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Abstract

We assess New Zealand's vulnerability to oil shocks by estimating its price and income elasticities of demand for imported oil and by testing for Granger causality between oil imports, their price and GDP. Based on data for the period 1987Q2–2012Q4, we find the short-run price and income elasticities to be statistically insignificant. However, the long-run price and income elasticity estimates are significant and equal to −0.34 and 1.61, respectively. We also find that oil imports, and to some extent oil prices, Granger-cause real GDP, indicating that the New Zealand economy is vulnerable to shocks in the world oil market.

Keywords: Oil imports; Price elasticity; Income elasticity; Granger causality; Cointegration; Vector error correction model.

JEL classifications: C32, Q41, Q43

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1. Introduction

Oil is the single largest source of energy consumed within the New Zealand (NZ) economy, accounting for 34% of its total primary energy supply in 2011. NZ produces some oil, but most of this is exported, as it is lighter and sweeter than is suitable for its only oil refinery at Marsden Point. In any case, indigenous crude oil production normally represents a relatively small fraction of domestic oil consumption. For example, NZ's net oil dependency, defined as one minus the ratio of indigenous crude oil production to total domestic oil consumption, was 62% in 2011 (Ministry of Economic Development, 2013a). Consequently, NZ largely depends on imported oil to satisfy domestic demand. These imports are processed at the Marsden Point refinery before being distributed to consumers as petrol, diesel, aviation fuel, fuel oil, bitumen and other petroleum products. The refinery supplies around 70% of New Zealand's petrol and diesel demand, which is supplemented by imports of refined petroleum products.

The oil shocks of 1973 and 1979 clearly highlight the danger of being dependent on foreign oil supplies and the possibility of future supply-side shocks cannot be ruled out. NZ consumers of petroleum products would clearly be adversely affected by such an event, but it is less clear whether the economy as a whole would be noticeably affected. It is possible that the high oil prices experienced in the 1970s encouraged structural change within the economy that has enhanced its ability to cope with such events. So, it is an open question whether economic activity in NZ is currently vulnerable to shocks originating in the world oil market.

The extent to which an economy is sensitive to such shocks depends, in part at least, on its price elasticity of demand for oil. A low elasticity indicates that consumers have little ability to reduce their dependence on oil when its price rises – by either improving efficiency or switching to alternative energy sources – and this increases the risk to economic activity. An economy's vulnerability to oil shocks can also be assessed by testing for a Granger-causal relationship between the level of oil imports and the level of economic activity, i.e., real gross domestic product (GDP). If oil imports Granger-cause GDP, then this indicates that supply-side disruptions to the global oil market have the potential to harm domestic economic activity.

Therefore, this paper estimates the short- and long-run price (and income) elasticities of demand for oil imported into NZ and also examines the nature of Granger causality, if it exists, between oil imports and NZ's GDP. The issue of the NZ economy's vulnerability to disruptions in oil imports has not been previously investigated to our knowledge, although Granger causality between oil consumption (rather than imports) and GDP, and the price elasticity of oil imports have been examined separately (Cooper, 2003; Fatai et al., 2004). Both of these earlier studies, however, have some limitations that have the potential to affect their conclusions and our study seeks to address these limitations.

The remainder of the paper is organised as follows. Section 2 reviews the empirical literature that models the demand for oil imports and considers the Granger-causal relationship between oil imports and GDP, with particular emphasis on the studies that consider the NZ case. In Section 3, the data and methodology we employ are discussed, and the elasticity estimates and the Granger-causality test results they produce are presented in Section 4. Section 5 concludes the paper by highlighting the main empirical findings and outlining their policy implications.

2. Literature review

There are numerous studies of the causal relationship between energy consumption and economic growth. Some specifically focus on the causal relationship between the consumption of oil and economic growth, and a subset of these also estimate short- and long-run price and income elasticities of demand for oil imports. The studies within this last group, however, do differ in terms of the specific variables included in their model and/or the econometric methodology they employ to analyse it.

For example, Ghosh (2009) and Royfaizal (2009) both estimate an Autoregressive Distributed Lag (ARDL) model of the demand for imported oil in India and Japan, respectively, and use the Bounds test (Pesaran and Shin, 1999; Pesaran et al., 2001) to determine whether the variables within their model have a long-run equilibrium (or cointegrating) relationship. Their choice of the Bounds test is based on the fact that it can be applied regardless of whether the individual variables are all stationary, all integrated of order one, or some combination of the two (Pesaran et al., 2001). In addition, the Bounds test is expected to generate robust results for relatively small samples (Pesaran and Shin, 1999).

If a cointegrating relationship is found then, aside from providing estimates of the long-run price and income elasticities of demand for imported oil, it can also be used to construct the error- (or equilibrium-) correction term within a Vector Error Correction model (VECM). Both studies are able to do this and use their VECM to examine the direction of Granger causality between oil imports and real GDP, and to generate estimates of the short-run price and income elasticities of demand for oil imports.

However, these two studies differ in that Ghosh (2009) models the relationship between the volume of oil imports, the **real** price of oil and real GDP, whereas Royfaizal (2009) models the volume of oil imports, the **nominal** price of oil and real GDP. When modelling import demand it is standard practice to control for the effects on the demand for one good of changes in the prices of other goods (Goldstein and Khan, 1985; Sawyer and Sprinkle, 1999). This is often done – as Ghosh (2009) does – by deflating the imported good's own price by a broadly-defined price index (e.g., a GDP deflator or a consumers price index). Hence, Royfaizal's (2009) results need to be interpreted in the light of his nonstandard approach.

Ghosh's (2009) estimate of the long-run income elasticity of India's oil imports demand is 1.97. His estimates of both the short- and long-run price elasticities, and the short-run income elasticity are all statistically insignificant. Royfaizal's (2009) estimates of the long-run price and income elasticities of Japanese demand for oil imports are −0.08 and 1.35, respectively. However, his estimate of the short-run income elasticity is noticeably larger at 1.78, which is contrary to theoretical expectations and may be a reflection of his model's omission of a broadly-defined price variable. With respect to the pattern of Granger causality between oil imports and real GDP, the findings of the two studies are the same: real GDP is found to Granger-cause oil imports without feedback in both India and Japan.

Other studies to use the ARDL modelling approach and the Bounds test for cointegration to obtain estimates of the price and income elasticities of demand for imported oil, but which do not explore the issue of Granger causality, include Altinay (2007), Asali (2011) and Moore (2011). Altinay's (2007) study considers the case of Turkey and uses annual data (for the period 1980–2005). Two alternative price variables are considered for use (alongside real GDP) in Turkey's import demand equation: the real price of oil and the nominal oil price expressed in US dollar terms. Only the model containing the latter measure is found to generate significant evidence of cointegration and, on this basis, Altinay (2007) estimates Turkey's short-run (long-run) price elasticity of demand for oil to be −0.10 (−0.18) and its income elasticity to be 0.64 (0.61).

Asali (2011) estimates the price and income elasticities of the G7 nations along with those of Brazil, Russia, India and China. The model employed in this study differs slightly from those mentioned above in that all variables, except the real price of oil, are defined in per capita terms. The price elasticity estimates found are relatively consistent across the countries in the sample, ranging from −0.02 to −0.10 in the short run and from −0.05 to −0.18 in the long run. Considerably greater variation, however, is found among the income elasticity estimates, which range from 0.11 to 0.89 in the short run and from 0.35 to 1.35 in the long run.

Moore's (2011) study of oil import demand in Barbados differs from the others in that it is based on a relatively short span (1998–2009) of monthly data. He reports a long-run price elasticity of demand for oil of −0.55, whereas the long-run effect of income on import demand is not found to be statistically significant. However, the latter finding is likely to be a reflection of the inclusion of electricity consumption as an explanatory variable in Moore's (2011) import demand model, given that almost half of all oil imported by Barbados is used for electricity generation

Not all researchers in this area have used the ARDL model-based Bounds test approach. Ziramba (2010), for example, uses Johansen's (1988, 1991, 1995) maximum likelihood method to estimate the long-run relationship between South Africa's volume of oil imports and its determinants, namely real GDP and the real oil price. Based on annual data for the period 1980–2006, his estimates of the long-run price and income elasticities for South Africa are −0.15 and 0.43, respectively. (The short-run elasticity estimates are not reported.) To test the direction of Granger causality between the variables, Ziramba (2010) estimates a VECM containing an error-correction term based on the single long-run cointegrating vector identified by his Johansen test results. In common with Ghosh (2009) and Royfaizal (2009), Ziramba (2010) also finds a unidirectional causal relationship running from real GDP to oil imports.

Very little work appears to have been done on the determinants of NZ's demand for imported oil or on the relationship between its oil imports and economic activity. Only two studies, to our knowledge, attempt to tackle either issue. As part of a multi-country study, Cooper (2003) estimates a simple partial-adjustment model of per capita oil import demand for NZ (over the period 1971–2000) and obtains short- and long-run price elasticities of −0.054 and −0.326, respectively. (Per capita real GDP is included in the model but the income elasticity estimates are not reported.) However, the time-series properties of the data set are not tested and no test for cointegration is undertaken. Therefore, as at least some of the model's variables are likely to be non-stationary, Cooper's (2003) results may be subject to the spurious regression problem (Granger and Newbold, 1974).

Fatai et al. (2004) test for Granger causality between NZ's real GDP and its level of oil consumption using data for the period 1960–1999. Based on the results of the Johansen testing approach, they are unable to find evidence of cointegration between the two series and so test for Granger causality using first-differenced data only. On this basis they find no evidence of causality in either direction. However, their cointegration test results – and hence their Granger-causality test results – may have been affected by the exclusion of an oil price variable from the proposed cointegrating vector.

A further point to consider is that both Cooper (2003) and Fatai et al. (2004) make use of data that straddles the period of the original oil shocks. Hence, it is possible that their results may be distorted by any structural changes to the NZ economy that occurred in response to those shocks. One indicator of a possible structural change is the share of oil in NZ's total primary energy supply, which fell from 49% in 1974 to 31% by 1985. Over the same period, NZ's net oil dependency also fell, from 95% to 63%. Both measures subsequently fluctuate in value, but they have nonetheless remained close to their 1985 levels over the last quarter-century. Specifically, the average values of oil's share in the primary energy supply and net oil dependency over the period 1985–2011 are 33% and 62%, respectively (Ministry of Economic Development, 2013a). Given the change in the NZ economy's reliance on oil in general, and imported oil in particular, over the decade following the first oil shock, the aim of the present study is to assess NZ's **current** vulnerability to oil shocks through the use of data and methods that address our concerns with the existing studies.

3. Methodology and data

3.1 Methodology

Crude oil is not directly consumed within an economy, except by industries producing oil-based products such as plastic. Most oil is refined into other products, such as petrol, diesel, fuel oil, bitumen, etc., and these are then consumed by all sectors of the economy. Standard theories of production and consumption suggest that the total amount of crude oil demanded should therefore depend on the level of economic activity, the conventional measure of which is real GDP, the price of oil itself and the prices of substitute products.

Outside of, arguably, electricity generation (which in NZ is dominated by hydroelectric generation in any case) and central heating systems (which are not a common feature of NZ's housing stock), fossil fuels such as coal and natural gas are typically not good substitutes for oil and its refined products given the current state of technology and the existing stock of capital. Therefore, and in common with most previous studies in this area, substitute prices are represented by a general price index (which we use to deflate the nominal oil price), rather than one defined over non-oil energy sources alone.

Assuming a log-linear relationship among the variables, our model of demand for imported oil is as follows:

$$LOIMP_t = \theta_0 + \theta_1 LRGDP_t + \theta_2 LRPOIL_t + u_t \quad (1)$$

where *LOIMP* is the logarithm of the volume of oil imports, *LRGDP* is the logarithm of real GDP, *LRPOIL* is the logarithm of the real price of oil and u is a random error. Equation (1) represents the long-run relationship among the variables and so θ_1 is interpreted as the long-run income elasticity and θ_2 as the long-run price elasticity of demand for oil imports. The value of θ_1 is expected to be positive and that of θ_2 negative.

Even though equation (1) looks simple and straightforward, econometric problems may be encountered when estimating it. One potential problem is that, although the nominal (i.e., US dollar) price of oil is set on the world market and so can be considered exogenously determined from NZ's perspective, the real price of oil faced by NZ consumers also depends on the NZ dollar's exchange rate against the US dollar and on domestic inflation, both of which could be influenced by the state of the NZ economy (i.e., *LRGDP*). In which case, *LRPOIL* may not be entirely exogenously determined. Moreover, the theory of production suggests that *LRGDP* itself may also be an endogenous variable, as oil is an input into production and so shocks to *LOIMP* may be reflected in *LRGDP*. Therefore, there is some risk of simultaneity bias if equation (1) is estimated using ordinary least squares. This can be avoided if a vector autoregressive (VAR) modelling approach is employed instead.

When equation (1) is transformed into a VAR model format it takes the following form:

$$LOIMP_t = a_{10} + \sum_{i=1}^{p} a_{1i} LOIMP_{t-i} + \sum_{i=1}^{p} b_{1i} LRGDP_{t-i} + \sum_{i=1}^{p} c_{1i} LRPOIL_{t-i} + u_{1t}$$

$$LRGDP_t = a_{20} + \sum_{i=1}^{p} a_{2i} LOIMP_{t-i} + \sum_{i=1}^{p} b_{2i} LRGDP_{t-i} + \sum_{i=1}^{p} c_{2i} LRPOIL_{t-i} + u_{2t} \quad (2)$$

$$LRPOIL_t = a_{30} + \sum_{i=1}^{p} a_{3i} LOIMP_{t-i} + \sum_{i=1}^{p} b_{3i} LRGDP_{t-i} + \sum_{i=1}^{p} c_{3i} LRPOIL_{t-i} + u_{3t}$$

where *LOIMP*, *LRGDP* and *LRPOIL* are as defined above, u_{it} is the random error term for the i-th equation and time period t, and p is the lag length of the VAR. This format of the model, however, is only valid if *LOIMP*, *LRGDP* and *LRPOIL* are all individually integrated of order zero, i.e., $I(0)$. If this is not the case – specifically, if they are integrated of order d, $I(d)$, and **are not** cointegrated – then all terms in equation (2) must be differenced d times prior to estimation. On the other hand, if the variables are $I(d)$ but **are** cointegrated, then an error-correction term derived from the cointegrating relationship must be included in the model in addition to dth-differenced variables. For example, in the case where all variables are $I(1)$ and have only one valid cointegrating relationship, the appropriate model is a VECM of the following form:

$$\Delta LOIMP_t = a_{10} + \partial_1 ECT_{t-1} + \sum_{i=1}^{p-1} a_{1i} \Delta LOIMP_{t-i} + \sum_{i=1}^{p-1} b_{1i} \Delta LRGDP_{t-i} + \sum_{i=1}^{p-1} c_{1i} \Delta LRPOIL_{t-i} + u_{1t}$$

$$\Delta LRGDP_t = a_{20} + \partial_2 ECT_{t-1} + \sum_{i=1}^{p-1} a_{2i} \Delta LOIMP_{t-i} + \sum_{i=1}^{p-1} b_{2i} \Delta LRGDP_{t-i} + \sum_{i=1}^{p-1} c_{2i} \Delta LRPOIL_{t-i} + u_{2t} \quad (3)$$

$$\Delta LRPOIL_t = a_{30} + \partial_3 ECT_{t-1} + \sum_{i=1}^{p-1} a_{3i} \Delta LOIMP_{t-i} + \sum_{i=1}^{p-1} b_{3i} \Delta LRGDP_{t-i} + \sum_{i=1}^{p-1} c_{3i} \Delta LRPOIL_{t-i} + u_{3t}$$

where Δ is the first-difference operator and *ECT* is the error-correction term. *ECT* represents the deviation from the long-run, or cointegrating, relationship among the variables – i.e., $ECT_t = LOIMP_t - \theta_0 - \theta_1 LRGDP_t - \theta_2 LRPOIL_t$, where the cointegrating vector is normalised on *LOIMP*. If the lagged error-correction term is not included in the model, it will suffer from specification error (Engle and Granger, 1987).

If, for example, the null hypothesis that $\partial_1 = 0$ can be rejected, this implies that *LOIMP* changes in response to shocks that cause a deviation from the long-run equilibrium relationship (i.e., $ECT \neq 0$). As this relationship is normalized on *LOIMP*, ∂_1 is expected to take a value between 0 and −1, as it denotes the fraction of the deviation from the long-run equilibrium observed in period $t-1$ that is expected to be 'corrected' in period t. If the other adjustment parameters, ∂_2 and ∂_3, prove to be non-zero, this indicates that *LRGDP* and

LRPOIL, respectively, are also sensitive to shocks that disturb the system's long-run equilibrium – i.e., they are endogenously determined. However, if the null hypothesis that $\partial_2 = 0$ ($\partial_3 = 0$) cannot be rejected, it can be concluded that *LRGDP* (*LRPOIL*) is weakly exogenous in the context of the model.

Therefore, to choose the correct model, one must first determine the order of integration of each variable in equation (1) by means of a unit-root test. If some or all of these variables are found to be individually non-stationary, it then becomes necessary to determine whether they are cointegrated – i.e., there exists a linear combination of the variables that is stationary.

We use the Johansen (1988, 1991, 1995) approach to test for cointegration in preference to the Bounds test for the following reasons. First, as it tests for cointegration within a VAR framework, the Johansen method does not require the variables within the proposed cointegrating vector (other than the selected dependent variable) to satisfy a weak-exogeneity assumption (which, as mentioned above, may be problematic in the present context). Instead, all are initially treated as if they are endogenously determined and their actual status is evaluated subsequently. Second, because the Johansen test uses a systems estimation method it has the advantage of allowing the number of cointegrating relationships to be determined by the data, rather than assuming there is (at most) only one such relationship, as is done in the Bounds test. Finally, our sample size is reasonably large (T = 103), which somewhat lessens the advantage the Bounds test can have over the Johansen methodology in relation to small samples.

Engle and Granger (1987) demonstrate that, if there is evidence of a cointegration among a set of variables, it implies that there is Granger causality between those variables in at least one direction. Granger causality implies that the past and present values of one variable can help to improve the forecasts of another (Granger, 1969). The existence and direction of causation between any pair of variables from within the cointegrating relationship can be assessed by estimating a VECM that incorporates an error-correction term derived from that relationship (Granger, 1986; 1988). Specifically, evidence of Granger causality running from one variable, X, to another, Y, may be obtained by a joint test of the significance (in the VECM's regression equation with ΔY as the dependent variable) of the *ECT* and the lags of ΔX (Enders, 2004, 334). For example, if after estimating equation (3) the null hypothesis that $\partial_1 = b_{11} = ... = b_{1,p-1} = 0$ can be rejected, then *LRGDP* can be said to Granger-cause *LOIMP*.

If it is also possible to reject the null that $\partial_2 = a_{21} = ... = a_{2,p-1} = 0$, then *LOIMP* can be said to Granger-cause *LRGDP* – i.e., there is bi-directional causality (or causality with feedback) between these two variables. Each of these null hypotheses can also be tested as two separate hypotheses – e.g., $\partial_1 = 0$ and $b_{11} = ... = b_{1,p-1} = 0$. In this way it can be determined whether the source of Granger causality is the process of adjustment back to the long-run equilibrium relationship and/or the VECM's short-run dynamics, respectively.

3.2. Data

Our data set contains quarterly observations of each variable for the period 1987Q2–2012Q4. The choice of the sample period is dictated by the availability of some key data series but, as it falls some time after the two major oil shocks of the 1970s, it has the advantage of reducing the risk of structural changes in the relationships between the variables distorting our econometric results.

Data on the volume of NZ's oil imports are obtained from the Ministry of Business, Innovation and Employment (2013). The quarterly oil imports are in gross petajoules (PJ), which are converted into barrels of oil equivalent at the rate of 1.634×10^5 barrels per PJ. The price of West Texas Intermediate (WTI) 40 API, Midland Texas, is used as a proxy for the world price of oil. The WTI price series is highly correlated with other oil price series and, as Asali (2011, p. 192) notes, "... one can assume the existence of one global price for crude oil, such that using WTI in demand for oil equations of sample countries as a proxy for their domestic crude oil price would not cause any significant problem from a statistical point of view." Data on the WTI price in US dollars per barrel are obtained from the International Monetary Fund's *International Financial Statistics* database (http://www.imf.org/external/ data.htm), as is the US\$/NZ\$ exchange rate used to convert the WTI series into NZ dollar terms. The real oil price series is then obtained by deflating the nominal series with the Consumer Price Index taken from Statistics New Zealand's *Infoshare* database (www.stats.govt.nz/infoshare/), which is also the source of the real (seasonally adjusted) GDP series. Summary statistics of the three variables are presented in Table 1. Note that the real GDP and the real price of oil series have different base years, but this should not create any difficulties as all series are converted in logarithmic terms prior to econometric testing. Plots of *LOIMP*, *LRGDP* and *LRPOIL* are shown in Figure 1

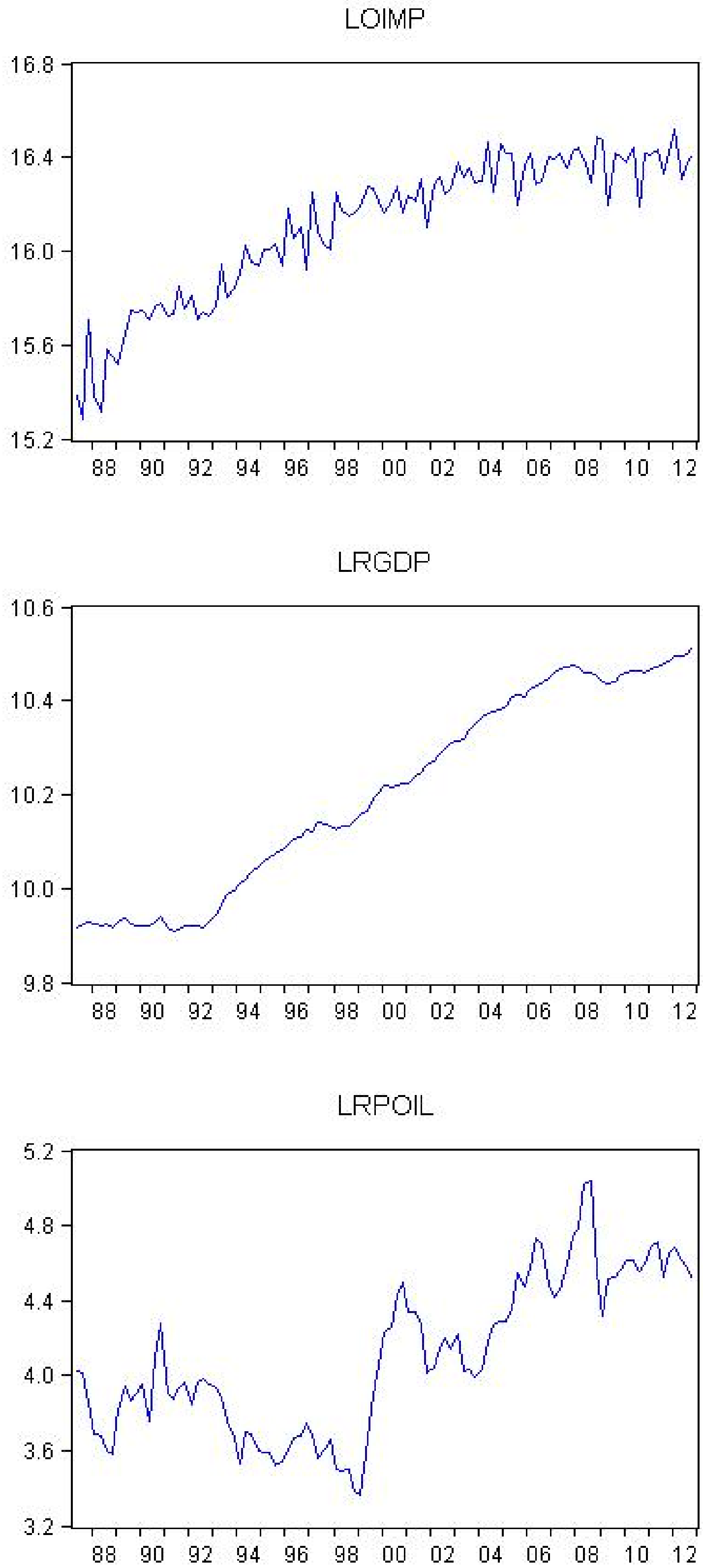

Figure 1
Plots of *LOIMP*, *LRGDP* and *LRPOIL*

Table 1
Descriptive statistics for all variables

	Oil imports (000s of barrels equivalent)	Real oil price (2006 NZ$)	Real GDP (1995/96 NZ$m)
Mean	10,321.4	65.72	27,653
Median	10,846.9	56.26	27,363
Maximum	14,997.2	153.56	36,806
Minimum	4,343.0	28.84	20,113
Std. Dev.	2,778.1	27.70	5,788
Observations	103	103	103

4. Econometric results

4.1 Unit-root test results

To determine whether the variables have non-stationary data-generating processes, three unit-root tests are employed: the Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1981), the Phillips-Perron (PP) test (Phillips and Perron, 1988) and the KPSS test (Kwiatkowski et al., 1992). Under the ADF and PP tests, the null hypothesis is that the series in question has a unit-root process, whereas the null hypothesis under the KPSS test is that it does not. In all cases a linear time trend and a constant term have been included in the test equation. The selection of the optimal lag length for each test equation is based on either the Schwarz criterion (for the ADF test) or the Bartlett Kernel with a Newey-West bandwidth (for the PP and the KPSS tests). The results obtained for each test are presented in Table 2.

All three unit-root tests agree on the time-series properties of *LRGDP* and *LRPOIL*, in that their first-differences are stationary, but when expressed in levels terms they exhibit a unit root. Therefore, we conclude that both series are $I(1)$. The PP test results for *LOIMP*, however, contradict those for the ADF and KPSS tests. The PP test finds evidence that this series is stationary in levels, whereas the other two tests indicate that only its first-difference is stationary. As there is some evidence that *LOIMP* has a unit root, we err on the side of caution and decide to treat it as an $I(1)$ series. Hence, with all three variables considered to be $I(1)$, it is necessary to establish whether they are cointegrated, i.e., whether there is at least one linear combination of these variables that is stationary.

Table 2
Unit-root test results

Variable	ADF test	PP test	KPSS test
LRGDP	–2.0018 (1)	–1.9737 (6)	0.1310* (8)
Δ*LRGDP*	–6.7987*** (0)	–6.8813*** (3)	0.1615 (6)
LOIMP	–1.5903 (3)	–6.7544*** (8)	0.3012*** (8)
Δ*LOIMP*	–13.3166*** (2)	–31.8379*** (8)	0.0441 (7)
LRPOIL	–2.8461 (0)	–2.9488 (2)	0.1821** (8)
Δ*LRPOIL*	–8.5655*** (1)	–8.5743*** (4)	0.0511 (4)

Notes: *** (**) [*] indicates rejection of the null hypothesis at the 1% (5%) [10%] level. Numbers in parentheses are the lag length for the ADF test and bandwidth for the PP and KPSS tests. Δ denotes the first-difference operator.

4.2 Johansen cointegration test results

The first step when applying the Johansen cointegration test is to determine the optimal lag length of the underlying VAR model, i.e., the value of p in equation (2). We follow the optimal lag selection procedure suggested by Enders (2004, pp. 358-359). Specifically, an unrestricted VAR model with p = 5 (= $T^{1/3}$) is initially estimated and then shorter lag lengths are considered. Several lag selection criteria – including a sequential modified LR test statistic, the Final Prediction Error, the Akaike Information Criterion and the Hannan-Quinn Information Criterion – suggest that the optimal lag is p = 4.

The Johansen methodology generates two tests for cointegration: the trace and maximum-eigenvalue cointegration rank (r) tests. The trace test statistic (λ_{trace}) evaluates the null hypothesis that there are, at most, r cointegrating vectors against the alternative that they number more than r. The maximum-eigenvalue (λ_{max}) test is more specific in that its null hypothesis is that there are r cointegrating vectors and the alternative is that there are r + 1 cointegrating vectors. Both tests begin by setting r = 0 and then progressively increase its value until the null hypothesis cannot be rejected. The results obtained are shown in Table 3.

Both the λ_{trace} and λ_{max} test statistics indicate that there is only one cointegrating vector among the three variables under study and this equation is shown – normalised on *LOIMP* – in Table 3. As this equation can be considered to represent the long-run equilibrium relationship among the variables, the coefficients on *LRPOIL* and *LRGDP* are estimates of NZ's long-run price and income elasticities of demand for imported oil. Both estimates have their expected sign and are significantly different from zero at the 1% level of significance. The value of the long-run income elasticity is 1.61, which is comparable to the values found for India (1.97; Ghosh, 2009), France, Italy (1.35 and 1.32, respectively; Asali, 2011) and Japan (1.35; Royfaizal, 2009). The long-run price elasticity is inelastic as expected, and its value of −0.34 is also similar to the estimates found for most other countries.

Table 3
Johansen test for cointegration results

(a) Trace test:

H_0	H_1	λ_{trace}	*p*-value
$r = 0$	$r \geq 1$	37.3690	0.0055
$r \leq 1$	$r \geq 2$	9.8099	0.2956
$r \leq 2$	$r = 3$	1.5275	0.2165

(b) Maximum-eigenvalue test:

H_0	H_1	λ_{max}	*p*-value
$r = 0$	$r = 1$	27.5592	0.0054
$r = 1$	$r = 2$	8.2823	0.3507
$r = 2$	$r = 3$	1.5275	0.2165

(c) Cointegrating equation:

$$LOIMP_t = -1.1333 - \underset{(-4.173)^*}{0.3422}\, LRPOIL_t + \underset{(10.216)^*}{1.6056}\, LRGDP_t$$

Notes: * indicates significance at the 1% level. Numbers in parentheses are *t*-values (underlying asymptotic standard errors corrected for degrees of freedom are calculated using the formula in Boswijk, 1995).

4.3 Tests for structural change and nonlinearity

Our choice of sample period should reduce the risk of parameter instability in NZ's oil import demand relationship due to structural change, but it does not necessarily eliminate the risk. Therefore, we apply Seo's (1998) set of Lagrange Multiplier (LM) tests for structural change, as they are specifically designed for models estimated by the maximum likelihood method used in the Johansen approach. Specifically, Seo (1998) defines three LM statistics: the average (Ave-LM), exponential average (Exp-LM) and the supremum (Sup-LM). All three are based on the methods described by Andrews (1993) and Andrews and Ploberger (1994) and each can be used to test for structural change (at an unknown point) in either (a) the VAR model's adjustment vector (α, which defines its speed of adjustment to long-run equilibrium), (b) the cointegrating vector (β, which defines the long-run equilibrium relationship between the variables), or (c) both α and β jointly.

It is advisable to apply all three tests to evaluate each form of structural change as each has different properties. In particular, the power of the Ave-LM test is concentrated on the alternative that is near the null hypothesis, whereas that of the other two tests is concentrated on more distant alternatives (Seo, 1998). Hence, rejection of the null hypothesis (of no structural change) by any one of these tests would constitute evidence of structural change. It should also be noted that the distribution of each test statistic is nonstandard due to the presence of a nuisance parameter (i.e., the unknown point of structural change). Seo (1998) provides suitable critical values for each test and these depend on the number of variables in the cointegrating vector, its rank and the admissible range for the change point's location (i.e., the extent to which the endpoints of the sample period are excluded from the search for the point of structural change).

The test results obtained are reported in Panel A of Table 4. All three test statistics fall well short of their 5% critical value for each of all three forms of structural change considered. Hence, we conclude there is no evidence of significant structural change in either NZ's long-run oil import demand relationship and/or its adjustment vector.

Another possible source of model misspecification worth considering is the assumption of linearity in the adjustment process to the long-run equilibrium relationship that underlies the Johansen test (in common with most other cointegration tests). It is possible that this assumption is invalid and that the process actually takes a nonlinear form. For example, adjustment may follow a smooth transition process (e.g., exponential, logistic, square-root, quadratic, or logarithmic) or switch to a different regime when a particular threshold is crossed. The appropriateness of the standard assumption of linearity in the cointegrating vector's error-correction process can be assessed by the specification error test (SET_n^{β}) proposed by Seo (2011).

Table 4
Structural change and nonlinearity test results

(A) Structural change tests (Seo, 1998)

(a) Adjustment vector (α):

Test	Test statistic	5% critical value
Ave-LM_n^{α}	2.548	6.070
Exp-LM_n^{α}	1.674	4.220
Sup-LM_n^{α}	5.927	14.150

(b) Cointegrating vector (β):

Test	Test statistic	5% critical value
Ave-LM_n^{β}	0.920	4.320
Exp-LM_n^{β}	0.498	3.240
Sup-LM_n^{β}	2.313	12.550

(c) Joint tests (α and β):

Test	Test statistic	5% critical value
Ave-$LM_n^{\beta\alpha}$	3.468	8.740
Exp-$LM_n^{\beta\alpha}$	2.254	6.130
Sup-$LM_n^{\beta\alpha}$	7.468	18.710

(B) Nonlinearity tests (Seo, 2011)

Polynomial order (k)	SET_n^{β} statistic	p-value
2	2.4109	0.6607
3	2.4548	0.6527
4	2.4971	0.6452
5	2.5364	0.6381

Notes: The admissible range for all structural change tests is defined as [0.15T, 0.85T].

The SET_n^{β} test evaluates the null hypothesis of the standard (i.e., linear) model of vector error correction against an alternative model that allows for general nonlinear specifications of the long-run relationship. In particular, the alternative model is constructed from the polynomials (of order k) of the vector of nonstationary variables in the model and so does not assume a specific nonlinear functional form. This implies that both smooth transition and threshold cointegration models are contained within its specification (Seo, 2011). Our SET_n^{β} test statistics (for k = 2, 3, 4 and 5) are presented in Panel B of Table 4. They reveal no significant evidence against the standard assumption of linear error correction.

4.4 VECM estimation results and tests for Granger causality

As the variables are integrated of the same order and are cointegrated, the appropriate basis for testing Granger causality between oil imports and real GDP is the VECM described by equation (3). This is estimated with $p = 4$ and its error correction term (*ECT*) defined by the cointegrating relationship reported in Table 3. Following Altinay (2007), the model includes a dummy variable (*D*) to control for the effects of the 1991 Gulf War. This dummy takes the value of one in all quarters of 1991 and zero otherwise.

The estimated VECM is reported in Table 5. A range of standard diagnostic tests for stability, heteroskedasticity, autocorrelation and error normality are applied to this model and their results (which are not reported, but are available on request) reveal no significant evidence of any undesirable statistical properties. It can be seen that the coefficient on ECT_{t-1} is statistically significant in the oil imports equation alone, which implies that only the quantity of oil imported adjusts in response to any deviation from the long-run equilibrium relationship in order to re-establish the long-run relationship. This coefficient is negative, as expected, and its magnitude implies that 34% of the deviation from the long-run equilibrium relationship is eliminated in each quarter. The insignificance of the ECT_{t-1} terms in the other two equations implies that both real GDP and real oil prices are weakly exogenously determined in the context of this model.

The short-run price and income elasticities of NZ's demand for imported oil are represented by the coefficients on $\Delta LRPOIL(-1)$ and $\Delta LRGDP(-1)$, respectively, in the $\Delta LOIMP$ equation. The value of the former is 0.09 and the latter is 0.78, but both estimates are statistically insignificant. This implies that NZ's demand for oil imports is slow to respond to changes in both its level of economic activity and oil prices.

It is interesting to note that the estimated coefficient on the Gulf War dummy variable, *D*, is negative and statistically significantly different from zero at the 5% level in the $\Delta LRGDP$ equation in Table 5. This result suggests that the Gulf War in 1991 had adversely affected, although to an economically small extent, the real GDP of NZ.

Table 5
Vector error correction model estimates

Independent variables	Dependent variables		
	$\Delta LOIMP$	$\Delta LRGDP$	$\Delta LRPOIL$
$ECT(-1)$	–0.3418**	0.0109	–0.2355
	(–3.9328)	(1.3521)	(–1.7224)
$\Delta LOIMP(-1)$	–0.6970**	0.0148	0.2706
	(–6.6761)	(1.5191)	(1.6472)
$\Delta LOIMP(-2)$	–0.6859**	0.0020	0.1981
	(–6.6591)	(0.2120)	(1.2224)
$\Delta LOIMP(-3)$	–0.3844**	0.0161	–0.0215
	(–4.3022)	(1.9323)	(–0.1531)
$\Delta LRGDP(-1)$	0.7792	0.2910**	–0.1444
	(0.6967)	(2.7976)	(–0.0821)
$\Delta LRGDP(-2)$	–0.5152	0.1013	0.2952
	(–0.4547)	(0.9609)	(0.1659)
$\Delta LRGDP(-3)$	–0.4239	0.0700	1.2371
	(–0.3923)	(0.6962)	(0.7278)
$\Delta LRPOIL(-1)$	0.0939	–0.0082	0.2620*
	(1.3616)	(–1.2819)	(2.4156)
$\Delta LRPOIL(-2)$	0.0409	–0.0126*	–0.2544*
	(0.6132)	(–2.0269)	(–2.4231)
$\Delta LRPOIL(-3)$	0.0911	–0.0089	0.2195
	(1.2992)	(–1.3713)	(1.9897)
CONSTANT	0.0253*	0.0035**	–0.0035
	(2.1571)	(3.2031)	(–0.1880)
D	0.0182	–0.0085*	–0.0419
	(0.4240)	(–2.1351)	(–0.6194)

Notes: Figures in parentheses are *t* statistics. ** (*) indicates statistical significance at the 1% (5%) level in two-sided tests.

To determine the pattern of Granger causality within our VECM, Wald χ^2 tests are conducted and the results are reported in Table 6. These reveal evidence that oil imports are Granger-caused by real GDP and the real price of oil through the error-correction process that re-establishes the long-run equilibrium relationship, but not through the model's short-run dynamics. It can also be seen from Table 6 that oil imports Granger-cause real GDP through the model's short-run dynamics. The positive coefficient estimates for the lagged $\Delta LOIMP$ terms within the $\Delta LRGDP$ equation in Table 5 indicate that this causal relationship is positive. Hence, disruptions to the supply of oil are expected to adversely affect real GDP in the short run.

Table 6
Granger-causality test (Wald χ^2) results

Dependent variable	Sources of causation						
	Short-run			Long-run	Short-run plus long-run		
	Δ*LOIMP*	Δ*LRGDP*	Δ*LRPOIL*	*ECT*	Δ*LOIMP* + *ECT*	Δ*LRGDP* + *ECT*	Δ*LRPOIL* + *ECT*
Δ*LOIMP*	–	0.709 (0.871)	0.332 (0.343)	15.467** (0.000)	–	15.676** (0.004)	15.658** (0.004)
Δ*LRGDP*	8.855* (0.031)	–	7.562 (0.056)	1.828 (0.176)	15.248** (0.004)	–	7.568 (0.109)
Δ*LRPOIL*	4.340 (0.227)	0.726 (0.867)	–	2.967 (0.085)	5.252 (0.262)	4.081 (0.395)	–

Notes: ** indicates statistical significance of the test statistic at the 1% level. * indicates statistical significance at the 5% level. Figures in parentheses are *p*-values.

Table 6 also shows that the price of imported oil is not Granger-caused by either NZ's real GDP or its oil imports. This is as expected, as NZ is too small to have the economic or political influence required to affect outcomes in the world oil market. However, the null hypothesis that real GDP is Granger-caused by the real price of oil through the model's short-run dynamics can almost be rejected at the 5% level of significance. This result offers some evidence that oil price shocks also have the ability to adversely affect economic activity in the short run (as the coefficient estimates in Table 5 for the lagged Δ*LRPOIL* terms within the Δ*LRGDP* equation are negative).

5. Conclusions

This paper assesses the NZ economy's vulnerability to shocks originating in the world market for oil. These shocks can take the form of a sudden and dramatic rise in the price of oil or disruptions to oil supplies caused by wars, natural calamities, or oil embargos by exporting countries, etc. The oil price shocks of the 1970s highlighted the importance of this commodity to the operation of most economies. Although efforts have been made to improve energy efficiency and develop alternative energy sources since then, most economies are still very dependent on oil. NZ, in particular, has reduced its dependence on oil since 1973, but nonetheless it still remains the single most important source of energy for the economy.

Through cointegration analysis and vector error correction modelling, we find the following results. First, NZ's demand for oil imports is price-inelastic in both the short and long run. Specifically, in the short run there is no statistically discernible effect on demand in response to a change in the world oil price. In the long run, the demand for imported oil will react, but only by one-third of a percent for every one percent change in the price. Hence, in the event of a dramatic rise in the oil price, NZ's trade balance would be expected to fall sharply, *ceteris paribus*. Second, there is evidence that oil imports, and possibly oil prices as well, Granger-cause economic activity. Specifically, NZ's real GDP is expected to be adversely affected by disruptions to the availability of imported oil and increases in its price.

In summary, the NZ economy is still vulnerable to shocks originating in the world oil market. Measures that can be taken to lessen the adverse effects of such shocks include the creation of a strategic oil reserve to maintain supply in the event of a disruption to the availability of oil imports, the promotion of energy efficiency and conservation through taxes and subsidies, the further development of domestic oil resources to reduce reliance on foreign oil, and the development of renewable energy resources with a view to lessen the importance oil as a source of primary energy. The NZ Government has given priority in its energy strategy for the period 2011-2021 to some of these measures. In particular, its goal is to develop all available domestic renewable and non-renewable energy resources (such as petroleum, waves, sun, wind, water, geothermal, etc.), improve energy efficiency and conservation, and to achieve a secure and affordable energy supply (Ministry of Economic Development, 2013b). It should also be noted here that the Government maintains a 90-day oil reserve to respond to a serious international oil supply disruption.

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