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Oil price drivers, geopolitical uncertainty and oil exporters' currencies

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Oil price drivers, geopolitical uncertainty and oil exporters' currencies

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Abstract

Empirical relationships between crude oil prices and exchange rates of oil exporting countries tend to vary over time. I use econometric models of the Norwegian and Canadian nominal exchange rates to investigate whether such time-variation could reflect shifts in the key oil price drivers over time. Results suggest that demand- and supply-driven oil price increases strengthen these currencies to different extents. In contrast, heightened geopolitical uncertainty and associated oil price increases go together with a weakening of oil exporters' currencies. The latter result may explain coincidences of higher oil prices and a weakening of oil exporters' currencies.

Keywords: Exchange rates, commodity currencies, oil prices, uncertainty.

JEL Codes: *F31, F32, Q41, C22, C51.*

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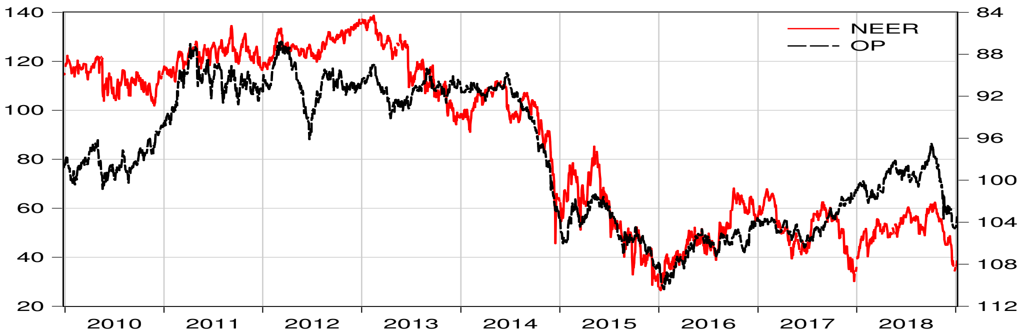
1 Introduction

Exchange rates of major oil exporters tend to appreciate when oil prices increase and depreciate when they fall.[1] However, the strength of this relationship varies over time and even switch signs with e.g. high oil prices coinciding with weak exchange rates; see e.g. Maier and DePratto (2008), Beckmann et al. (2017) and Akram and Mumtaz (2019). Figure 1 provides examples of time-variations in the co-movements of oil prices and the Norwegian and the Canadian nominal effective exchange rates. Norway and Canada are among the world's major oil exporters and their petroleum sectors contribute substantially to their total exports and GDPs.[2]



(a) *Norwegian nominal effective exchange rate and oil prices.*

(b) *Canadian nominal effective exchange rate and oil prices.*

Figure 1: *Brent Blend crude oil prices in* USD *(left) and the nominal effective exchange rates indices of* Norway *and* Canada *over the period 2010-2018, business daily observations.*

In the following, I offer some evidence suggesting the time-varying response of

[1]See Amano and van Norden (1995), Chen and Rogoff (2003), Akram (2004), Bodart et al. (2012), Choudhri and Schembri (2014), Zhang et al. (2016) and Kohlscheen et al. (2017).

[2]Oil and natural gas constitute about 40 percent of Norway's total exports and contribute about 16 percent to its total GDP. The corresponding numbers for Canada are about half of those for Norway; see e.g. www.norskpetroleum.no and www.nrcan.gc.ca for details.

oil exporters' exchange rates to oil prices could reflect shifts in the key drivers of oil prices over time.[3] Specifically, exchange rates may respond differently to oil price changes owing to demand, supply and geopolitical uncertainty shocks. Moreover, uncertainty shocks by themselves could weaken relatively small currencies because of possible capital flights from such currencies when uncertainty increases; see e.g. Forbes and Warnock (2012), Rey (2013), Goldberg and Krogstrup (2018) and Caldara and Iacoviello (2018). An increase in geopolitical uncertainty could therefore contribute simultaneously to high oil prices and weak exchange rates of oil-exporting countries.

Previously, Kilian (2009) has pointed out that changes in the composition of oil price shocks may explain unstable relationships between oil prices and macrovariables. Peersman and Robays (2012) find that the drivers of oil price shocks indeed matter for the response of exchange rates. In particular, exchange rates of oil exporters tend to appreciate in response to higher oil prices but the extent of appreciation depends on whether oil prices increase in response to oil-supply factors, global economic activity or oil-market specific demand, such as precautionary oil demand arising from geopolitical uncertainty. The relative importance of the different oil price shocks to exchange rates varies across countries, however, making it difficult to draw general conclusions on whether e.g. supply-driven oil price shocks are more or less important than other kind of oil price shocks to exchange rates; see Peersman and Robays (2012). Their evidence suggests, however, fairly uncertain responses of the exchange rates' to oil price shocks. In almost all cases, only oil price shocks driven by economic activity seem to have statistically significant effects on the exchange rates of the four oil exporters studied including Norway and Canada.[4]

This study complements previous research by its focus on the Norwegian and Canadian exchange rates, geopolitical uncertainty as a distinct risk factor for oil-

[3]There could be numerous alternative explanations of the observed time-variation in the relationship between oil prices and exchange rates with references to incomplete models, and shifts in economic structure, policy and agents' expectations; see e.g. Maier and DePratto (2008), Akram and Mumtaz (2019) and the references therein.

[4]The exception is the Norwegian exchange rate, which responds significantly (at the 30 percent level) to both economic activity and oil supply-driven oil price shocks, but barely significantly to those caused by oil-market specific demand.

exporter's currencies and its use of a more recent and a higher frequency data set, in contrasts with previous studies reliance' on monthly and quarterly data. This study's main findings underscore the importance of differentiating between oil price shocks when explaining exchange rates, but are in contrast with those offered by e.g. Peersman and Robays (2012) in terms of the relative importance of the different oil price shocks to exchange rates.

Specifically, the analysis presented is based on econometric models of the Norwegian nominal effective exchange rate and the Canadian exchange rate against USD; the latter exchange rate varies closely with the Canadian nominal effective exchange rate as the bilateral trade between Canada and the US is around 70 percent of Canada's foreign trade. The models are based on weekly data for the period January 2010–December 2018. Main explanatory variables are short- and long-term interest rate spreads relative to trading partners', crude oil prices and uncertainty indicators based on financial markets prices in addition to those based on newspapers suggested by Baker et al. (2016) and Caldara and Iacoviello (2018).[5] There are several approaches to decompose oil prices including Kilian (2009) and Baumeister and Hamilton (2019), but I employ the readily available decomposition published weekly by the Federal Reserve Bank of New York, which is based on Groen et al. (2013).[6]

The remaining paper is organised as follows. The next section argues briefly why exchange rates may respond differently to demand-, supply- and uncertainty-driven oil price changes. Section 3 formulates econometric models used in the empirical analysis and describes their key variables. Section 4 presents the main results while Section 5 concludes. The appendix provides additional details about the data and robustness tests of the main results.

[5] See www.policyuncertainty.com for details, data and additional references.

[6] see www.newyorkfed.org/research/policy/oil_price_dynamics_report for details and data.

2 Demand, supply and uncertainty driven oil prices

Higher oil prices are commonly assumed to have appreciating effects on oil exporters' currencies relative to oil importers' currencies. It is an empirical issue, however, whether supply-driven oil price changes have stronger or weaker effects than demand-driven oil price changes. Whether an exchange rate responds more strongly to a supply-driven oil price increase than to a demand-driven increase may depend on in which case an oil exporter gains more, or loses less, relative to oil importers.

Higher oil prices imply an increase in wealth transfers from oil importers to oil exporters; see e.g. Golub (1983). They may also slow down world economic growth and international trade in general; see e.g. Kilian (2009), Korhonen and Ledyaeva (2010), Peersman and Robays (2012) and Baumeister and Hamilton (2019). Thus when higher oil prices result from an actual or expected fall in oil supply, oil importers may suffer from both higher oil prices and a possible decline in their exports of goods and services. Oil exporters gain from higher oil prices, but these gains may be partly or fully offset by a fall in their exports of non-oil goods and services; see e.g. Mork et al. (1994) and Korhonen and Ledyaeva (2010). In contrast, when oil prices follow higher demand due to an upswing in global economic activity, oil exporters benefit from their oil exports as well as from an increase in their non-oil exports. Oil importers may also benefit from their exports following higher global economic activity, but their oil-imports expenditures increase reducing their overall gains from higher global economic activity.

One could say, oil exporters gain more than oil importers when there is a demand-driven oil price increase while oil importers lose more than oil exporters when there is a supply-driven oil price increase. While the exchange rate of an oil exporter may appreciate in both cases, it is an empirical issue whether it will appreciate more or less in response to a demand-driven oil price increase than to a supply-driven oil price increase. The exchange rate response to a given oil price shock may also differ across countries, not only because of differences in the macroeconomic effects of different oil price shocks, but also because of cross-country differences in policy responses to various oil price shocks.

Arguably, an exchange rate's response to oil prices may become modified and possibly invariant to the type of oil price shock if a country's policies actively counter oil price impulses to the economy. For example, Norway's adoption of a fiscal policy rule in 2001 was partly motivated by the desire to insulate the Norwegian economy from large fluctuations in oil prices; see NOU (2015). To manage the flow of oil revenues into the mainland economy, the Norwegian government has since then largely followed the fiscal policy rule and limited the government's petroleum-revenues spending to about 3–4 percent of its sovereign (petroleum) wealth fund, currently valued at more than thrice Norwegian mainland GDP. The rule may have limited the impact of particularly adverse or benign oil price shocks on the economy and could therefore have contributed to largely similar macroeconomic effects of different oil price shocks.

It is also an empirical question whether oil price increases owing to an increase in geopolitical uncertainty go together with appreciations of oil exporters' currencies or not. On the one hand, an increase in geopolitical uncertainty can make oil production or delivery more uncertain contributing to a higher precautionary oil demand and a rise in oil prices. An increase in oil prices following higher geopolitical uncertainty may therefore have comparable effects to those of oil supply shocks and lead to an appreciation of oil exporters' currencies. On the other hand, an increase in geopolitical uncertainty can itself contribute to capital outflows from relatively risk-sensitive currencies and thereby to their depreciation; see Caldara and Iacoviello (2018) and Goldberg and Krogstrup (2018). The responses of oil exporters' currencies' to an uncertainty induced increase in oil prices can therefore be ambiguous.

Capital outflows from a relatively large number of currencies including Norwegian krone have been found to become particularly sensitive to financial market risk in general after the financial crisis; see Goldberg and Krogstrup (2018) and Choi and Furceri (2018). More specifically, capital flights from especially small currencies have been found to increase with VIX, the popular uncertainty measure based on implied volatility in (S&P 500) equity prices. Caldara and Iacoviello (2018) find the contribution of higher geopolitical uncertainty to such capital flights to be in addition to that of an increase in VIX.

3 Empirical approach

To investigate the relationship between different oil price drivers and exchange rates, I estimate and compare exchange rate models with oil prices against those that include oil prices decomposed in accordance with their presumed drivers at each point in time.

I estimate the following model on weekly data to act as a benchmark model for the Norwegian and Canadian nominal exchange rates:

$$e_t = \overline{e} - \alpha(i - i^f)_t - \beta(i^L - i^{L,f})_t - \lambda op_t + \varepsilon_t, \tag{1}$$

where e is the log of the nominal exchange rate while $\overline{e}$ is assumed to be a constant intercept term. $(i - i^f)$ and $(i^L - i^{L,f})$ represent spreads between home and foreign 12-month (nominal) money market rates and 10-year yields, respectively; op is the log of Brent Blend crude oil prices in USD while ε is an unobserved stochastic error term. The Greek letters without time (t) subscript denote coefficients assumed to be constant and positive. A negative (positive) sign in front of a coefficient indicates the exchange rate is expected to appreciate (depreciate) when the value of the associated explanatory variable increases.[7] Models comparable to (1) estimated on weekly data are part of the suite of exchange rate models at Norges Bank; see e.g. Flatner et al. (2010) and Martinsen (2017).

To investigate whether possible oil price effects on the nominal exchange rate depend on the factors driving oil prices, I estimate versions of the model where oil prices are replaced with their components whose relationship with the exchange rate

[7] The short and long interest rates spreads can be rearranged to express model (1) as: $e_t = \overline{e} - \alpha_1(i - i^f)_t - \beta\{(i^L - i) - (i^{L,f} - i^f)\}_t - \lambda op_t + \varepsilon_t$, where $\alpha_1 = \alpha + \beta$. The third term on the right-hand side reflects differences in the slopes of the domestic and foreign yield curves which may arise due to expected differences in their monetary policies going forward.

may differ from each other. I also include a measure of geopolitical uncertainty to specifically control for the possible influence of geopolitical uncertainty on exchange rates; this in addition to other measures of uncertainty aimed to capture overall economic uncertainty. Several uncertainty measures are discussed in Subsection 3.2.

An exchange rate model with decomposed oil prices and uncertainty measures may be formulated as follows:

$$e_t = \bar{e} - \alpha(i - i^f)_t - \beta(i^L - i^{L,f})_t - \lambda_1 op_t^{Dem} - \lambda_2 op_t^{Sup} \pm \lambda_3 op_t^{Res} \\ + \gamma_1 risk_t + \gamma_2 gprisk_t + \epsilon_t, \quad (2)$$

where op_t^{Dem} and op_t^{Sup} are oil price components assumed to be driven by demand and supply sides of the oil market, respectively, while op_t^{Res} is a residual component of oil prices defined as $op_t^{Res} = op_t - op_t^{Dem} - op_t^{Sup}$. In the following, the term 'aggregate oil prices' will refer to the log of oil prices, *op*.

Fluctuations in the residual component (op_t^{Res}) could be interpreted as oil price changes associated with uncertainty regarding the availability of oil due to supply or demand surprises, originating from e.g. weather, an overall increase in uncertainty or specifically from geopolitical events. Finally, model (2) includes *risk* and *gprisk* representing measures of overall economic uncertainty and geopolitical uncertainty, respectively. The greek letters are defined as above.

The next subsection elaborates on the decomposition of oil price dynamics and some measures of uncertainty, in particular geopolitical uncertainty.

3.1 Decomposition of oil price dynamics

I employ the decomposition of Brent Blend crude oil prices obtained from the New York Fed's weekly Oil Price Dynamics Report.[8] This decomposition is based on the approach in Groen et al. (2013) where demand and supply shocks are identified from the way a large number of financial variables correlate with oil prices. The report decomposes weekly oil price changes into demand- and supply-driven changes in ad-

[8] *www.newyorkfed.org/research/policy/oil_price_dynamics_report.*

dition to residual changes left unaccounted for. The residual changes may contain oil price changes reflecting pure idiosyncrasies of the oil market including uncertainties related to weather and geopolitics. It could also contain measurement errors due to imprecise and erroneous classification of demand and supply components of oil prices.

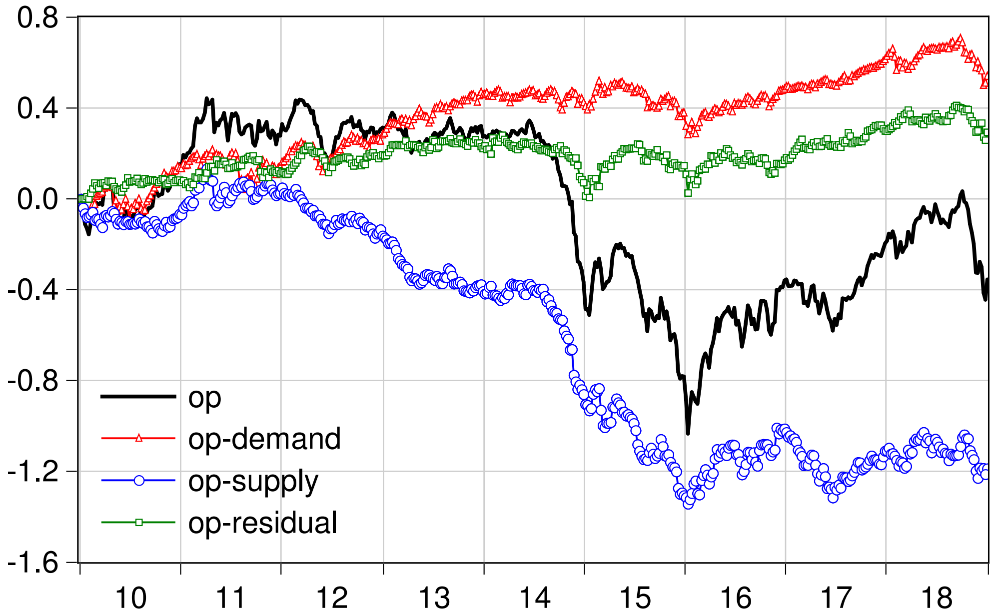


Figure 2: *Decomposition of Brent Blend crude oil prices in demand, supply and 'residual' driven oil prices over the period 2010–2018; weekly data. The three oil price components represented by the rectangled, circled and boxed lines, respectively, add up to the log of oil prices (solid line) at each point in time. The series have been scaled by their values in the first week of 2010.*

Figure 2 presents contributions of demand, supply and the residual components to crude oil prices since 2010 from the New York Fed's Oil Price Dynamics Report (of 15 January 2019). It shows that all of the three components have contributed substantially to oil price dynamics over time. Overall, the demand side has contributed to higher oil prices over time, up to around 60 percent relative to their level in early 2010. The contribution of the supply side has been mostly negative, suggesting increasing supply or stable oil supply conditions over the sample period. Supply side factors have contributed to lower oil prices by around 120 percent by 2015 relative to their level in early 2010. The contribution of the residual component (*op-residual*) to oil prices has been positive and increasing over the sample period, especially from late 2016 to around mid-2018. The latter contribution has been relatively smaller, but substantial, up to 40 percent during 2018.

3.2 Oil prices and geopolitical uncertainty

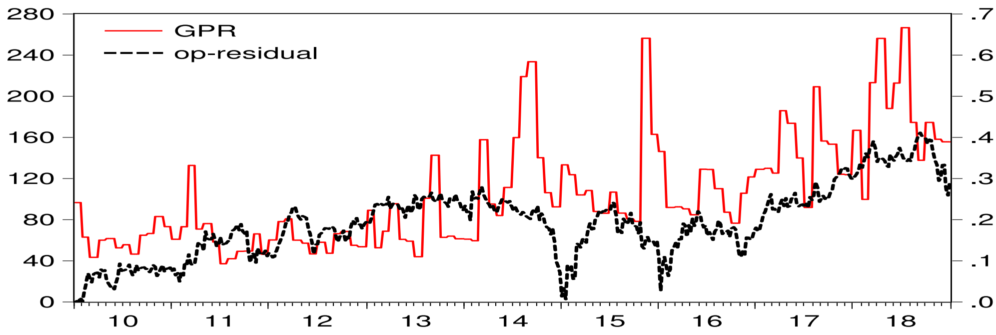
An explanation of the positive contribution of *op-residual* to oil prices could be that it captures the possible influence of e.g. geopolitical uncertainty that may contribute to uncertainty regarding oil supply and thereby to precautionary oil demand as in e.g. Kilian (2009). The rich set of variables used in the oil price decomposition approach of Groen et al. (2013) includes risk measures such as VIX. It is possible however that the risk measures used do not sufficiently reflect uncertainties of particular relevance to the oil market such as geopolitical uncertainty. The following figures suggest that while *op-residual* largely covaries with an index of geopolitical uncertainty, it does not display comparable covariation with VIX and some broader measures of economic and policy uncertainty.

Figure 3.a plots the residual oil price component (*op-residual*) and a measure of geopolitical uncertainty (GPR) developed by Caldara and Iacoviello (2018). The latter index is based on analysis of news in eleven US, UK and Canadian newspapers. It indicates geopolitical uncertainty defined as "...the risk associated with wars, terrorist acts, and tensions between states that affect the normal and peaceful course of international relations."[9] Even though this definition is quite broad and may capture events that could appear only remotely related to the oil market, most of the notable fluctuations in the index are related to well-known events in the Middle-East potentially or actually disruptive to oil production or deliveries; see Caldara and Iacoviello (2018) for details.

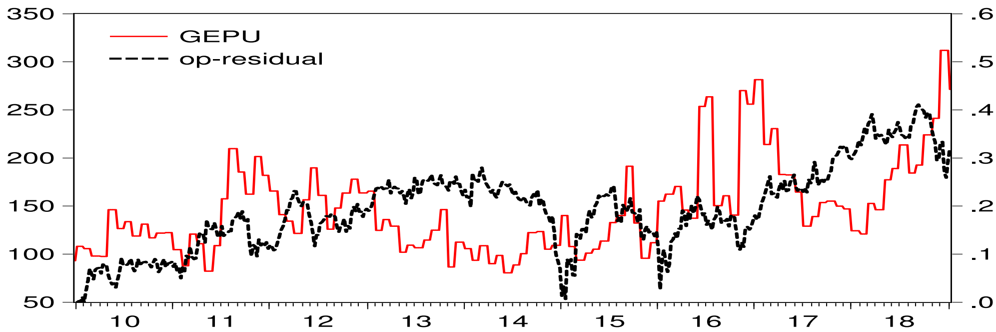
There seems to be a positive covariation between *op-residual* and GPR. There are, however, a few notable deviations from this overall pattern such as during July–September 2014 (Ukraine and ISIS escalations) and November 2015 (Paris terror incidents) when high geopolitical uncertainty as measured by GPR largely coincides with particularly low values of *op-residual*.

In contrast, there does not seem to be any obvious relationship between *op-*

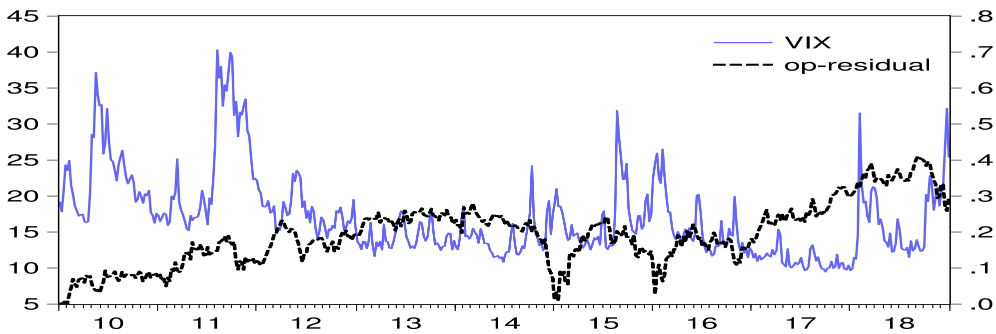
[9] For data and additional details, see www2.bc.edu/matteo-iacoviello/gpr.htm.



(a) *Geopolitical risk index and 'residual' oil prices (right axis).*



(b) *Global economic policy uncertainty index and 'residual' oil prices (right axis).*

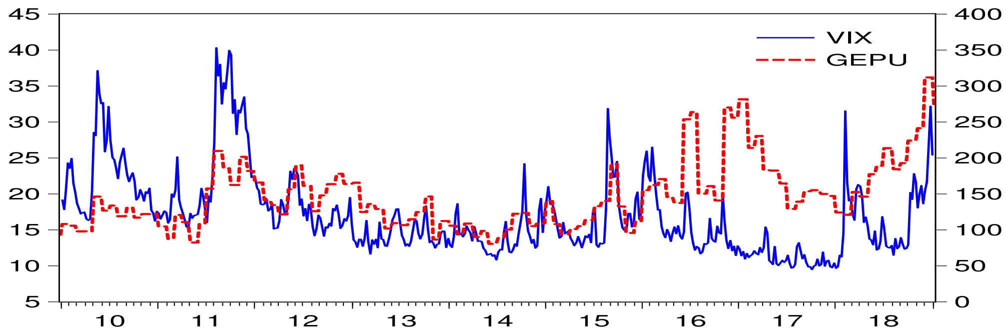


(c) *Equity volatility index and 'residual' oil prices (right axis).*

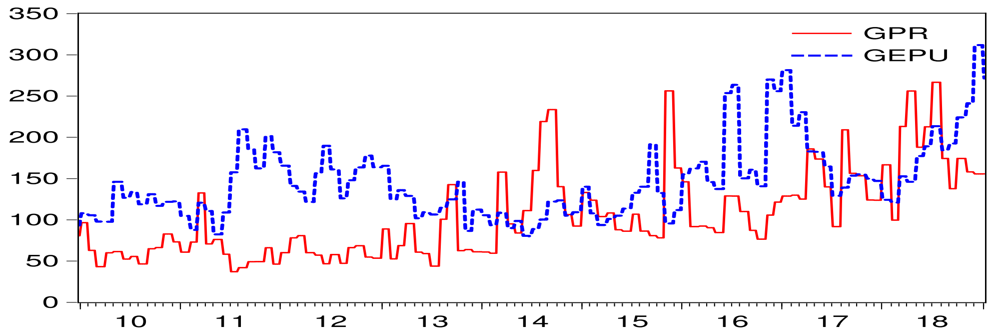
Figure 3: *Geopolitical risk index (*GPR*), global economic policy uncertainty index (*GEPU*),* S&P 500*-options based implied volatility index (*VIX*) and 'residual' oil prices (op-residual) over the sample period, 2010–2018; weekly data.*

residual and measures of overall uncertainty such as global economic policy uncertainty (GEPU) and VIX; see Figure 3.b and 3.c. The latter measures display relatively large (positive) covariation before 2016, but less so afterwards; see Figure 4.a. In contrast, there are relatively large discrepancies between the overall uncertainty measures and geopolitical uncertainty represented by GPR; see Figures 4.b and 4.c.

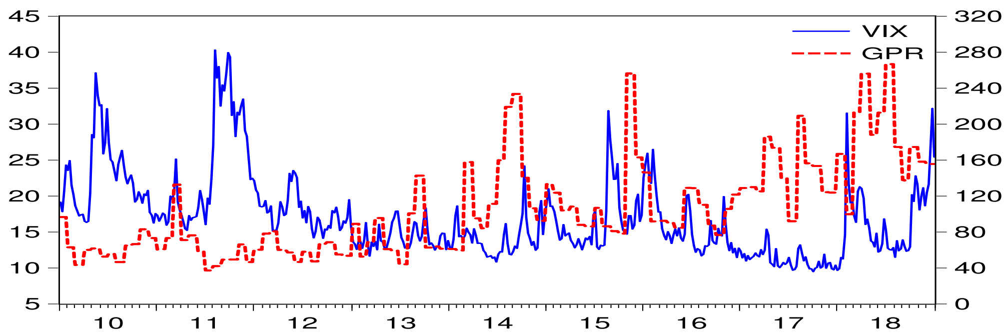
The overall economic uncertainty measure based on equity prices (VIX) and cur-



(a) *Global economic policy uncertainty index and* VIX *(left axis).*



(b) *Global economic policy uncertainty index and geopolitical risk index.*

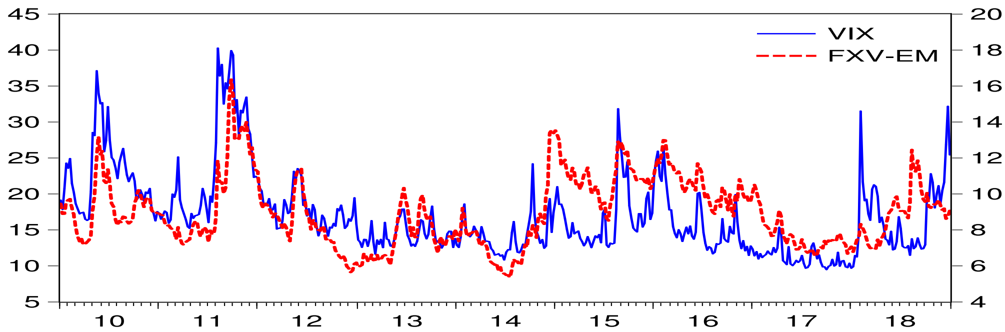


(c) *Geopolitical risk index and* VIX *(left axis).*

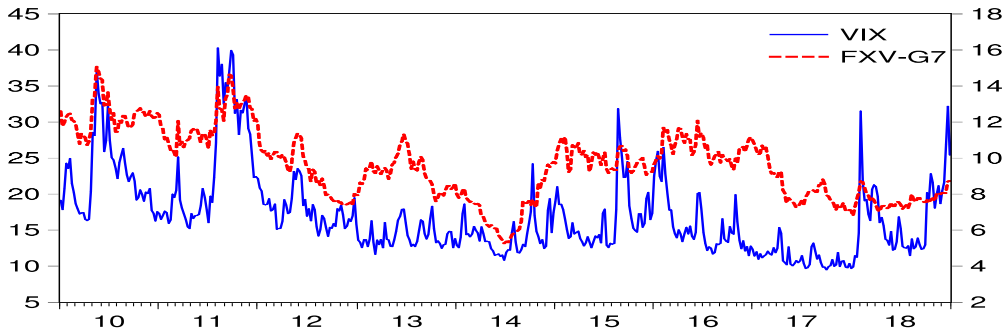
Figure 4: *Global economic policy uncertainty index (*GEPU*),* S&P 500 *options-based implied risk index* VIX *and geopolitical risk index (*GPR*) over the sample period, 2010–2018; weekly data.*

rency risk based on implied volatility of emerging economies' currencies (FXV-EM) largely move together; see Figure 5.a. Such covariation is not apparent between VIX and currency risk measures of major currencies, such as those for G7 countries including Canada (FXV-G7); see Figure 5.b.

The following empirical analysis suggests the relatively small Norwegian and Canadian currencies vary more with the currency volatility index for emerging



(a) VIX *(left axis) and the currency volatility index for emerging economies' currencies.*



(b) VIX *(left axis) and the currency volatility index for* G7 *currencies.*

Figure 5: VIX *versus currency volatility indices for emerging and* G7 *economies. Sample period: 2010–2018; weekly data.*

economies (and VIX) than with the currency volatility index for the G7 currencies, dominated by volatility in the four major currencies (USD, euro, yen and pound sterling). In terms of daily turnover and possibly the liquidity risk, the Norwegian and the Canadian exchange rates could have more in common with the major emerging economies' currencies than with the four major currencies.[10]

4 Estimation results

Models (1) and (2) have been estimated on weekly data for the period 15 January 2010 and 31 December 2018. Most of the variables are assumed to be integrated of order one based on unit root tests; see Table A1 in Appendix A. The exception

[10] BIS (2016) reports the Canadian dollar and the Norwegian krone were, respectively, 5.1 percent and 1.7 percent on one side of all foreign exchange transactions in April 2016. The corresponding shares for e.g. the Chinese renminbi (CNY) was 4 percent while those for the other BRICS-currencies were about 1 percent. In contrast, the shares of the US dollar, euro, yen and pound sterling were about 88, 31, 22 and 13 percent, respectively.

is the uncertainty measures, which may be regarded as stationary. The residual component of oil prices (op^{Res} = *op-residual*) could be considered near-integrated as the null-hypothesis of unit root may be rejected at around the 10 percent level of significance.

The models have been estimated as long-run relationships using the fully modified OLS method proposed by Phillips and Hansen (1990), which takes into account the possible endogeneity of the right-hand side variables. The results are robust to estimations by using e.g. the dynamic OLS method proposed by Stock and Watson (1993) which also takes into account the possible endogeneity of the regressors and the omission of dynamic effects in models; see Table A4 in Appendix B. The resulting residuals from the estimated models may be considered stationary, consistent with an interpretation of the estimated relationship as valid models; ADF-tests reject null hypotheses of a unit root in the residuals at the one percent level of significance; cf. Figure 6 of selected residuals.

Table 1 presents estimated versions of models (1) and (2) for the Norwegian nominal effective exchange rate while Table 2 presents those for the USD/CAD nominal exchange rate. The left-hand columns in the tables list explanatory variables used in the different models. The parentheses below coefficient estimates include their estimated standard errors and t-values, respectively.

Models denoted N1 and C1 in Tables 1 and 2, respectively, are estimated versions of model (1) with log of oil prices and without any uncertainty measure included. In comparison, models denoted N2 and C2 in Tables 1 and 2, respectively, are estimated versions of model (1) with (the log of) oil prices but with the uncertainty measure GPR and FXV-EM included (in logs). These measures contribute to increase the explanatory power of the models relative to alternative uncertainty measures such as (the log of) GEPU, VIX, FXV-G7 and CVIX, which is an index for overall currency volatility; see Tables A2 and A3 in Appendix B. The other models (N3–N4 and C3–C5) are estimated versions of model (2) with decomposed oil prices, without and with the two preferred uncertainty measures.

Table 1: ***Models of the Norwegian NEER***

	N1	N2	N3	N4
intercept	5.115 (0.028)[183.456]	4.979 (0.0511)[97.341]	4.661 (0.021)[221.208]	4.513 (0.035)[128.213]
$i - i^f$	-0.102 (0.010)[-10.532]	-0.085 (0.009)[-9.018]	-0.038 (0.012)[-3.190]	-0.027 (0.011)[-2.381]
$i^L - i^{L,f}$	-0.125 (0.014)[-9.138]	-0.106 (0.013)[-8.060]	-0.115 (0.012)[-9.810]	-0.105 (0.011)[-9.799]
gpr		0.023 (0.009)[4.754]		0.015 (0.004)[3.780]
fxvem		0.007 (0.009)[0.829]		0.026 (0.007)[3.563]
op	-0.077 (0.008)[-9.319]	-0.083 (0.008)[-10.951]		
op^{Dem}			-0.115 (0.020)[-5.681]	-0.116 (0.020)[-5.948]
op^{Sup}			-0.119 (0.009)[-14.089]	-0.116 (0.008)[-15.058]
op^{Res}			0.076 (0.032)[2.415]	0.094 (0.029)[3.260]
$\hat{\sigma}$	0.0178	0.0167	0.0144	0.0136
$\frac{\hat{\sigma}}{\hat{\sigma}_{N1}}$	1	0.9403	0.8116	0.7665

Note: Columns headed 'N1' and 'N2' present (FMOLS) coefficient estimates (signed), standard errors and corresponding t-statistics of models with aggregate oil prices (op), without and with the uncertainty measures: *gpr* and *fxvem*. The first column lists the corresponding right-hand side variables; see Appendix A for precise data definitions. Columns headed 'N3' and 'N4' present estimation results for the models with decomposed oil prices, without and with the two uncertainty measures, respectively. The lower part of the table reports standard errors of regressions for the different models. It also reports the relative standard errors of regressions where that of model N1 has been used as the denominator. Here and elsewhere in the paper, the models have been estimated using weekly data for the period 15 January 2010–31 December 2018.

4.1 Main findings

All of the estimated models, N1–N4 and C1–C5, suggest that increases in spreads of 12-month money market rates and 10-year bond yields go together with appreciations of the nominal exchange rates; see Tables 1 and 2. The longer term interest spread has relatively stronger effects than the shorter term interest rate spreads.

The estimation results also suggest that an increase in geopolitical uncertainty is associated with depreciations of the exchange rates. Furthermore, the Norwegian and Canadian exchange rates tend to depreciate with an increase in the currency volatility of emerging economies. The latter volatility measure is not statistically significant at standard levels of significance in the models with aggregate oil prices (op), i.e. in models N1–N2 and C1–C2, but is statistically significant in the models

Table 2: *Models of USD/CAD*

	C1	C2	C3	C4	C5
intercept	0.638 (0.062)[10.215]	0.423 (0.089)[4.737]	0.037 (0.037)[5.119]	0.031 (0.006)[5.423]	−0.152 (0.030)[−5.159]
$i - i^f$	−0.043 (0.009)[−4.688]	−0.039 (0.008)[−4.692]	−0.032 (0.007)[−4.540]	−0.026 (0.006)[−4.412]	−0.024 (0.005)[−4.958]
$i^L - i^{L,f}$	−0.191 (0.016)[−12.003]	−0.147 (0.017)[−8.778]	−0.084 (0.014)[−5.940]	−0.092 (0.013)[−7.151]	−0.079 (0.011)[−7.424]
gpr		0.043 (0.008)[5.164]			0.012 (0.005)[2.513]
fxvem		0.022 (0.015)[1.465]			0.057 (0.008)[6.968]
op	−0.126 (0.014)[−8.882]	−0.129 (0.014)[−9.373]			
op^{Dem}			−0.051 (0.035)[−1.470]	−0.092 (0.017)[−5.318]	−0.053 (0.016)[−3.193]
op^{Sup}			−0.185 (0.011)[−16.215]	−0.193 (0.010)[−18.608]	−0.179 (0.009)[−20.604]
op^{Res}			−0.062 (0.049)[−1.266]		
$\hat{\sigma}$	0.0292	0.0268	0.0182	0.0183	0.0153
$\frac{\hat{\sigma}}{\hat{\sigma}_{C1}}$	1	0.9162	0.6216	0.6257	0.5252

Note: Columns headed 'C1' and 'C2' present (FMOLS) coefficient estimates (signed), standard errors and corresponding *t*-statistics of models with oil prices, without and with the uncertainty measures: *gpr* and *fxvem*. The first column lists the corresponding right-hand side variables. The column headed 'C3' presents estimation results for the model with all of the three components of oil prices while the column headed 'C4' presents estimates without 'residual' oil prices. The final column ('C5') presents estimation results for the model with demand- and supply-driven oil prices and the two uncertainty measures. The lower part of the table reports standard errors of regressions for the different models. It also reports the relative standard errors of regressions where that of model C1 has been used as the denominator.

with decomposed oil prices: models N3–N4 and C3–C5.

Focusing on oil prices, models N1–N2 and C1–C2 suggest that higher (lower) oil prices are associated with appreciations (depreciations) of the Norwegian and Canadian nominal exchange rates. Also models estimated with decomposed oil prices suggest that demand- as well as supply-driven oil price changes have statistically significant effects on the exchange rates who tend to appreciate in response to such oil price increases.

However, there are relatively weaker and ambiguous effects of 'residual oil prices' (op^{Res}) on the exchange rates. Such oil price increases tend to coincide with depreciations of the Norwegian exchange rate and appreciations of the Canadian exchange rate. The latter effects are statistically insignificant, however. Versions C4 and C5 of the Canadian exchange rate model are therefore estimated without residual oil prices. An interpretation of residual oil prices could be that they proxy to some extent geopolitical uncertainty of particular relevance to the oil market and complement the news-based geopolitical uncertainty measure GPR, which may reflect geopolitical uncertainty more broadly.

Models with decomposed oil prices shed additional light on the relationship between oil prices and exchange rates. In models N3 and N4 of the Norwegian effective exchange rate, demand- and supply-driven oil price changes have similar effects and they are somewhat larger than the effects of aggregate oil prices (*op*) in models N1 and N2, though they are not statistically different from each other at the 5 percent level of significance; see Table 1. In the models of the Canadian exchange rate, however, supply-driven oil price changes have relatively stronger effects than demand-driven oil price changes. The estimated effects of changes in aggregate oil prices in models C1 and C2 are approximately in-between those of demand- and supply-driven oil price changes in models C4 and C5; see Table 2. The effects of the former as well as the latter oil price changes are significantly different from those of aggregate oil prices.

The differences in the Norwegian and Canadian exchange rates' responses to demand- and supply-driven oil price changes could possibly reflect institutional differences regarding the flows of petroleum revenues to their economies. While the Norwegian fiscal policy rule may to some extent shield the Norwegian economy from the impact of large oil price fluctuations irrespective of their source and potentially enforce largely symmetric effects, a comparable fiscal policy rule or an equally effective mechanism does not seem to exist in Canada. This conjecture could be worth investigating in further research on the topic using more adequate models of overall macroeconomic effects taking into account fiscal and monetary policy responses to different oil price shocks in both countries.

The substantial difference in the estimated effects of the three oil price components points to the importance of distinguishing between different oil price drivers when analysing exchange rates. This also seems important in order to obtain more precise coefficient estimates of the other variables in the models. Notably, the model with decomposed oil prices suggests significantly lower interest rate effects than those suggested by models with aggregate oil prices. In the case of the Norwegian exchange rate, the coefficient estimates associated with the short-term interest rate spread are significantly smaller (in absolute values) at the 5 percent level of significance in models N3 and N4 than corresponding coefficient estimates in models N1 and N2. The coefficient estimates associated with the long-term interest rates spread are comparable across these models; see Table 1. In the case of the Canadian exchange rate, however, both the short-term and long-term interest rate spreads are significantly smaller at the 5 percent level of significance in models C4 and C5 relative to those in models C1 and C2; see Table 2. Furthermore, as shown next, models with decomposed oil prices may have higher explanatory power than those with aggregate oil prices.

4.2 Models' explanatory power

Tables 1 and 2 report the explanatory power of the models as measured by estimated standard errors of regressions. The estimated standard errors are also compared to those of the benchmark models, N1 and C1, i.e. the models with aggregate oil prices and without the uncertainty measures.

In the case of the Norwegian exchange rate models, the model with decomposed oil prices (N3) has a higher explanatory power than the benchmark model (N1), about 19 percent at the face value; see Table 1. The explanatory power increases by an additional 4–5 percent if the uncertainty measures are included to obtain model N4. Specifically, the ratio of the standard errors of regressions are 0.81 and 0.77, respectively. The contribution of the uncertainty measures are approximately the same in the models with aggregate oil prices and decomposed oil prices, i.e. in models N2 and N4, respectively.

The gains from using decomposed oil prices in terms of explanatory power are relatively larger in the models of the Canadian exchange rate. The explanatory power of the models with decomposed oil prices (C3 and C4) is about 38 percent higher than that of the benchmark model with aggregate oil prices (C1). The explanatory

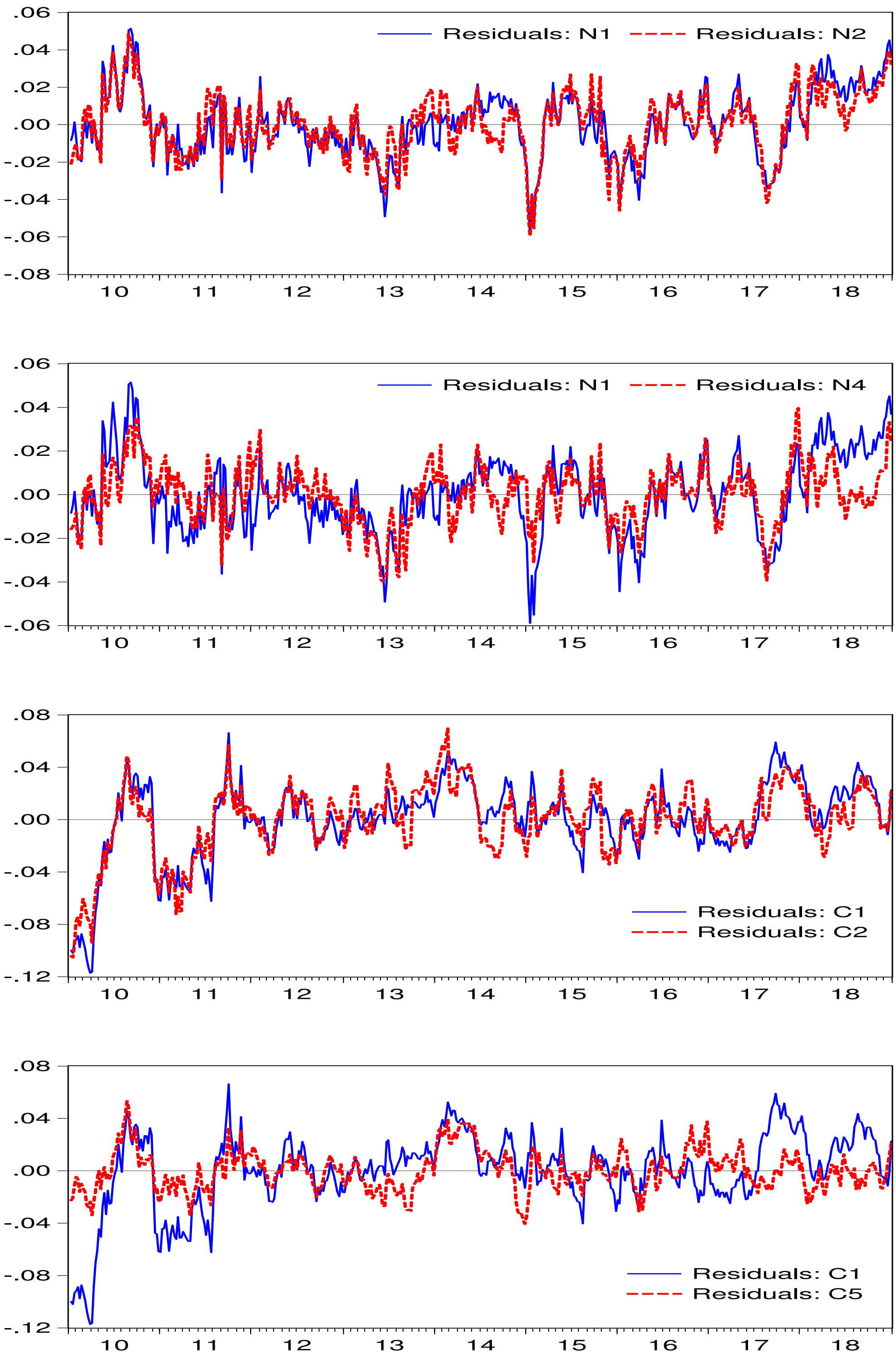


Figure 6: *Residuals from selected Norwegian and Canadian exchange rate models over the sample period 2010–2018. Residuals are defined as deviations between observed and fitted values of the exchange rates based on the indicated models (N1, N2, N4, C1, C2 and C5), which are presented in Tables 1 and 2.*

power of the model with decomposed oil prices almost doubles relative to the model with aggregate oil prices when decomposed oil prices are included jointly with the uncertainty measures in model C5.

The relatively higher explanatory powers of the models with decomposed oil prices and uncertainty measures do not seem to be confined to some specific periods but prevail over most of the sample period. Figure 6 presents residuals from selected models of the Norwegian and Canadian exchange rates. They point to the contribution of decomposed oil prices and uncertainty measures to the explanation of the exchange rates over the sample period. The figure suggests that decomposed oil prices in particular contribute to increase explanatory power over most of the sample period. This is notable especially in the case of the Canadian exchange rate. The contribution of the uncertainty measures indicated by the comparison between the models with (N2 and C2) and without the uncertainty measures (N1 and C1) is also apparent in several periods but to a smaller extent.

5 Conclusion

The empirical analysis of the Norwegian and Canadian exchange rates suggests that different drivers of oil prices could explain time-varying relationships between oil prices and oil exporters' currencies. It also points to the importance of geopolitical uncertainty for fluctuations in their currencies. Heightened geopolitical uncertainty may lay behind the occasional coincidences of higher oil prices and a weakening of oil exporters' currencies.

In summary, oil price increases driven by oil demand and oil supply factors may lead to an appreciation of oil exporters' currencies. In contrast, oil price increases driven by factors escaping classification as outright demand or supply factors may have insignificant effects on the exchange rates, or opposite to those of demand- and supply-driven oil price increases. Such oil price fluctuations tend to covary with geopolitical uncertainty, which may itself lead to exchange rate depreciations. Higher oil prices coinciding with a rise in geopolitical uncertainty may therefore be followed by a depreciation of oil exporters' currencies rather than an appreciation.

Furthermore, supply-driven oil price changes have been found to have larger effects than those of demand-driven oil price changes on the Canadian exchange rate. This is in contrast with the results for the Norwegian exchange rate where demand- and supply-driven oil price changes have about the same effects. One conjecture worth further investigation is that the latter finding reflects the Norwegian fiscal policy rule, which tends to smooth the exposure of the Norwegian economy to oil price fluctuations and thereby contribute to comparable effects of demand- and supply-driven oil price changes.

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A Appendix: Data

The data series employed in the empirical analysis are listed below. The data source is Bloomberg, unless otherwise stated. Bloomberg tickers for the series used are provided in brackets. Table A1 presents the outcomes of ADF-tests for a unit root in each of the time series.

Norway

• i^s - Norwegian 12-month nominal money market (swap) interest rates; [NKSW1V3 curncy].

• $i^{s,f}$ - Norwegian trading partners' 12-month nominal money market interest rates. This series refers to a weighted average of the money market interest rates in 7 trading partners with weights and Bloomberg tickers in the corresponding parentheses: Euro area (0.5301, EUSA1 curncy), USA (0.1916, USSW1 curncy), Sweden (0.1273, SKSW1 curncy), UK (0.0670, BPSW1 curncy), Poland (0.0334, PZSW1 curncy), Canada (0.0272, CDSW1 curncy) and Japan (0.0235, JYSW1 curncy), respectively. Source: Norges Bank.

• i^L - Norwegian 10-year nominal swap rates; [NKSW10 curncy].

• $i^{L,f}$ - Norwegian trading partners' 10-year nominal government bond yields with weights as above. Data source is Datastream with the tickers as follows for the bonds in Euro area, US, Sweden, UK, Poland, Canada and Japan: ICEIB10, ICUSD10, ICSEK10, ICGBP10, ICPLN10, ICCAD10 and ICJPY10.

• $NEER$ - Norwegian nominal effective exchange rate (I-44). Source: Norges Bank.

Canada

• $NEER - Cad$ - Canadian nominal effective exchange rate; [CERINOM index].

• USD/CAD - Canada-USD bilateral nominal exchange rate; [USDCAD curncy].

• i^s - Canada Bankers Acceptances 1-year nominal rate; [CDOR12 index].

$i^{s,f}$ - ICE LIBOR USD 12-month nominal money market interest rates; [US0012M index].

• i^L - Canadian government bonds 10-year nominal yield; [GCAN10YR index].

• $i^{L,f}$ - US generic government 10-year nominal yield; [USGG10YR index].

Other variables

• OP - Brent Blend crude oil prices in USD per barrel; [CO1 comdty].

• GPR - Geopolitical Risk index; GPR_NARROW. A monthly index of geopolitical risk developed and updated by D. Caldara and M. Iacoviello; Source: www2.bc.edu/matteo-iacoviello/gpr.htm.

• $GEPU$ - Global Economic Policy Uncertainty Index. A GDP-weighted average of economic policy undertainty indices for 20 countries; GDPs at current prices. Source: www.policyuncertainty.com.

• *FXV-EM* - Barclays' emerging economies currency volatility index; [BXIIVEMG index].

• *FXV-G7* - J.P. Morgan's currency volatility index for G7 countries; [JPMVXYG7 index].

• $CVIX$ - Deutche Bank's currency volatility index, which measures the implied volatility of overall currency markets; [CVIX index].

• VIX - Chicago Board Options Exchange volatility index, which measures the implied volatility of equity markets based on the $S\&P$ 500; [VIX index].

Table A1: ***ADF-tests for a unit root in the series***

Variables	ρ	$t-$ADF	*p-value*
Norway:			
neer	-0.0033	-0.6342	0.8599
$i - i^f$	-0.0127	-1.8349	0.3634
$i^L - i^{L,f}$	-0.0136	-1.5325	0.5164
Canada:			
usd/cad	-0.0014	-0.4114	0.9039
$i - i^f$	-0.0021	-0.8722	0.7966
$i^L - i^{L,f}$	-0.0089	-1.5765	0.4938
Other:			
op	-0.0063	-1.2064	0.6731
op^{Dem}	-0.0103	-2.1579	0.2223
op^{Sup}	-0.0011	-0.4944	0.8893
op^{res}	-0.0247	-2.5148	0.1126
gpr	-0.0604	-3.6988	0.0044
gepu	-0.0515	-3.1678	0.0226
fxvem	-0.0460	-3.4449	0.0100
fxvg7	-0.0237	-2.4212	0.1364
cvix	-0.0214	-2.3247	0.1646
vix	-0.0759	-3.7407	0.0038

Note: Four autoregressive terms and an intercept term have been included in each of the ADF-models that were formulated to test the null hypothesis of a unit root in the time series listed in the first column. Small letters except for the interest rate spreads indicate the logs of the corresponding variables. The second column reports coefficient estimates associated with lagged levels of the left-hand variables, while the third column reports the associated t-values. The fourth column reports one sided p-values based on MacKinnon (1996).

B Appendix: Sensitivity analysis

B.1 Alternative uncertainty measures

In the following, Tables A2 and A3 present estimation results using alternative uncertainty measures: global economic policy uncertainty index (GEPU), VIX, overall currency volatility index (CVIX) and currency volatility index for G7 currencies (FXV-G7).

The analysis suggests that (the log of) the equity based volatility measure (VIX) have largely comparable effects to that of the emerging currency volatility measure (FXV-EM). This is consistent with their close covariation observed in Figure 5. The emerging currency volatility measure contributes to somewhat higher explanatory power of the models than VIX in the models of the Canadian exchange rate, however.

Table A2: ***Models of the Norwegian NEER - alternative uncertainty measures***

	N4.gepu	N4.vix1	N4.vix	N4.cvix	N4.fxvg7
intercept	4.479 (0.039)[114.502]	4.501 (0.038)[126.011]	4.530 (0.033)[136.978]	4.545 (0.044)[102.715]	4.569 (0.045)[102.218]
$i - i^f$	−0.025 (0.011)[−2.157]	−0.027 (0.011)[−2.434]	−0.034 (0.011)[−3.005]	−0.036 (0.011)[−3.100]	−0.038 (0.012)[−3.301]
$i^L - i^{L,f}$	−0.112 (0.012)[−9.618]	−0.105 (0.011)[−9.814]	−0.106 (0.011)[−9.760]	−0.107 (0.011)[−9.562]	−0.117 (0.023)[−9.481]
op^{Dem}	−0.090 (0.023)[−3.869]	−0.098 (0.023)[−4.257]	−0.090 (0.023)[−3.870]	−0.109 (0.023)[−4.690]	−0.118 (0.023)[−5.080]
op^{Sup}	−0.113 (0.008)[−13.925]	−0.117 (0.008)[−15.250]	−0.118 (0.008)[−15.027]	−0.115 (0.008)[−14.076]	−0.116 (0.008)[−14.064]
op^{Res}	0.061 (0.032)[1.904]	0.073 (0.032)[2.294]	0.050 (0.030)[1.654]	0.076 (0.030)[2.544]	0.074 (0.030)[2.445]
gpr	0.014 (0.004)[3.297]	0.014 (0.004)[3.443]	0.012 (0.004)[2.944]	0.015 (0.004)[3.455]	0.014 (0.004)[3.450]
gepu	0.008 (0.006)[1.429]				
fxvem	0.014 (0.009)[1.472]	0.017 (0.009)[1.802]			
vix	0.012 (0.008)[1.584]	0.013 (0.008)[1.649]	0.022 (0.006)[3.563]		
cvix				0.018 (0.018)[1.662]	
fxvg7					0.011 (0.044)[1.014]
$\hat{\sigma}$	0.0134	0.0135	0.0136	0.0142	0.0142
$\frac{\hat{\sigma}}{\hat{\sigma}_{N4}}$	0.9856	0.9903	0.9974	1.0372	1.0400

Note: Estimated models of the Norwegian exchange rate with decomposed oil prices and alternative uncertainty measures. The first column lists right-hand side variables used in the different models. The right-hand side variables are the same across models except the measure(s) of uncertainty used in addition to the geopolitical uncertainty measure, log of GPR. The second column headed 'N4.gepu' contains coefficient estimates, standard errors and corresponding t-statistics of a model with the addition of logs of GEPU, FXV-EM and VIX. The third column headed 'N4.vix1' reports estimation results after excluding the log of GEPU. The columns headed 'N4.vix', 'N4.cvix' and 'N4.fxvg7' report estimation results for models where the log of FXV-EM has been left out and replaced with just the log of VIX, overall currency volatility index (CVIX) and the log of the currency volatility index for G7 economies (FXV-G7), respectively. The lower panel of the table presents standard errors of regressions for the different models. It also presents the relative standard errors of regressions where that of model N4 described in Table 1 has been used as the denominator. The estimation method is FMOLS and the sample period is 15 January 2010–31 December 2018 as for models in Tables 1 and 2.

In contrast with (the log of) FXV-EM and VIX, the overall and G7 currency volatility measures, CVIX and FXV-G7, have statistically insignificant coefficient estimates in the equations for both the Norwegian and Canadian exchange rates; see Tables A2 and A3.

Table A3: ***Models of USD/CAD - alternative uncertainty measures***

	C5.gepu	C5.vix1	C5.vix	C5.cvix	C5.fxvg7
$intercept$	−0.211 (0.043)[−4.938]	−0.160 (0.031)[−5.172]	−0.103 (0.032)[−3.222]	−0.066 (0.049)[−1.357]	−0.052 (0.050)[−1.060]
$i - i^f$	−0.0169 (0.006)[−2.888]	−0.023 (0.005)[−4.794]	−0.021 (0.005)[−4.041]	−0.024 (0.006)[−4.102]	−0.024 (0.006)[−4.144]
$i^L - i^{L,f}$	−0.085 (0.011)[−7.930]	−0.080 (0.017)[−7.613]	−0.088 (0.012)[−7.631]	−0.087 (0.013)[−6.800]	−0.088 (0.013)[−6.828]
op^{Dem}	−0.055 (0.018)[−3.132]	−0.046 (0.017)[−2.697]	−0.057 (0.019)[−3.033]	−0.0717 (0.0249)[−2.886]	−0.0784 (0.0246)[−3.196]
op^{Sup}	−0.184 (0.009)[−21.024]	−0.182 (0.009)[−20.780]	−0.196 (0.009)[−21.384]	−0.189 (0.011)[−17.916]	−0.191 (0.011)[−17.952]
gpr	0.012 (0.005)[2.410]	0.011 (0.005)[2.236]	0.005 (0.0053)[0.877]	0.0089 (0.006)[1.504]	0.0084 (0.006)[1.407]
$gepu$	0.011 (0.007)[1.621]				
$fxvem$	0.047 (0.010)[4.764]	0.049 (0.010)[4.984]			
vix	0.0086 (0.008)[1.044]	0.010 (0.008)[1.256]	0.035 (0.007)[4.742]		
$cvix$				0.0231 (0.014)[1.624]	
$fxvg7$					0.0188 (0.015)[1.284]
$\hat{\sigma}$	0.0152	0.0152	0.0168	0.0179	0.0180
$\frac{\hat{\sigma}}{\hat{\sigma}_{C5}}$	0.9900	0.9935	1.0944	1.1671	1.1729

Note: Estimated models of the Canadian exchange rate with decomposed oil prices and alternative uncertainty measures. The first column lists right-hand side variables used in the models. The right-hand side variables are the same across models except the measure(s) of uncertainty used in addition to the geopolitical uncertainty measure, log of GPR. The second column headed 'C5.gepu' contains coefficient estimates, standard errors and corresponding t-statistics of a model with the addition of logs of GEPU, FXV-EM and VIX. The third column headed 'C5.vix1' reports estimation results after excluding the log of GEPU. The columns headed 'C5.vix', 'C5.cvix' and 'C5.fxvg7' report estimation results for models where the log of FXV-EM has been left out and replaced with just the log of VIX, overall currency volatility index (CVIX) and the log of the currency volatility index for G7 economies (FXV-G7), respectively. The lower panel of the table presents standard errors of regressions for the different models. It also reports the relative standard errors of regressions where that of model C5 described in Table 2 has been used as the denominator. The estimation method is FMOLS and the sample period is 15 January 2010–31 December 2018 as for models in Table 2.

B.2 Alternative estimation method

Table A4 presents selected models for the Norwegian nominal effective exchange rate, 'N4', and for the Canada-US exchange rate, 'C5', estimated with dynamic OLS.

Table A4: *Models of the Norwegian NEER and USD/CAD - Dynamic OLS estimates*

	N4	$N4_{HAC}$	C5	$C5_{HAC}$
intercept	4.521	4.521	−0.173	−0.173
	[114.424]	[117.667]	[−4.368]	[−5.288
$i - i^f$	−0.028	−0.028	−0.021	−0.021
	[−2.268]	[−2.381]	[−4.204]	[−4.029]
$i^L - i^{L,f}$	−0.105	−0.105	−0.083	−0.083
	[−9.082]	[−9.764]	[−6.468]	[−5.897]
gpr	0.014	0.014	0.0167	0.017
	[3.098]	[3.356]	[2.454]	[3.317]
$fxvem$	0.025	0.025	0.057	0.057
	[3.176]	[3.183]	[5.694]	[6.415]
op^{Dem}	−0.115	−0.115	−0.060	−0.060
	[−5.428]	[−5.800]	[−3.224]	[−3.525]
op^{Sup}	−0.116	−0.116	−0.180	−0.180
	[−14.118]	[−14.795]	[−19.064]	[−21.125]
op^{Res}	0.089	0.089		
	[2.837]	[3.307]		

Note: Models N4 and C5 for the Norwegian nominal effective exchange rate (NEER) and Canada-US exchange rate have been estimated with dynamic OLS (DOLS) with coefficient covariance matrices based on rescaled OLS and HAC (Newey-West), respectively; Bartlett kernel, Newey-West fixed bandwidth set at 6. Corresponding t-values are presented in the brackets below the coefficient estimates. The data sample is as above: weekly data from 15 January 2010 to 31 December 2018. In the case of the Norwegian NEER, one lead and one lag for short-run dynamics were chosen by the Akaike information criterion (AIC). In the case of USD/CAD, this criterion preferred 7 leads and no lag for the short-run dynamics. While the reported results are those based on the leads and lags preferred by the AIC, alternative number of leads and lags led to comparable results.