economies; the real exchange rate is a main conduit of commodity price effects on economic performance. Our empirical results provide a cautionary note regarding the indiscriminate use of empirical commodity price effect estimates in evaluating commodity price variability on the macro economy. Policymaking pertaining to commodity and exchange rate management should benefit from further detailed analyses of the response of commodity currencies to sectoral and even individual commodity prices under varying market conditions.

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Table 1. Aggregate and Sectoral Commodity Export Shares (%)

		Aggregate	Agriculture	Energy	Metals
Australia	Full	68.90	18.49	22.27	28.14
	Pre-GFC	63.59	23.42	18.56	21.61
	Post-GFC	76.80	12.11	27.07	37.62
Canada	Full	33.91	12.35	14.24	7.32
	Pre-GFC	29.35	13.24	10.23	5.88
	Post-GFC	40.22	11.51	19.35	9.36
Norway	Full	67.93	8.04	53.86	6.03
	Pre-GFC	65.48	7.77	51.22	6.49
	Post-GFC	70.85	9.06	56.55	5.24
New Zealand	Full	51.47	44.53	2.55	4.39
	Pre-GFC	51.50	44.51	2.05	4.94
	Post-GFC	51.75	45.43	2.81	3.51

Notes: The numbers are average export shares during a) "Full" – the full sample period 1990Q2-2019Q4, b) "Pre-GFC" – the pre-GFC period 1990Q2-2007Q2, and c) "Post-GFC" – the post-GFC period 2009Q1-2019Q4 period. See the text for definitions and information on the aggregate and sectoral commodity exports.

Table 2. Descriptive Statistics

			REER	Aggregate	Agriculture	Energy	Metals	R US$
Australia	Full	Mean	-0.016	0.215	-0.063	0.068	0.210	0.060
		SE	3.701	4.821	0.781	2.566	2.758	2.297
		Corr		0.459	0.394	0.378	0.338	-0.332
	Pre-GFC	Mean	0.096	0.356	-0.083	0.167	0.273	-0.030
		SE	3.190	2.366	0.842	1.212	1.219	2.179
		Corr		0.176	0.170	-0.013	0.236	0.090
	Post-GFC	Mean	0.245	-0.066	0.015	-0.260	0.179	0.185
		SE	3.278	5.853	0.597	2.618	4.000	2.153
		Corr		0.443	0.537	0.256	0.401	-0.601
Canada	Full	Mean	-0.199	0.073	-0.008	0.066	0.016	0.060
		SE	2.723	2.407	0.466	1.753	0.589	2.297
		Corr		0.520	0.249	0.500	0.440	-0.401
	Pre-GFC	Mean	-0.101	0.296	0.007	0.221	0.067	-0.030
		SE	2.478	1.226	0.433	0.830	0.396	2.179
		Corr		0.248	-0.104	0.324	0.205	-0.101
	Post-GFC	Mean	-0.132	-0.106	0.001	-0.167	0.060	0.185
		SE	2.567	2.561	0.419	1.963	0.609	2.153
		Corr		0.665	0.465	0.570	0.640	-0.635
Norway	Full	Mean	-0.183	0.361	-0.004	0.359	0.006	0.060
		SE	2.226	6.464	0.815	5.989	0.542	2.297
		Corr		0.485	0.308	0.455	0.296	-0.323
	Pre-GFC	Mean	-0.053	1.017	-0.040	0.982	0.074	-0.030
		SE	2.053	5.853	0.715	5.401	0.504	2.179
		Corr		0.318	0.362	0.290	0.065	-0.056
	Post-GFC	Mean	-0.259	-0.594	0.072	-0.678	0.012	0.185
		SE	2.089	5.614	0.982	5.304	0.418	2.153
		Corr		0.448	0.200	0.402	0.449	-0.396
New Zealand	Full	Mean	0.035	0.015	0.003	0.005	0.006	0.060
		SE	3.356	2.562	2.098	0.562	0.318	2.297
		Corr		0.312	0.246	0.312	0.338	-0.248
	Pre-GFC	Mean	0.160	0.079	0.030	0.024	0.025	-0.030
		SE	3.288	1.947	1.761	0.230	0.311	2.179
		Corr		0.010	0.002	-0.056	0.088	0.030
	Post-GFC	Mean	0.306	0.179	0.134	0.030	0.016	0.185
		SE	3.227	2.853	2.491	0.391	0.229	2.153
		Corr		0.476	0.406	0.548	0.582	-0.540

Notes: The rows “Mean” and “SE” present, respectively, the means and standard errors of the changes in the variables listed in the column headings. The row “*Corr*” presents the correlation estimates between changes in the REER and in the RCPI (or in the US REER) listed in the column headings. The label “Full” shows the results from the full sample period 1990Q2-2019Q4, the label “Pre-GFC” from the pre-GFC period 1990Q2-2007Q2, and the label “Post-GFC” from the period 2009Q1-2019Q4.

Table 3. Commodity Price Effects with and without Controlling for the US Dollar Effect

	(2a)	(2b)	(3-i)	(3-ii)	(3-iii)	(3a)	(3b)
Australia							
Aggregate	0.347*** (0.117)	0.296*** (0.109)					
Agriculture			1.869** (0.737)			1.272** (0.514)	1.145** (0.467)
Energy				0.546*** (0.208)		0.310 (0.199)	0.268 (0.197)
Metals					0.453*** (0.160)	0.230** (0.114)	0.192* (0.105)
R US$		-0.247 (0.209)					-0.231 (0.218)
Adjusted R^2	0.211	0.223	0.148	0.136	0.107	0.225	0.235
Canada							
Aggregate	0.580*** (0.079)	0.489*** (0.103)					
Agriculture			1.459 (0.891)			-0.552 (0.634)	-1.033 (0.739)
Energy				0.776*** (0.132)		0.618*** (0.152)	0.553*** (0.156)
Metals					2.035*** (0.503)	1.308** (0.519)	1.129** (0.504)
R US$		-0.165 (0.138)					-0.253 (0.161)
Adjusted R^2	0.269	0.275	0.054	0.243	0.187	0.281	0.303
Norway							
Aggregate	0.167*** (0.034)	0.147*** (0.034)					
Agriculture			0.842*** (0.234)			0.580*** (0.199)	0.527** (0.222)
Energy				0.169*** (0.038)		0.141*** (0.035)	0.133*** (0.035)
Metals					1.216** (0.568)	0.325 (0.393)	0.267 (0.373)
R US$		-0.115 (0.100)					-0.070 (0.104)
Adjusted R^2	0.229	0.233	0.087	0.200	0.080	0.242	0.239
New Zealand							
Aggregate	0.412** (0.175)	0.335* (0.184)					
Agriculture			0.393* (0.226)			0.163 (0.156)	0.146 (0.167)
Energy				1.862*** (0.549)		0.842 (0.574)	0.742 (0.630)
Metals					3.569** (1.491)	2.292* (1.290)	2.208* (1.267)
R US$		-0.161 (0.208)					-0.071 (0.180)
Adjusted R^2	0.093	0.094	0.052	0.090	0.106	0.120	0.114

Notes: The table summarizes the results of estimating (2a), (2b), (3a) and (3b) for the full sample period 1990Q2-2019Q4. Columns 3-i to 3-iii present the individual sectoral RCPI effects. Heteroskedasticity and autocorrelation consistent standard errors are in the parentheses underneath estimates. ***, **, and * indicate significance at the 1%, 5%, and 10% level. See the text for definitions of variables.

Table 4. Commodity Price Effects - Pre-GFC period

	(2a)	(2b)	(3-i)	(3-ii)	(3-iii)	(3a)	(3b)
Australia							
Aggregate	0.215	0.263					
	(0.165)	(0.188)					
Agriculture			0.645			0.458	0.399
			(0.482)			(0.422)	(0.477)
Energy				-0.034		-0.285	-0.270
				(0.301)		(0.236)	(0.276)
Metals					0.619*	0.610	0.754*
					(0.376)	(0.394)	(0.443)
R US$		0.211					0.248
		(0.247)					(0.253)
Adjusted R^2	0.014	0.019	0.014	-0.015	0.042	0.034	0.047
Canada							
Aggregate	0.493**	0.482**					
	(0.235)	(0.239)					
Agriculture			-0.596			-1.367*	-1.607
			(0.750)			(0.792)	(0.987)
Energy				0.967***		0.930**	0.912**
				(0.337)		(0.361)	(0.377)
Metals					1.280**	1.234***	1.143***
					(0.556)	(0.418)	(0.420)
R US$		-0.019					-0.135
		(0.166)					(0.207)
Adjusted R^2	0.048	0.034	-0.004	0.091	0.028	0.128	0.126
Norway							
Aggregate	0.111***	0.116***					
	(0.038)	(0.041)					
Agriculture			1.039***			0.904***	1.144***
			(0.323)			(0.307)	(0.423)
Energy				0.110***		0.082**	0.089**
				(0.040)		(0.039)	(0.040)
Metals					0.264	-0.340	-0.302
					(0.400)	(0.441)	(0.440)
R US$		0.044					0.175
		(0.126)					(0.144)
Adjusted R^2	0.087	0.075	0.118	0.071	-0.011	0.133	0.147
New Zealand							
Aggregate	0.019	0.037					
	(0.177)	(0.205)					
Agriculture			0.004			0.020	0.030
			(0.199)			(0.235)	(0.245)
Energy				-0.805		-1.496	-1.408
				(1.608)		(1.723)	(1.750)
Metals					0.930	1.309	1.349
					(1.425)	(1.447)	(1.482)
R US$		0.054					0.050
		(0.213)					(0.207)
Adjusted R^2	-0.015	-0.029	-0.015	-0.012	-0.007	-0.029	-0.044

Notes: The table summarizes the results of estimating (2a), (2b), (3a) and (3b) for the pre-GFC 1990Q2-2007Q2 period. See notes to Table 3.

Table 5. Commodity Price Effects - Post-GFC period

	(2a)	(2b)	(3-i)	(3-ii)	(3-iii)	(3a)	(3b)
Australia							
Aggregate	0.257***	0.141*					
	(0.062)	(0.078)					
Agriculture			2.951***			2.491***	0.943
			(0.764)			(0.927)	(0.892)
Energy				0.321*		-0.001	0.050
				(0.190)		(0.221)	(0.234)
Metals					0.329***	0.203*	0.150
					(0.112)	(0.121)	(0.121)
R US$		-0.747***					-0.616**
		(0.269)					(0.286)
Adjusted R^2	0.199	0.386	0.272	0.043	0.141	0.293	0.359
Canada							
Aggregate	0.660***	0.444***					
	(0.114)	(0.149)					
Agriculture			2.846***			0.522	-0.189
			(0.888)			(0.835)	(0.850)
Energy				0.745***		0.420***	0.362**
				(0.157)		(0.158)	(0.160)
Metals					2.695***	1.880***	1.409**
					(0.495)	(0.548)	(0.562)
R US$		-0.382*					-0.346*
		(0.202)					(0.202)
Adjusted R^2	0.445	0.488	0.197	0.309	0.395	0.471	0.495
Norway							
Aggregate	0.167***	0.126*					
	(0.062)	(0.066)					
Agriculture			0.425**			0.290	0.263
			(0.195)			(0.249)	(0.245)
Energy				0.158**		0.103*	0.097
				(0.070)		(0.062)	(0.063)
Metals					2.243***	1.460**	1.085
					(0.719)	(0.704)	(0.892)
R US$		-0.234					-0.129
		(0.159)					(0.193)
Adjusted R^2	0.183	0.211	0.017	0.142	0.182	0.209	0.200
New Zealand							
Aggregate	0.543***	0.261					
	(0.188)	(0.228)					
Agriculture			0.525**			0.088	0.044
			(0.214)			(0.200)	(0.214)
Energy				4.524***		2.275*	1.902
				(1.171)		(1.334)	(1.473)
Metals					8.213***	5.231**	4.299**
					(2.077)	(2.096)	(2.145)
R US$		-0.584*					-0.245
		(0.301)					(0.268)
Adjusted R^2	0.216	0.290	0.145	0.283	0.323	0.349	0.345

Notes: The table summarizes the results of estimating (2a), (2b), (3a) and (3b) for the post-GFC 2009Q1-2019Q4 period. See notes to Table 3.

Table 6. Sectoral Commodity Price Effects - RCPI data with Fixed Weights

	Australia			Canada		
	Full	Pre-GFC	Post- GFC	Full	Pre-GFC	Post- GFC
Agriculture	0.323***	0.089	0.176	-0.074	-0.160	-0.065
	(0.119)	(0.150)	(0.120)	(0.091)	(0.128)	(0.111)
Energy	0.014	-0.054	0.003	0.058**	*0.043*	0.059**
	(0.040)	(0.064)	(0.058)	(0.029)	*(0.046)*	(0.030)
Metals	0.114**	0.194**	*0.106***	0.123***	0.108***	0.145***
	(0.048)	(0.098)	*(0.053)*	(0.039)	(0.031)	(0.048)
R US$	-0.058	0.247	-0.419*	-0.233	-0.066	-0.399*
	(0.210)	(0.236)	(0.232)	(0.161)	(0.194)	(0.228)
Adjusted R^2	0.306	0.039	0.417	0.265	0.045	0.508

	Norway			New Zealand		
	Full	Pre-GFC	Post- GFC	Full	Pre-GFC	Post- GFC
Agriculture	0.053***	0.094***	0.020	0.057	-0.045	0.030
	(0.020)	(0.029)	(0.023)	(0.090)	(0.104)	(0.126)
Energy	0.072***	0.045**	*0.068***	-0.014	-0.016	-0.003
	(0.020)	(0.021)	*(0.033)*	(0.023)	(0.034)	(0.044)
Metals	0.020	-0.028	0.044	0.174***	0.078	0.210**
	(0.024)	(0.032)	(0.050)	(0.061)	(0.084)	(0.086)
R US$	-0.022	0.174	-0.092	-0.090	0.054	-0.349
	(0.105)	(0.138)	(0.187)	(0.184)	(0.219)	(0.276)
Adjusted R^2	0.273	0.173	0.235	0.136	-0.041	0.338

Notes: The table summarizes the results of estimating (3b) using RCPI data with fixed weights. The column labeled "Full" shows the results from the full sample period 1990Q2-2019Q4, the column labeled "Pre-GFC" from the pre-GFC period 1990Q2-2007Q2, and the column labeled "Post-GFC" from the period 2009Q1-2019Q4. See notes to Table 3.

Table 7. Sectoral Commodity Price Effects - Nominal Exchange Rates and Commodity Prices

	Australia			Canada		
	Full	Pre-GFC	Post-GFC	Full	Pre-GFC	Post-GFC
Agriculture	1.166**	0.583	0.524	-0.671	-0.886	-0.370
	(0.489)	(0.526)	(0.819)	(0.568)	(0.729)	(0.873)
Energy	0.216	-0.374	0.031	0.496***	0.764**	0.331**
	(0.217)	(0.267)	(0.234)	(0.161)	(0.318)	(0.164)
Metals	*0.170*	*0.745*	0.138	1.045*	0.995**	1.371**
	(0.108)	*(0.494)*	(0.117)	(0.561)	(0.490)	(0.644)
R US$	-0.230	0.315	-0.708**	-0.261	-0.103	-0.397*
	(0.237)	(0.258)	(0.296)	(0.166)	(0.196)	(0.214)
Adjusted R^2	0.210	0.063	0.360	0.325	0.101	0.484

	Norway			New Zealand		
	Full	Pre-GFC	Post-GFC	Full	Pre-GFC	Post-GFC
Agriculture	0.366*	1.083***	0.130	0.174	0.156	0.039
	(0.199)	(0.403)	(0.231)	(0.169)	(0.280)	(0.232)
Energy	0.112***	*0.056*	*0.110**	0.796	-1.568	1.915
	(0.035)	*(0.038)*	*(0.060)*	(0.715)	(1.822)	(1.652)
Metals	0.233	-0.229	0.454	*2.085*	1.441	*3.516*
	(0.378)	(0.421)	(1.043)	*(1.289)*	(1.419)	*(2.445)*
R US$	-0.168	0.095	-0.268	-0.049	0.052	-0.261
	(0.108)	(0.142)	(0.199)	(0.177)	(0.203)	(0.255)
Adjusted R^2	0.242	0.113	0.226	0.112	-0.037	0.296

Notes: The table summarizes the results of estimating (3b) using nominal exchange rate and commodity price data. See notes to Tables 3 and 6.

Table 8. Sectoral Commodity Price Effects in the Presence of Macroeconomic Fundamentals

	Australia			Canada		
	Full	Pre-GFC	Post-GFC	Full	Pre-GFC	Post-GFC
Agriculture	1.061**	0.337	-0.022	-0.800	-1.572	-0.165
	(0.493)	(0.549)	(1.025)	(0.788)	(1.017)	(0.947)
Energy	0.261	-0.296	0.009	0.657***	0.905**	0.467**
	(0.207)	(0.255)	(0.243)	(0.150)	(0.390)	(0.187)
Metals	0.210*	*0.610*	*0.277***	1.061**	1.415***	1.477**
	(0.115)	*(0.462)*	*(0.134)*	(0.515)	(0.419)	(0.625)
R US$	-0.177	0.304	-0.518*	-0.236	-0.179	*-0.257*
	(0.216)	(0.244)	(0.275)	(0.158)	(0.208)	*(0.181)*
F test	0.867	1.813	2.256*	1.022	1.243	1.688
Adjusted R^2	0.239	0.046	0.425	0.307	0.101	0.542
	Norway			**New Zealand**		
	Full	Pre-GFC	Post-GFC	Full	Pre-GFC	Post-GFC
Agriculture	0.527**	1.106***	0.346	0.158	0.082	-0.156
	(0.230)	(0.423)	(0.319)	(0.179)	(0.288)	(0.226)
Energy	0.195***	0.111**	*0.212****	0.570	-2.505	*2.185**
	(0.051)	(0.053)	*(0.079)*	(0.705)	(2.069)	*(1.264)*
Metals	0.396	-0.208	*2.026***	*2.123*	0.943	4.170**
	(0.384)	(0.459)	*(0.896)*	*(1.354)*	(1.551)	(2.061)
R US$	-0.029	0.177	-0.014	-0.054	0.053	-0.254
	(0.107)	(0.134)	(0.175)	(0.197)	(0.222)	(0.282)
F test	1.818	1.521	3.198**	2.031*	2.279*	2.141*
Adjusted R^2	0.253	0.142	0.322	0.126	-0.009	0.455

Notes: The table summarizes the results of estimating (4) that includes macro variables. The row labeled “F test” presents the F test statistics for the null hypothesis of the estimated coefficients on the macro variables are jointly zero. See the text for the list of macro variables and notes to Tables 3 and 6.

Table 9. Sensitivity to the Inclusion of the Crisis Period (1990Q2-2008Q4)

	Australia		Canada		Norway		New Zealand	
	1990Q2-2008Q4	2007Q3-2019Q4	1990Q2-2008Q4	2007Q3-2019Q4	1990Q2-2008Q4	2007Q3-2019Q4	1990Q2-2008Q4	2007Q3-2019Q4
Agriculture	0.782	*1.800**	-1.343	-0.077	0.900**	0.306	0.032	0.175
	(0.476)	*(1.045)*	(0.951)	(0.856)	(0.416)	(0.255)	(0.245)	(0.218)
Energy	*0.493**	0.196	0.758***	0.280*	0.141***	*0.131****	0.797	-0.402
	(0.263)	(0.184)	(0.251)	(0.167)	(0.051)	*(0.049)*	(0.742)	(0.705)
Metals	*0.341*	0.070	*0.694*	*0.713*	0.029	0.587	1.757	5.458***
	(0.380)	(0.116)	*(0.684)*	*(0.664)*	(0.496)	(0.631)	(1.407)	(1.665)
R US$	0.005	-0.671**	-0.192	-0.534**	0.025	-0.265	0.062	-0.270
	(0.315)	(0.277)	(0.222)	(0.240)	(0.151)	(0.163)	(0.212)	(0.243)
Adjusted R^2	0.214	0.554	0.220	0.505	0.249	0.429	0.028	0.403

Notes: The table summarizes the results of estimating (3b) for the augmented pre-GFC period (1990Q2-2008Q4) and the augmented post-GFC period (2007Q3-2019Q4). See notes to Tables 3 and 6.

Table 10. Currency Effects of Top Two Commodity Export Destinations

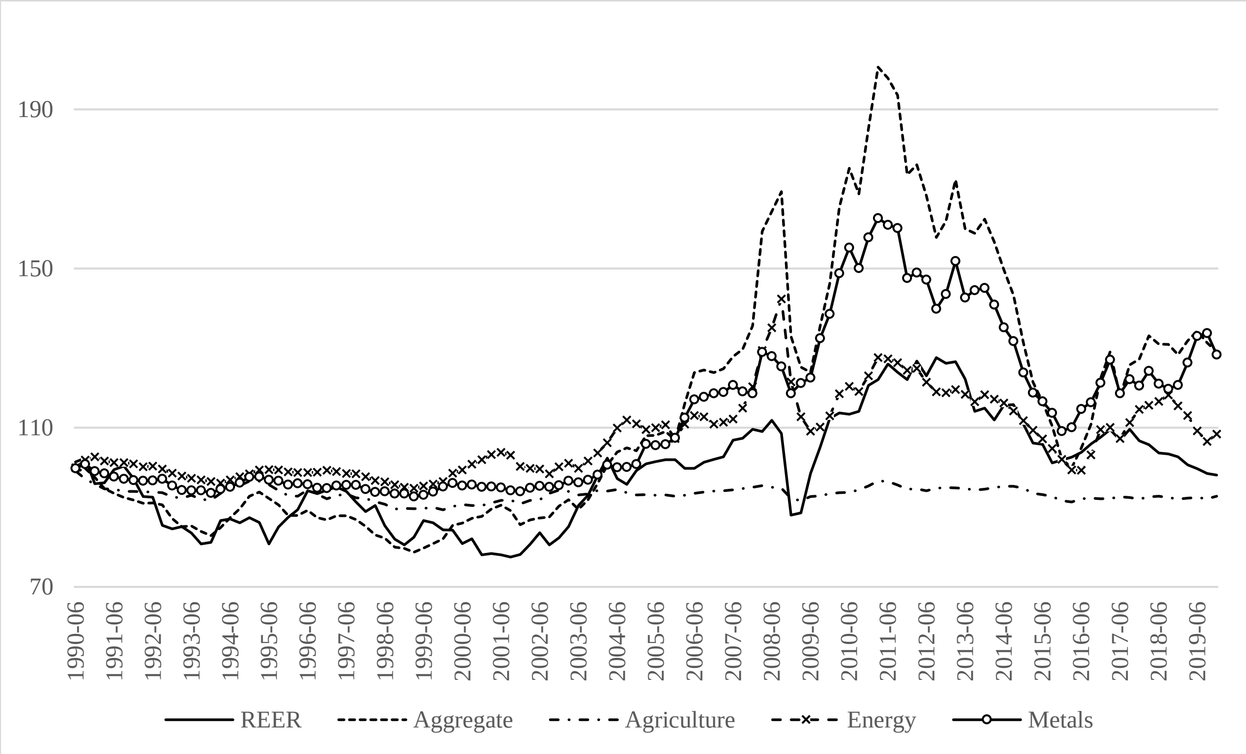
	Australia			Canada		
	Full	Pre-GFC	Post-GFC	Full	Pre-GFC	Post-GFC
Agriculture	0.811**	0.385	0.306	-0.967	-1.312	-0.190
	(0.384)	(0.390)	(0.742)	(0.698)	(0.974)	(0.876)
Energy	0.141	-0.209	0.060	0.463***	0.912***	0.362**
	(0.136)	(0.230)	(0.217)	(0.165)	(0.348)	(0.170)
Metals	*0.162*	*0.510*	0.081	0.893*	*0.629*	1.411**
	(0.108)	*(0.440)*	(0.116)	(0.493)	*(0.543)*	(0.592)
Top market 1	-0.305***	-0.233*	-0.138			
	(0.107)	(0.133)	(0.110)			
Top market 2	-0.198***	-0.119**	-0.773***	-0.114**	-0.136**	-0.003
	(0.049)	(0.051)	(0.230)	(0.051)	(0.067)	(0.075)
R US$	-0.279	0.081	-0.432**	*-0.331***	-0.254	*-0.346*
	(0.201)	(0.294)	(0.210)	*(0.154)*	(0.202)	*(0.211)*
F test	9.138***	2.892*	6.564***	3.536**	2.229	1.346
Adjusted R^2	0.364	0.112	0.499	0.327	0.158	0.481

	Norway			New Zealand		
	Full	Pre-GFC	Post-GFC	Full	Pre-GFC	Post-GFC
Agriculture	0.457**	0.860**	0.194	0.188	0.068	0.170
	(0.215)	(0.420)	(0.201)	(0.152)	(0.178)	(0.250)
Energy	0.147***	0.127***	*0.121****	*-1.138***	-1.292	0.428
	(0.035)	(0.040)	*(0.046)*	*(0.570)*	(1.618)	(1.656)
Metals	0.499	-0.264	0.630	*0.503*	-0.071	*1.345*
	(0.410)	(0.430)	(0.807)	*(1.150)*	(1.321)	*(2.491)*
Top market 1	0.215**	0.358***	0.029	0.591***	0.568***	0.469***
	(0.092)	(0.095)	(0.101)	(0.085)	(0.099)	(0.181)
Top market 2	-0.069	0.067	-0.390***			
	(0.069)	(0.070)	(0.104)			
R US$	0.070	*0.428****	-0.227	-0.090	-0.057	-0.122
	(0.117)	*(0.133)*	(0.171)	(0.143)	(0.178)	(0.229)
F test	4.916***	7.268***	9.332***	24.435***	16.633***	3.358**
Adjusted R^2	0.284	0.259	0.434	0.373	0.248	0.433

Notes: The table summarizes the results of estimating (5) in the text. The row labeled "F test" presents the F test statistics for the null hypothesis of the estimated coefficients on the REER changes of the top two commodity export markets are jointly zero. For Australia, Canada, Norway, and New Zealand, their top two commodity export markets are, respectively, Japan and China, the US and Japan, the Euro area and the UK, and Australia and the US. See notes to Tables 3 and 6.

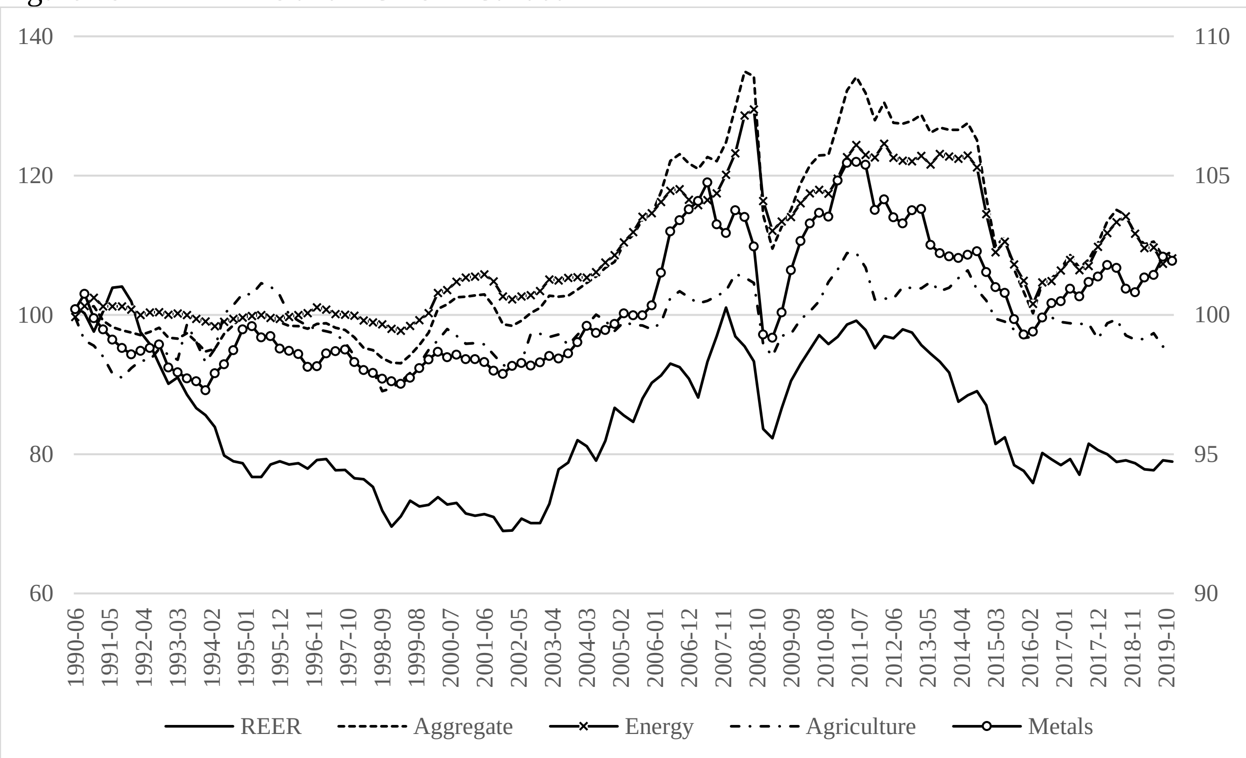
Figure 1. Country-Specific REERs and RCPIs

Figure 1a REERs and RCPIs in Australia



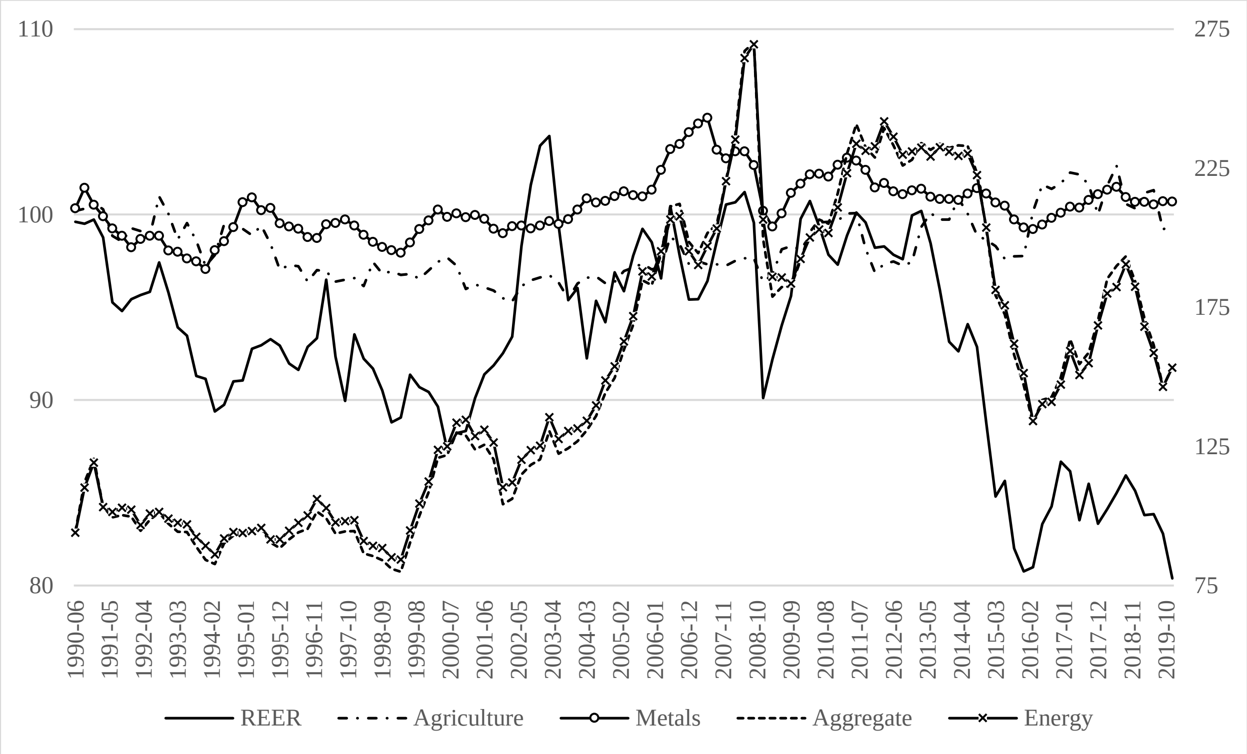
Note: All the indexes are normalized to 100 in 1990Q1.

Figure 1b REERs and RCPIs in Canada



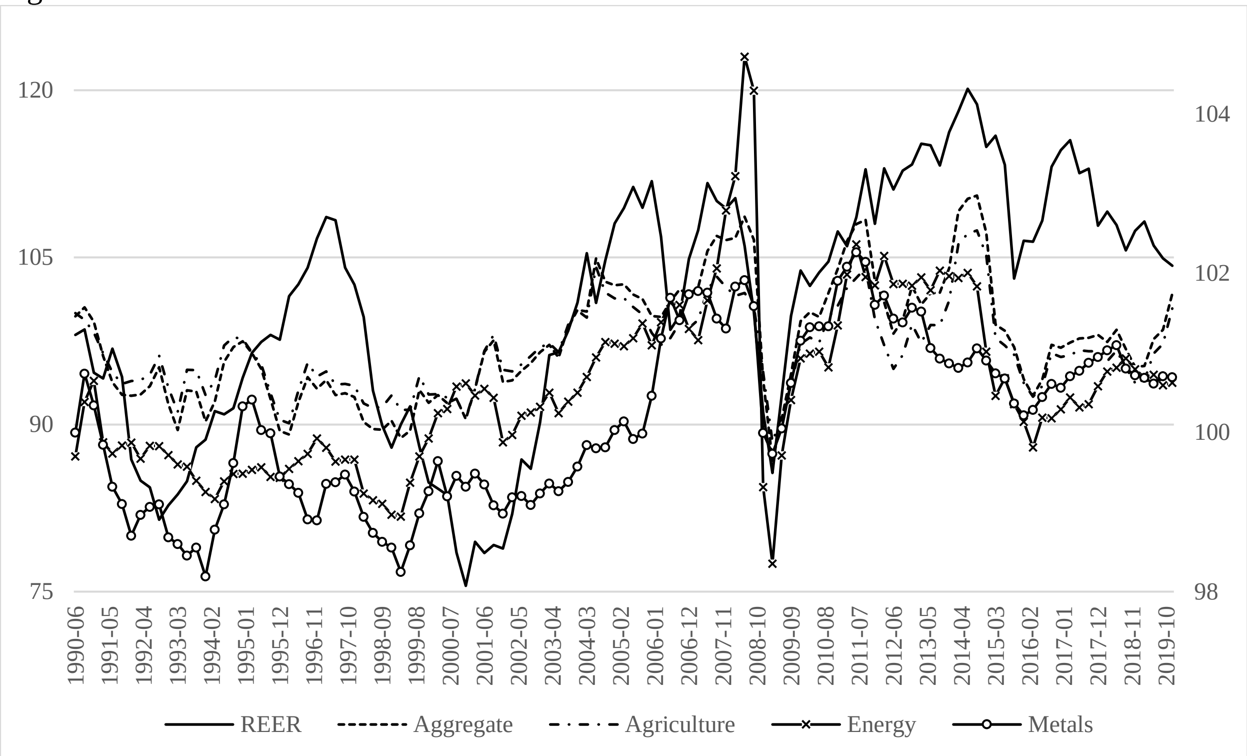
Notes: See note to Figure 1a. The scale on the right is for the Agriculture and Metals price indexes.

Figure 1c REERs and RCPIs in Norway



Notes: See note to Figure 1a. The scale on the right is for the Aggregate and Energy price indexes.

Figure 1d REERs and RCPIs in New Zealand



Notes: See note to Figure 1a. The scale on the right is for the Energy and Metals price indexes.

Appendix

A.1 A Modified Exchange Rate Model of Patel, *et al*. (2019)

The discussion below is based on the Global Value Chains REER model proposed by Patel, *et al*. (2019). The model has two countries: the home country and foreign country.

On production, the home country produces non-tradable final goods and a group of commodities. The foreign country produces non-tradable final goods and tradable final goods. The final goods are produced with two inputs: labor and commodities. The first order conditions of production that incorporate the Balassa-Samuelson effect yield the relationship between the price of final goods (non-tradable or tradable goods) and the prices of commodities.

On consumption, the home country consumes the non-tradable final goods and the tradable final goods imported from the foreign country. The foreign country consumes the non-tradable final goods and the tradable final goods. The first order conditions identify the proportions of non-tradable and tradable goods in each country that are used to construct the home country and foreign country price indexes.

Some specifics of the setup are outlined below.

A.1.i Production

The home country production function of the *i*-th commodity (*i* = 1, 2, 3…, m) is:

$$Q_{ci} = A_{ci}\beta_i L_{ci}\,, \qquad \text{(A.1.1)}$$

where Q_{ci} is the *i*-th commodity output, A_{ci} is the productivity, L_{ci} is the labor input, and $0 < \beta_i < 1$ is the labor intensity in commodity production.

The production function of non-tradable final goods is:

$$Q_N = A_N[(L_N)^{\frac{\sigma_N - 1}{\sigma_N}} + (COM_N)^{\frac{\sigma_N - 1}{\sigma_N}}]^{\frac{\sigma_N}{\sigma_N - 1}}\,, \qquad \text{(A.1.2)}$$

where Q_N is the output of non-tradable final goods, A_N is its productivity, L_N is the labor input, COM_N is the aggregate commodity input, σ_N is the elasticity of substitution between labor and commodity.

The aggregate commodity input is:

$$COM_N = [\Sigma_i (C_{Ni})^{\frac{\sigma_{Nc} - 1}{\sigma_{Nc}}}]^{\frac{\sigma_{Nc}}{\sigma_{Nc} - 1}}\,, \qquad \text{(A.1.3)}$$

where C_{Ni} is the *i*-th commodity input, σ_{Nc} is the elasticity of substitution among commodities.

The foreign country production function of the non-tradable final goods is

$$Q_N^* = A_N^*[(L_N^*)^{\frac{\sigma_N^* - 1}{\sigma_N^*}} + (COM_N^*)^{\frac{\sigma_N^* - 1}{\sigma_N^*}}]^{\frac{\sigma_N^*}{\sigma_N^* - 1}}\,, \qquad \text{(A.1.4)}$$

$$COM_N^* = [\Sigma_i (C_{Ni}^*)^{\frac{\sigma_{Nc}^* - 1}{\sigma_{Nc}^*}}]^{\frac{\sigma_{Nc}^*}{\sigma_{Nc}^* - 1}} \qquad \text{(A.1.5)}$$

where "*" indicates parameters and variables of the foreign country.

The production function of tradable final goods is

$$Q_T^* = A_T^*[(L_T^*)^{\frac{\sigma_T^* - 1}{\sigma_T^*}} + (COM_T^*)^{\frac{\sigma_T^* - 1}{\sigma_T^*}}]^{\frac{\sigma_T^*}{\sigma_T^* - 1}}\,, \qquad \text{(A.1.6)}$$

$$COM_T^* = [\Sigma_i (C_{Ti}^*)^{\frac{\sigma_{Tc}^* - 1}{\sigma_{Tc}^*}}]^{\frac{\sigma_{Tc}^*}{\sigma_{Tc}^* - 1}} \qquad \text{(A.1.7)}$$

where the subscript "*T*" indicates "tradable" goods.

A.1.ii Consumption

The home country consumption function is

$$F = [(Q_N)^{\frac{\theta-1}{\theta}} + (\kappa Q_T^*)^{\frac{\theta-1}{\theta}}]^{\frac{\theta}{\theta-1}} \quad \text{(A.1.8)}$$

where Q_N is the home non-tradable final goods, Q_T^* is the foreign tradable final goods, κ is the share of tradable final goods imported by the home country, θ is the elasticity of substitution between non-tradable final goods and imported final goods.

The foreign country consumption function is

$$F^* = \{(Q_N^*)^{\frac{\theta^*-1}{\theta^*}} + [(1-\kappa)Q_T^*]^{\frac{\theta^*-1}{\theta^*}}\}^{\frac{\theta^*}{\theta^*-1}} \quad \text{(A.1.9)}$$

where the "*" indicates the foreign country parameters and inputs.

A.1.iii First order conditions of productions

In the home country, the first order condition of commodity production is:

$$\frac{\mathrm{d}(P_{ci}Q_{ci} - w_{ci}L_{ci})}{\mathrm{d}(L_{ci})} = P_{ci}A_{ci}\beta_i - w_{ci} = 0 \Rightarrow P_{ci}A_{ci}\beta_i = w_{ci}, \quad \text{(A.1.10)}$$

where P_{ci} is the price of the *i*-th commodity, and w_{ci} is the labor wage rate prevailing in the *i*-th commodity sector.

The first order conditions of non-tradable final goods are:

$$\frac{\mathrm{d}(P_N Q_N - w_N L_N - \Sigma_i P_{ci} C_{Ni})}{\mathrm{d}(L_N)} = P_N A_N (Q_N / A_N)^{1/\sigma_N} (L_N)^{-1/\sigma_N} - w_N = 0 \quad \text{(A.1.11)}$$

$$\Rightarrow P_N = w_N (L_N)^{1/\sigma_N} [A_N (Q_N / A_N)^{1/\sigma_N}]^{-1}$$

$$\frac{\mathrm{d}(P_N Q_N - w_N L_N - \Sigma_i P_{ci} C_{Ni})}{\mathrm{d}(C_{Ni})} = \frac{\mathrm{d}(P_N Q_N)}{\mathrm{d}(COM_N)} \frac{\mathrm{d}(COM_N)}{\mathrm{d}(C_{Ni})} - \frac{\mathrm{d}(\Sigma_i P_{ci} C_{Ni})}{\mathrm{d}(C_{Ni})}$$

$$= P_N A_N (Q_N / A_N)^{1/\sigma_N} (COM_N)^{\frac{\sigma_N - \sigma_{Nc}}{\sigma_{Nc}\sigma_N}} (C_{Ni})^{-1/\sigma_{Nc}} - P_{ci} = 0 \quad \text{(A.1.12)}$$

$$\Rightarrow P_N = P_{ci} (COM_N)^{\frac{\sigma_{Nc} - \sigma_N}{\sigma_{Nc}\sigma_N}} (C_{Ni})^{1/\sigma_{Nc}} [A_N (Q_N / A_N)^{1/\sigma_N}]^{-1}$$

Assuming the labor moves freely across sectors, and the wage rates of labors in commodity sectors and non-tradable sector are the same. That is,

$$w_N = w_{ci} = \Sigma \tau_i w_{ci} \quad \text{(A.1.13)}$$

where τ_i is the sectoral wage weight of the *i*-th commodity and $\Sigma \tau_i = 1$. One possible way to specify τ_i is $\tau_i = C_{Ni} / \Sigma_i C_{Ni}$, which is the ratio of the *i*-th commodity input to the total commodity input in producing the non-tradable products.

Similarly, in the foreign country, the first order conditions of non-tradable goods production and tradable goods production are:

$$\frac{\mathrm{d}(P_N^* Q_N^* - w_N^* L_N^* - \Sigma_i P_{ci}^* C_{Ni}^*)}{\mathrm{d}(L_N^*)} = P_N^* A_N^* (Q_N^* / A_N^*)^{1/\sigma_N^*} (L_N^*)^{-1/\sigma_N^*} - w_N^* = 0 \quad \text{(A.1.14)}$$

$$\Rightarrow P_N^* = w_N^* (L_N^*)^{1/\sigma_N^*} [A_N^* (Q_N^* / A_N^*)^{1/\sigma_N^*}]^{-1}$$

$$\frac{\mathrm{d}(P_N^* Q_N^* - w_N^* L_N^* - \Sigma_i P_{ci}^* C_{Ni}^*)}{\mathrm{d}(C_{Ni}^*)} = \frac{\mathrm{d}(P_N^* Q_N^*)}{\mathrm{d}(COM_N^*)} \frac{\mathrm{d}(COM_N^*)}{\mathrm{d}(C_{Ni}^*)} - \frac{\mathrm{d}(\Sigma_i P_{ci}^* C_{Ni}^*)}{\mathrm{d}(C_{Ni}^*)}$$

$$= P_N^* A_N^* (Q_N^* / A_N^*)^{1/\sigma_N^*} (COM_N^*)^{\frac{\sigma_N^* - \sigma_{Nc}^*}{\sigma_{Nc}^*\sigma_N^*}} (C_{Ni}^*)^{-1/\sigma_{Nc}^*} - P_{ci}^* = 0$$

$$\Rightarrow P_N^* = P_{ci}^* (COM_N^*)^{\frac{\sigma_{Nc}^* - \sigma_N^*}{\sigma_{Nc}^* \sigma_N^*}} (C_{Ni}^*)^{1/\sigma_{Nc}^*} [A_N^* (Q_N^* / A_N^*)^{1/\sigma_N^*}]^{-1} \quad \text{(A.1.15)}$$

where P_{ci}^* is the foreign country price of the *i*-th commodity. Assuming the Law of One Price, $P_{ci} = eP_{ci}^*$, where *e* is the nominal exchange rate.

$$\frac{\mathrm{d}(P_T^* Q_T^* - w_T^* L_T^* - \Sigma_i P_{ci}^* C_{Ti}^*)}{\mathrm{d}(L_T^*)} = P_T^* A_T^* (Q_T^* / A_T^*)^{1/\sigma_T^*} v_L^{1/\sigma_T^*} (L_T^*)^{-1/\sigma_T^*} - w_T^* = 0 \quad \text{(A.1.16)}$$

$$\Rightarrow P_T^* = w_T^* (L_T^*)^{1/\sigma_T^*} [A_T^* (Q_T^* / A_T^*)^{1/\sigma_T^*}]^{-1}$$

$$\frac{\mathrm{d}(P_T^* Q_T^* - w_T^* L_T^* - \Sigma_i P_{ci}^* C_{Ti}^*)}{\mathrm{d}(C_{Ti}^*)} = \frac{\mathrm{d}(P_T^* Q_T^*)}{\mathrm{d}(COM_T^*)} \frac{\mathrm{d}(COM_T^*)}{\mathrm{d}(C_{Ti}^*)} - \frac{\mathrm{d}(\Sigma_i P_{ci}^* C_{Ti}^*)}{\mathrm{d}(C_{Ti}^*)}$$

$$= P_T^* A_T^* (Q_T^* / A_T^*)^{1/\sigma_T^*} (COM_T^*)^{\frac{\sigma_T^* - \sigma_{Tc}^*}{\sigma_{Tc}^* \sigma_T^*}} (C_{Ti}^*)^{-1/\sigma_{Tc}^*} - P_{ci}^* = 0 \quad \text{(A.1.17)}$$

$$\Rightarrow P_T^* = P_{ci}^* (COM_T^*)^{\frac{\sigma_{Tc}^* - \sigma_T^*}{\sigma_{Tc}^* \sigma_T^*}} (C_{Ti}^*)^{1/\sigma_{Tc}^*} [A_T^* (Q_T^* / A_T^*)^{1/\sigma_T^*}]^{-1}$$

A.1.iv First order conditions of consumptions

In the home country, the first order conditions of consumption are

$$\frac{\mathrm{d}(F - P_N Q_N - P_T \kappa Q_T^*)}{\mathrm{d}(Q_N)} = F^{\frac{1}{\theta}} (Q_N)^{-\frac{1}{\theta}} - P_N = 0 \Rightarrow Q_N = P_N^{-\theta} F \quad \text{(A.1.18)}$$

$$\frac{\mathrm{d}(F - P_N Q_N - P_T \kappa Q_T^*)}{\mathrm{d}(\kappa Q_T^*)} = F^{\frac{1}{\theta}} (\kappa Q_T^*)^{-\frac{1}{\theta}} - P_T = 0 \Rightarrow \kappa Q_T^* = P_T^{-\theta} F \quad \text{(A.1.19)}$$

In the foreign country, the first order conditions of consumption are

$$\frac{\mathrm{d}[F^* - P_N^* Q_N^* - P_T^* (1-\kappa) Q_T^*]}{\mathrm{d}(Q_N^*)} = (F^*)^{\frac{1}{\theta^*}} (Q_N^*)^{-\frac{1}{\theta^*}} - P_N^* = 0 \Rightarrow Q_N^* = (P_N^*)^{-\theta^*} F^* \quad \text{(A.1.20)}$$

$$\frac{\mathrm{d}[F^* - P_N^* Q_N^* - P_T^* (1-\kappa) Q_T^*]}{\mathrm{d}[(1-\kappa) Q_T^*]} = F^{\frac{1}{\theta^*}} [(1-\kappa) Q_T^*]^{-\frac{1}{\theta^*}} - P_T^* = 0$$

$$\Rightarrow (1-\kappa) Q_T^* = (P_T^*)^{-\theta^*} F^* \quad \text{(A.1.21)}$$

A.1.v The price index in home and foreign country

The home and foreign country price indexes are,

$$P = P_N \frac{Q_N}{F} + P_T \frac{\kappa Q_T^*}{F} = P_N^{1-\theta} + P_T^{1-\theta} \quad \text{(A.1.22)}$$

and

$$P^* = P_N^* \frac{Q_N^*}{F^*} + P_T^* \frac{(1-\kappa) Q_T^*}{F^*} = (P_N^*)^{1-\theta^*} + (P_T^*)^{1-\theta^*} \quad \text{(A.1.23)}$$

According to equation (A.1.10), (A.1.11) and (A.1.13), it can be shown that

$$P_N = \Sigma \tau_i P_{ci} A_{ci} \beta_i (L_N)^{1/\sigma_N} [A_N (Q_N / A_N)^{1/\sigma_N}]^{-1}, \quad \text{(A.1.24)}$$

and the non-tradable price can be determined assuming labor mobility and commodity prices are exogenous. From (A.1.14) and (A.1.16),

$$P_T^* = P_N^* (L_T^*)^{1/\sigma_T^*} (L_N^*)^{-1/\sigma_N^*} [A_T^* (Q_T^* / A_T^*)^{1/\sigma_T^*}]^{-1} [A_N^* (Q_N^* / A_N^*)^{1/\sigma_N^*}]. \quad \text{(A.1.25)}$$

Assume $\gamma_{TN}^* = \{(L_T^*)^{1/\sigma_T^*} (L_N^*)^{-1/\sigma_N^*} [A_T^* (Q_T^* / A_T^*)^{1/\sigma_T^*}]^{-1} [A_N^* (Q_N^* / A_N^*)^{1/\sigma_N^*}]\}^{1-\theta^*}$.

Then, the real exchange rate given by the home-to-foreign price ratio is

$$\frac{P}{eP^*}=\frac{1}{e}\frac{P_N^{1-\theta}+P_T^{1-\theta}}{(P_N^*)^{1-\theta^*}+(P_T^*)^{1-\theta^*}}=\frac{1}{e(1+\gamma_{TN}^*)}\frac{P_N^{1-\theta}+(eP_T^*)_T^{1-\theta}}{(P_N^*)^{1-\theta^*}}$$
$$=\frac{1}{e(1+\gamma_{TN}^*)}[\frac{P_N^{1-\theta}}{(P_N^*)^{1-\theta^*}}+\lambda(P_N^*)^{\theta^*-\theta}] \qquad (A.1.26)$$

where $\lambda=\{e(L_T^*)^{1/\sigma_T^*}(L_N^*)^{-1/\sigma_N^*}[A_T^*(Q_T^*/A_T^*)^{1/\sigma_T^*}]^{-1}[A_N^*(Q_N^*/A_N^*)^{1/\sigma_N^*}]\}^{1-\theta}$.

For simplicity, if we assume the preferences in two countries are the same; that is, the home and foreign country elasticities of substitution between non-tradable final goods and tradable final goods are same ($\theta=\theta^*$), then the second term in the square brackets in equation (A.1.26) drops out.

On P_N^*, from (A.1.15) and assume $\Sigma\tau_i^*=1$ (and $\tau_i^*=C_{Ni}^*/\Sigma_i C_{Ni}^*$), we have

$$P_N^*=\Sigma\tau_i^*P_{ci}^*(COM_N^*)^{\frac{\sigma_{Nc}^*-\sigma_N^*}{\sigma_{Nc}^*\sigma_N^*}}(C_{Ni}^*)^{1/\sigma_{Nc}^*}[A_N^*(Q_N^*/A_N^*)^{1/\sigma_N^*}]^{-1}. \qquad (A.1.27)$$

Then,

$$\frac{P_N^{1-\theta}}{(P_N^*)^{1-\theta^*}}=\eta\frac{(\Sigma\tau_iP_{ci}A_{ci}\beta_i)^{1-\theta}}{(\Sigma\tau_i^*P_{ci})^{1-\theta^*}}, \qquad (A.1.28)$$

where $\eta=\dfrac{\{(L_N)^{1/\sigma_N}[A_N(Q_N/A_N)^{1/\sigma_N}]^{-1}\}^{1-\theta}}{\{e^{-1}(COM_N^*)^{\frac{\sigma_{Nc}^*-\sigma_N^*}{\sigma_{Nc}^*\sigma_N^*}}(C_{Ni}^*)^{1/\sigma_{Nc}^*}[A_N^*(Q_N^*/A_N^*)^{1/\sigma_N^*}]^{-1}\}^{1-\theta^*}}$,

and is not related to commodity prices. Thus, (A.1.26), (A.1.27) and (A.1.28) imply the real exchange rate depends on τ_i, τ_i^*, β_i θ and θ^*. It could be shown that commodity prices positively affect the non-tradable price ratio if $A_{ci}\beta_i-\frac{\Sigma\tau_iP_{ci}A_{ci}\beta_i}{\Sigma\tau_i^*P_{ci}}\frac{\tau_i^*}{\tau_i}$ > 0. That is the commodity price effect depends on the labor intensity (β_i), commodity productivity (A_{ci}), and the relative ratio between cross-country sectoral wage weights (τ_i and τ_i^*). Note that these terms can change over time, which makes the effect time-varying.

Note that we do not work with a full-blown model, which requires additional assumptions on, for example, the market clearing conditions, trade balance, budget constraints, …, *etc*. However, for the purpose of illustrating the factors affecting the commodity price effect, we do not have to solve the model completely.

A.2 Measures of Openness, and Global FX Average Daily Turnover Ratios

	Openness I: Total Trade/GDP (%)	Openness II: Export/GDP (%)	Ranking of Global FX Turnover	Daily Turnover/GDP (%)	Daily Turnover/ Total Trade (%)
Australia	*34.75*	*18.10*	*5th*	*31.31*	*90.11*
Canada	*54.71*	*26.18*	*6th*	*19.51*	*35.66*
New Zealand	*40.94*	*19.77*	*10th*	*66.84*	*163.27*
Norway	*49.11*	*28.24*	*14th*	*27.65*	*56.30*

Notes: The Table lists two openness measures (total trade/GDP and exports/GDP), rankings of global FX average daily turnover, daily turnover to GDP ratios, and daily turnover to international trade ratios. Data on FX turnover are from BIS (2019), on GDP and international trade volume are from, respectively, IFS and IMF DOTS.

A.3 List of Individual Commodities

Agriculture			Energy	Metals
Apple	Legumes	Soya Bean Oil	Coal	Aluminum
Banana	Milk	Soybeans	Crude Oil	Cobalt
Barley	Natural Rubber	Sugar	Natural Gas	Copper
Beef	Oats	Sunflower Seed Oil		Gold
Cocoa	Olive Oil	Swine Meat		Iron Ore
Coffee	Oranges	Tea		Lead
Corn	Palm Kernel Oil	Timber		Molybdenum
Cotton	Palm Oil	Tobacco		Nickel
Fish	Plywood	Tomatoes		Palladium
Groundnuts	Poultry	Wheat		Platinum
Groundnuts Oil	Rapeseed Oil	Wood Pulp		Silver
Hides	Rice	Wool		Tin
Lamb	Shrimp			Zinc

Notes: The classification is based on IMF Primary Commodity Price database and the World Bank Commodities Price data. Copra is not included due to the lack of data.

A.4 Data

Here is a summary of the data source:

a. CPI-based real and nominal effective exchange rates are from IFS database.

b. Commodity prices are from the IMF Primary Commodity Price database and the World Bank Commodities Price data.

c. Manufactured exports unit value (MUV) index is from the Bloomberg.

d. Commodity export values are from the UN Comtrade database.

e. Nominal GDP data are from IFS, money supply (M3, M1 for New Zealand) and CPI inflation data from the OECD Main Economic Indicators database, and interest rates are euro-currency deposit rates from the DataStream.

A.5 Correlations and Graphs

A.5.i Full Sample

		REER	Aggregate	Agriculture	Energy	Metals
Australia	Aggregate	0.467				
	Agriculture	0.394	0.522			
	Energy	0.378	0.807	0.351		
	Metals	0.338	0.844	0.296	0.407	
	R US$	-0.332	-0.448	-0.315	-0.347	-0.335
Canada	Aggregate	0.524				
	Agriculture	0.249	0.680			
	Energy	0.500	0.939	0.485		
	Metals	0.440	0.748	0.532	0.521	
	R US$	-0.401	-0.594	-0.579	-0.480	-0.490
Norway	Aggregate	0.485				
	Agriculture	0.308	0.333			
	Energy	0.455	0.987	0.200		
	Metals	0.296	0.515	0.258	0.429	
	R US$	-0.323	-0.477	-0.378	-0.428	-0.388
New Zealand	Aggregate	0.317				
	Agriculture	0.246	0.960			
	Energy	0.312	0.652	0.438		
	Metals	0.338	0.572	0.380	0.583	
	R US$	-0.248	-0.534	-0.430	-0.536	-0.447

A.5.ii Pre-Crisis Period (1990Q2-2007Q2)

		REER	Aggregate	Agriculture	Energy	Metals
Australia	Aggregate	0.169				
	Agriculture	0.170	0.602			
	Energy	-0.013	0.720	0.197		
	Metals	0.236	0.798	0.304	0.308	
	R US$	0.090	-0.261	-0.015	-0.117	-0.309
Canada	Aggregate	0.249				
	Agriculture	-0.104	0.609			
	Energy	0.324	0.839	0.200		
	Metals	0.205	0.669	0.367	0.305	
	R US$	-0.101	-0.348	-0.409	-0.160	-0.267
Norway	Aggregate	0.317				
	Agriculture	0.362	0.439			
	Energy	0.290	0.988	0.319		
	Metals	0.065	0.403	0.260	0.309	
	R US$	-0.056	-0.311	-0.494	-0.254	-0.197
New Zealand	Aggregate	0.011				
	Agriculture	0.002	0.974			
	Energy	-0.056	0.468	0.320		
	Metals	0.088	0.393	0.204	0.363	
	R US$	0.030	-0.296	-0.246	-0.279	-0.214

A.5.iii Post-Crisis Period (2009Q1-2019Q4)

		REER	Aggregate	Agriculture	Energy	Metals
Australia	Aggregate	0.467				
	Agriculture	0.537	0.497			
	Energy	0.256	0.730	0.350		
	Metals	0.401	0.908	0.340	0.398	
	R US$	-0.601	-0.430	-0.715	-0.206	-0.356
Canada	Aggregate	0.676				
	Agriculture	0.465	0.651			
	Energy	0.570	0.935	0.473		
	Metals	0.640	0.725	0.510	0.467	
	R US$	-0.635	-0.690	-0.668	-0.520	-0.661
Norway	Aggregate	0.449				
	Agriculture	0.200	0.185			
	Energy	0.402	0.979	-0.007		
	Metals	0.449	0.570	0.223	0.481	
	R US$	-0.396	-0.456	-0.222	-0.388	-0.641
New Zealand	Aggregate	0.484				
	Agriculture	0.406	0.984			
	Energy	0.548	0.647	0.524		
	Metals	0.582	0.643	0.522	0.639	
	R US$	-0.540	-0.644	-0.560	-0.642	-0.688

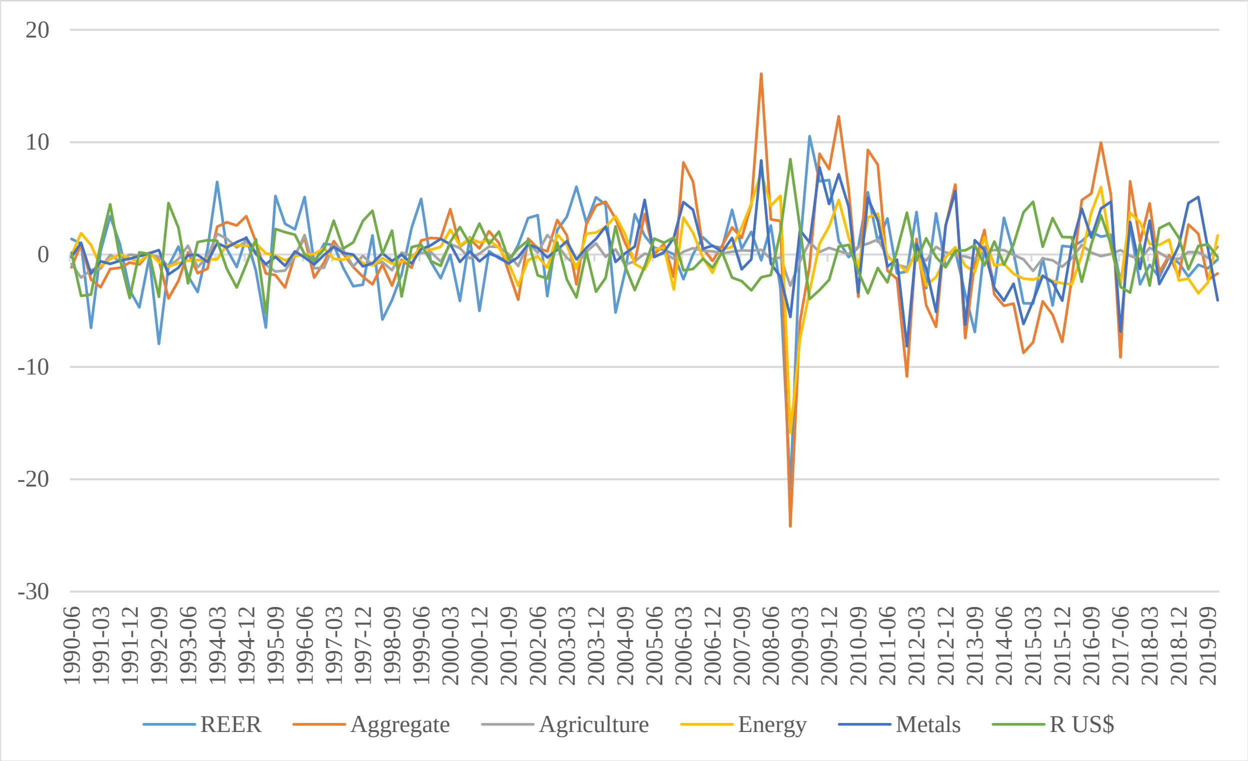
A.5.iv Correlations between changes of log US REER and of log REER of the top two commodity export destinations

		Australia	Canada	Norway	New Zealand
Full Period	Top market 1	-0.104	-	-0.510	-0.332
	Top market 2	0.318	-0.104	-0.131	-
Pre-Crisis	Top market 1	-0.425	-	-0.595	0.090
	Top market 2	0.271	-0.425	-0.050	-
Post-Crisis	Top market 1	0.014	-	-0.317	-0.601
	Top market 2	0.467	0.014	-0.138	-

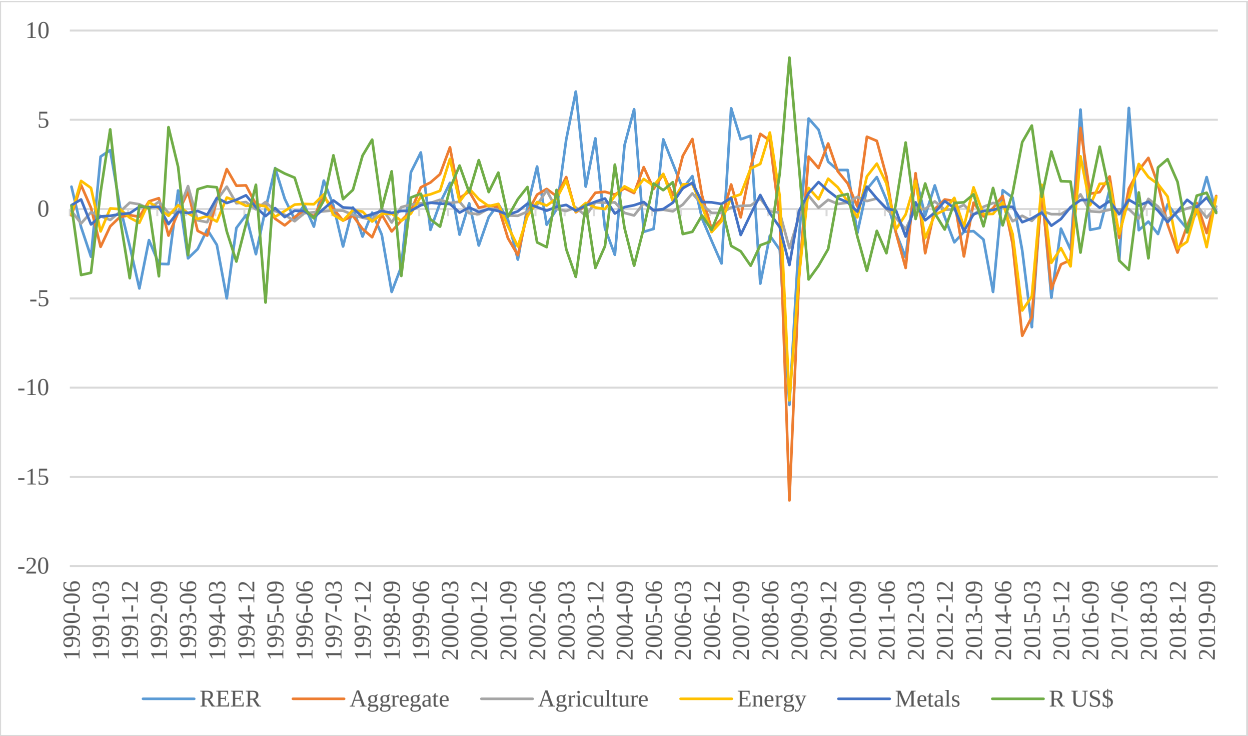
Notes: For Australia, Canada, Norway, and New Zealand, their top two commodity export markets are, respectively, Japan and China, the US and Japan, the Euro area and the UK, and Australia and the US.

A.5.v Graphs of Changes in REERs and RCPIs

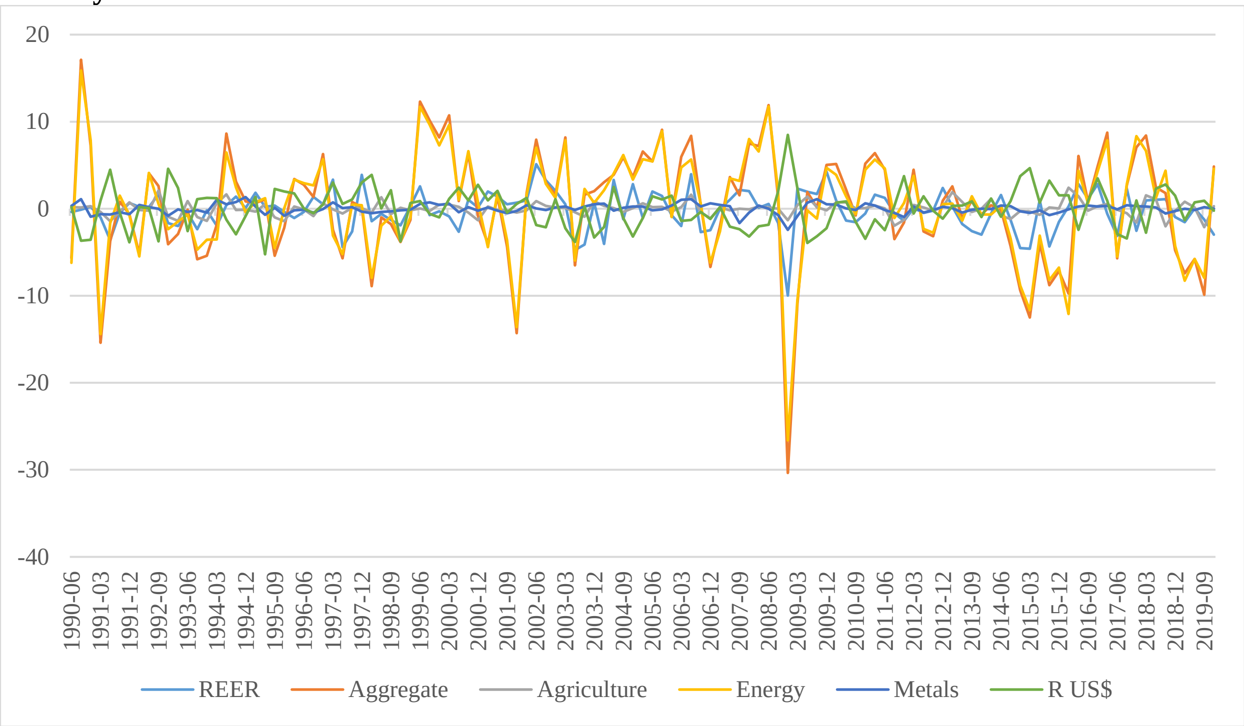
Australia



Canada



Norway



New Zealand