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Pollution, energy use, GDP and trade: Estimating the long-run relationship for Vietnam

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Abstract

Since the beginning of economic reform in the 1980s and, in particular, with its openness to international trade accelerating since the 1990s, the Vietnamese economy has registered significant growth. At the same time, energy consumption and the level of pollution in Vietnam has also increased. This paper aims to focus on the link between openness to trade and pollution in Vietnam. Due to lack of data, very few existing studies have focused on Vietnam. Using annual data from 1980 to 2011 and employing the bounds testing approach to cointegration, based on an Autoregressive Distributed Lagged (ARDL) model, we find that there is a statistically significant long-run relationship amongst pollution, openness to trade, energy consumption and real national income in Vietnam. This conclusion continues to hold when the possibility of a structural break in the relationship is allowed for using the Gregory-Hansen approach to cointegration. Analysis of the cointegration relationship suggests that, in response to any exogenous shock to the system, adjustment back to the long-run equilibrium is very fast.

Key Words: Pollution, energy consumption, openness, Vietnam, ARDL, structural breaks

JEL Classifications: Q430, O530, P280

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1. Introduction

There are many studies of the link between the growth of Gross Domestic Product (GDP) and energy use. In developing economies, the issue of increasing pollution as a result of rising energy use has become important. Particular attention has been paid to China (Zhang & Chen (2009), Jalil & Malmud (2009), Chang (2010) and Wang, et al., (2011)). Other developing and transition economies recently studied include Taiwan (Chen, 2012), Tunisia (Belloumi, 2009), Turkey (Soytas & Sari, 2009), India (Paul & Bhattacharaya, 2004), Malaysia (Lee, 2009), Pakistan (Aqeel & Butt, 2008) and a number of sub-Saharan countries (Le, 2016). Vietnam provides an interesting case because of its recent transformation from one of the poorest countries of Asia to a middle-income economy (World Bank, 2012). We can find only one study specific to Vietnam, that of Tang & Tan (2015), who find evidence of a long-run relationship between CO2 emissions, energy consumption, income and foreign direct investment. Having some reservations about the modelling strategy in Tang & Tan (2015), which we take up in the literature review, our aim is to add to the limited evidence for Vietnam.

In studying the GDP-energy nexus, it is clear that there is a range of other variables that may affect this relationship. Data limitations constrain the number of factors that can be controlled for, but two variables are crucial in the emerging economy context: the economy’s degree of openness and its level of pollution. It is possible that these two variables are connected via the pollution haven hypothesis (Dong, et al., 2012; Tang, 2015) in that emerging economies that want to attract foreign investment may be relatively lax with respect to environmental regulation.

It is widely considered that a shift towards more outward-oriented policies has been an important driver of GDP growth in the emerging economies in general, with China being the outstanding example (Tingvall & Ljungwall, 2012). For a fixed technology, energy consumption goes in step with output; in other words, economic growth entails increased energy consumption and therefore, for a given state of technology, increased levels of pollution. In practice, the energy intensity of output has varied greatly, both across countries and through time, with the developed countries of Western Europe always consuming less energy per dollar of GDP than the USA (World Bank, 2014b). As countries have become richer, it has been suggested that consumers have tended to demand a cleaner environment so that a Kuznets curve for pollution (Grossman & Krueger, 1995) has been observed, whereby pollution levels at first rise with income and then decline, although some have challenged the
existence of such a relationship or, at least, the robustness of the statistical evidence for it (Stern, 2004).

In considering the potential causal links amongst pollution, energy consumption, GDP and openness to trade, it is clear that we would expect increased energy consumption to cause increased pollution, but not the reverse. There could well be bi-directional causality between energy consumption and GDP. If, as one might expect, growth caused increased pollution, it is also possible that higher income would eventually create a demand for, or allow spending on, a cleaner environment so that an increase in pollution could cause a decrease in energy consumption through improved efficiency or abatement measures but it could conceivably even lead to a decrease in GDP. A government that increases its economy’s degree of openness is expecting this to lead to improved growth but we cannot rule out a feedback effect from higher growth to increased trade. It is also likely that export-led growth may increase energy use and possibly pollution. *A priori*, then, we should not rule out any combination of causal links between the four variables pollution, energy consumption, GDP and openness. We intend to model the long-run relationship amongst pollution, energy consumption, GDP and openness in Vietnam using appropriate time-series techniques and examine causality in the sense of Granger (Granger, 1988).

The remainder of this paper is structured as follows. In Section 2, we present background information on the Vietnamese economy and describe Vietnam’s recent economic performance. Section 3 outlines the previous recent literature, focussing on previous review articles and representative single-country studies. In Section 4, we outline our preferred approach to modelling these relationships as well as the data used. Section 5 presents the results and Section 6 concludes.

2. The Vietnamese economy

In the 1970s, Vietnam emerged from a lengthy period of colonial domination by France and then the American War as a single-party Communist state. The leaders of North Vietnam were proud of the achievement of defeating a much more powerful enemy and had confidence that their uniquely Vietnamese version of socialism was superior to the market-based system (Rama, 2008). However, the nation did not thrive economically; by 1980, food production in the North of the country had dropped to 215 kg *per capita*, the lowest level ever recorded (Steinfeld & Thai, 2013).
Even during the immediate post-unification period, trials of market-based mechanisms had taken place on a locally-controlled basis; for example, in 1979, in Ho Chi Minh City, the Party Secretary arranged a system to purchase rice “from farmers at the market price, in spite of it being five times higher than the price set by planners in Hanoi” (Rama, 2008: 17). By 1986, attitudes had slowly adjusted and more of the Communist Party leadership recognised that economic reform on a wider scale was essential if Vietnam were to make a successful transformation to a modern economy. Thus, a programme of economic renovation (Doi Moi) was put in place. Central to this policy was a so-called socialist market mechanism which amounted to the liberalisation of the price of many products and the encouragement of international trade and foreign direct investment (Vuong, 2014).

In the 20 years following the institution of Doi Moi, the economy of Vietnam grew at an average rate of 7.5% p.a. and, since the early 1990s, poverty, as measured by a basic needs approach, fell from 58% of the population to under 10% in 2010 (World Bank, 2012). Over the 21 years from 1990 to 2011, only two economies in the world, China and Vietnam, exceeded a 5% growth rate in each and every year (Malesky & London, 2014).

As with China, the strong growth of the Vietnamese economy has been associated with increasing trade. Openness to trade can be measured in a number of ways; here, we intend to measure it conventionally as the sum of exports and imports as a proportion of GDP. In 1980, this measure of openness of the Vietnamese economy sat at 0.625 and in 1990 it was almost the same, 0.623, having varied little over the 1980s. However, from the 1990s, openness grew very strongly to reach 1.628 in 2011 (World Bank 2014a).

The sectoral structure of the Vietnamese economy has changed substantially. The share of the labour force in agriculture fell from 70.5% in 1989 to 53% in 2009 for the work force as a whole and from 66.8% to 43.2% for those aged 25 to 29 while from 2000 to 2008, the annual growth rate of the labour force in manufacturing averaged 11.9% (McCaig & Pavcnik, 2013).

Since the Global Financial Crisis, Vietnam has, along with the rest of the world, faced slower economic growth although, in comparison to the countries of the OECD, its performance is still impressive, with GDP growing at 5.431% in 2013 as opposed to only 1.506% in the advanced economies (International Monetary Fund, 2014).

Naturally, along with impressive economic growth, involving a change in the structure of the economy from a poor agrarian society to an increasingly urbanised one reliant
on modern manufacturing and services sectors has gone higher levels of energy consumption and pollution. Emissions of CO₂ rose from 0.4 tonnes per capita in 1995 to 1.7 tonnes per capita in 2010 (World Bank, 2014b).

The American War left Vietnam with the legacy of the effects of the use of the chemical defoliant Agent Orange. Soldiers of the USA returning home after the War began to report not only their own illness but genetic damage in their children. Between 2007 and 2010, the US Congress set aside USD 9 million, primarily for cleaning up former dioxin-contaminated sites but also for health assistance for the estimated 3-5 million Vietnamese affected by dioxin in some way (Manyin, 2010). It might be thought that this would leave the population sensitised to issues surrounding pollution but often the relatively poor perceive themselves as having little option but to tolerate poor environmental conditions for the sake of income. This has been notable in the craft villages of Vietnam, where many have chosen to put up with potentially harmful levels of pollution for the sake of immediate economic security (Dang, T.D. et al., 2013).

Urbanisation, which has seen the proportion of the population living in cities grow from 19% in 1980 to 32% in 2013 (World Bank, 2015), has also brought with it traffic congestion and high levels of air pollution. According to the 2014 Environmental Performance Index, which is a joint project of the Yale Center for Environmental Law & Policy (YCELP) and the Center for International Earth Science Information Network (CIESIN) at Columbia University, Vietnam rates the ninth worse of the 178 countries on overall air quality and tenth worse for average exposure to PM₂.₅ (fine particulate matter) (Yale Center for Environmental Law & Policy and the Center for International Earth Science Information Network, 2015). Land clearance, taken together with increased storm activity caused by global warming, has heightened the risk of flooding in cities. Rising sea levels and storm surges in coastal areas where the population relies on fishing for their livelihoods is also a major threat. Vietnam, situated in a tropical cyclone zone and with its extensive coastline and otherwise mountainous geography, is very exposed to extreme weather events and to the consequences of predicted rises in sea level (Dang, V. et al., 2013).

3. Related literature
Two recent reviews of the literature on the connection between energy use and economic growth have noted the difficulty of making any general conclusions, because studies have
varied as to their coverage (countries, time periods) as well as in their methods. Oztur (2010) presents a general survey of the literature, drawing attention to the widely differing methods and conclusions, while Menegaki (2014) undertakes a meta-analysis.

Oztur (2010) suggests that it is inevitable that differing country characteristics such as energy supplies, political institutions and policies will make it impossible to generalise. In fact, amongst single-country studies, it is possible to find those that report bi-directional causality between energy consumption and GDP (or economic growth) as well uni-directional causality in either direction and even no causality whatsoever. Bi-directional causality is found for Tunisia (Belloumi, 2009), India (Paul & Bhattacharaya, 2004) and Korea (Glasure, 2002). Energy consumption causes growth in Malaysia (Lee, 2009), in Hong Kong (Ho & Siu, 2007), in Taiwan (Lee & Chang, 2005) and in Korea (Oh & Lee, 2004), but GDP causes energy consumption in China (Zhang & Cheng, 2009) and in Pakistan (Aqeel & Butt, 2008). No evidence for causality is found for Turkey (Soytas & Sari, 2009).

Given the difficulty of making any general conclusions from even the most objective of attempts to review the literature, a meta-analysis presents an alternative approach. The essence of a meta-analysis (Paldam, 2015) is to survey the literature which reports estimates of a particular parameter, to code this literature and then to arrive an estimate of a meta-average of the parameter of interest. Menegaki (2014) attempts a meta-analysis of studies of energy consumption and GDP over the last two decades and tends to confirm Ozturk’s more subjective findings, namely that the specific econometric method used affects the result as does the number of countries in the study and as do the control variables in the regression.

Since our study is focused on one country, Vietnam, we will leave aside cross-country studies and centre our attention on a selection of more recent individual country studies, particularly noting their choice of method, which has tended to converge on the ARDL approach to cointegration. There have been many studies of China, given its importance as the leading emerging economy; representative of the approaches taken are Jalil & Malmud (2009) and Wang, et al., (2011). Typical of recent studies for other countries are Lee (2009) for Malaysia and Le (2016) for a panel of sub-Saharan countries.

Jalil & Malmud (2009) use the ARDL method to study the long-run relationship amongst carbon emissions, energy consumption, GDP and foreign trade in China. They find that trade openness has no significant long-run effect on carbon emissions, but the other variables do. The short-run error-correction model (ECM) results indicate about 60% of any annual disequilibrium adjusts within a year.
Wang, et al., (2011) exploit access to provincial level data from China to implement a panel cointegration model of the relationships amongst carbon dioxide emissions, energy consumption and GDP (and the square of GDP). Their estimated long-run cointegrating relationship finds an elasticity of pollution with respect to energy use very close to 1. Unfortunately, the sign of the GDP variable is not significant while its square has a positive coefficient; the result that pollution increases with the square of GDP would be very worrying, if true.

Lee (2009) uses the ARDL Pesaran et al. (2001) ARDL approach to cointegration to consider the bi-variate relationships between CO2 emissions, FDI and GDP in Malaysia, noting the advantage of this approach when there is a mixture of AR(0) and AR(1) variables. Only one long-run co-integrating relationship is found, that between FDI and GDP and that only when FDI is the dependent variable. Lee (2009) concludes from this that there is long-run causality running from GDP to FDI. In contrast, the results of short-run Granger causality tests suggest causality running from FDI to GDP, as well as from FDI to CO2 and CO2 to GDP.

Le (2016) looks for a long-run cointegrating relationship amongst energy use, GDP, capital, openness and financial development in a panel of 15 sub-Saharan countries from 1983 to 2010. Results are reported for two sub-panels of low-income and middle-income countries, respectively. Appropriate panel unit root tests are applied and indicate that all variables are non-stationary in levels but stationary in differences. Panel cointegration tests find a long-run cointegrating relationship in both the full panel and both sub-panels, although the details of the results differ across the three panels. Granger causality tests also indicate differing patterns of causality in the full sample and sub-samples of middle and low-income countries. Given the sensitivity of results to the sample, Le’s findings support the view that it is safer to focus analysis on a single country.

The only study, of which we are aware, focussing specifically on Vietnam is Tang and Tan (2015), which uses the Johansen cointegration method to estimate both long-run (from the cointegrating vector) and short-run (from the error-correction model) elasticities of pollution (CO2 emissions) with respect to GDP, energy consumption and FDI (foreign direct investment). All of the variables in their model are in natural logs and are expressed in per capita terms and both GDP and its square are entered into the model. Both the use of variables in per capita terms and the use of the quadratic in GDP are problematic.

In the case of cross-country studies, there is evidently a need to express variables such as GDP in per capita terms to bring the variables for different countries to a common scale.
However, this is not necessary when studying a single country; it would be sufficient to ensure that income was in real terms. Expressing pollution in *per capita* terms creates a further difficulty of interpretation. Consider, for example, a doubling of both population and pollutants; this would leave CO₂ emissions *per capita* unchanged, yet it could have a potentially serious deleterious effect on the environment. It is clear that the variable of interest is the *total* emissions of CO₂.

When a variable and its square are entered into a regression, one should always check that the estimated coefficients make sense in the following way: the turning point of the implied quadratic ought to be within the range of the data used. In this case, both lnGDP and lnGDP² turn out to be significant at better than the 1% level in the long-run cointegrating relationship. These coefficients are estimated, respectively, to be 15.8507 and -0.4906. These figures appear to be consistent with increases in GDP at first increasing the level of pollution but eventually leading to pollution decreasing. However, if we calculate the turning point for this relationship, it turns out to be at a GDP per capita of 79,265. The units in which GDP are expressed are not stated in the paper but 79,265 is consistent neither with USD nor International dollars at PPP nor with domestic currency.

These concerns about the way the model in Tang & Tan (2015) is specified raise doubts about its findings. The issue of which econometric method is preferable will be taken up in the next section.

4. Empirical model and data

In order to examine the impact of openness to trade on pollution in Vietnam we use the following empirical model, where all variables are in natural logarithms.

\[
POLS = \alpha_0 + \alpha_1 ENC + \alpha_2 RGDP + \alpha_3 OPN + \mu
\]

\(POLS\) is the level of pollution as measured by carbon dioxide emissions total from consumption of fossil fuels in millions of tonnes; ENC is energy consumption in quadrillion btu; RGDP is real GDP in billions of US dollars; OPN is openness to trade measured by exports plus imports as a proportion of GDP; and \(\mu\) is the usual error term, which captures the impact of omitted variables.

All data are from the United Nations World Development Indicators (WDI, 2015) and the General Statistics Office (GSO, 2015) of Vietnam and are observed annually from 1980 to 2011. Over the period under consideration, RGDP grew at a compound annual rate of
6.82%, ENC at 8.04% and POL at 7.11%. Economic growth, of course, was very variable on an annual basis, but it never turned negative at all with the lowest annual increase being 1.69% in 1986-87. The highest annual growth rate experienced was 12.04% in 2004-05 and the standard deviation of growth of RGDP was 2.06%. The annual growth rates of ENC and POL were much more variable, with standard deviations of 7.71% and 9.32%, respectively. As already noted, openness was static in the 1980s but, between 1990 and 2011, the ratio OPN grew at a compound annual rate of 4.68%. Given the very strong rates of growth of the four variables under consideration, the clearest way to present the descriptive data visually is in natural logarithms. Running from the top to the bottom of the diagram, Figure 1 presents the time series from 1980 to 2011 of the natural logs of pollution, real output, openness and energy consumption (POL, RGDP, OPN and ENC, respectively). Note that, because of the differing units for each variable, their magnitudes should not be compared, but the pattern of growth of each is clear as is the need to take care to use methods to avoid the issue of spurious correlations.

--- insert Figure 1 about here ---

We first examined all variables for stationarity. It is clear from Figure 1 that non-stationarity is likely. It is well-known that different unit root tests can lead to different results and hence we used the Phillips-Perron (PP), Kwiatkowski-Phillips-Schmidt-Shin (KPSS), and Perron tests with structural breaks, as well as the usual Augmented Dicky-Fuller (ADF) test. The results of the first three tests are summarised in Table 1. The ADF results were similar to those of the PP test. The results of KPSS testing procedure suggest that, at the 5% level of significance, three variables are stationary in first differences and one variable is stationary in levels. The results of Phillip-Perron test suggest that all variables are non-stationary in levels and three variables are stationary in first differences. The results of Perron test with structural breaks suggest that all variables are non-stationary in levels with a structural break.

Given the mixed nature of the unit root testing results, we use the Pesaran et al. (2001) autoregressive distributive lags (ARDL) based bounds testing approach to cointegration. It is well-known that the ARDL-based bounds testing approach to cointegration is super-consistent in small samples. It is also preferred to Johansen’s approach because of the small sample size. A large number of studies involving relatively small sample size have utilised the ARDL-bounds testing procedure. (See, amongst others, Govundaraju, et al. (2011) and Behket & Al-Smadi (2015), as well as the references therein.) However, given the results of
the Perron test with structural breaks, we also use the Gregory-Hansen approach to cointegration in the presence of structural breaks.

Based on equation (1), which involves four variables, the Persaran et al. bounds testing approach involves the use of the following ARDL model:

$$\Delta POL_i = \phi_0 + \pi_1 POL_{t-1} + \pi_2 ENC_{t-1} + \pi_3 RGDP_{t-1} + \pi_4 OPN_{t-1} + \sum_{i=0}^{p} \lambda_i \Delta POL_{t-i} + \sum_{i=0}^{p} \gamma_i \Delta ENC_{t-i} + \sum_{i=0}^{p} \alpha_i \Delta RGDP_{t-i} + \sum_{i=0}^{p} \beta_i \Delta OPN_{t-i} + \varepsilon_t$$

(2)

\(\Delta\) is the first difference operator; \(\phi_0\) is the constant; \(\pi_s\) are the long run coefficients; \(\lambda, \gamma, \alpha, \beta\) represent short run dynamics and \(\varepsilon_t\) is the random variable, which is assumed to be white noise.

The ARDL approach involves estimating \((p + 1)^k\) regressions, where \(p\) is the maximum number of lags and \(k\) is the number of variables in the equation. We used the Schwartz-Bayesian Criteria (SBC) to determine the optimal lag length. The bounds testing approach involves the use of an F-test or a Wald-test to determine the presence of a long-run relationship among the variables of interest. The asymptotic distributions of the test statistic used are non-standard, regardless of whether the variables are I(0) or I(1) and hence the ARDL bounds testing results are based on the use of two critical bounds. These critical values are computed by stochastic simulations. Using 20,000 replications and employing Microfit 5, two asymptotic critical values are calculated; one when the variables are assumed to be I(0) and the other when the variables are assumed to be I(1). These are, respectively, known as lower critical bound (LCB) and upper critical bounds (UCB). If the estimated value of the test statistic exceeds the UCB, then there is evidence of a long-run relationship. Alternatively, if the test statistics are below the LCB then the null hypothesis cannot be rejected. However, if the sample test statistics fall between these two bounds, then the result is inconclusive.

Once cointegration has been established, the long-run relationship can be estimated using the selected ARDL model. For example, if the variables are cointegrated in equation (2) then there is a stable long run level relationship among the variables, which can be described as follows:

$$POL_i = \Phi_0 + \Phi_1 ENC_i + \Phi_2 RGDP + \Phi_3 OPN_i + \mu_i$$

(3)
\[ \Phi_0 = \varphi_0 / \pi_1, \Phi_1 = -\pi_2 / \pi_1, \Phi_2 = -\pi_3 / \pi_1, \Phi_3 = -\pi_4 / \pi_1 \] and \( \mu_t \) is a mean zero stationary process.

Also, once cointegration has been established, the underlying error correction model can be estimated. The underlying error correction model is as follows:

\[
(1-L)POL = a + \sum_{i=1}^{p} (1-L)b_{ii} + b_{12} b_{13} + b_{14} e_i + \theta ECT_{t-1} + \varepsilon_i 
\]

where \((1-L)\) is the difference operator; \( ECT_{t-1} \) is the lagged error-correction term derived from the long-run cointegrating relationship; and \( \varepsilon_i \) is a serially independent random error with mean zero and finite covariance matrix. The results of the ARDL as well as Gregory-Hansen estimation are presented and discussed in Section 5.

5. Empirical Results

5.1 ARDL Bounds Testing

We used a vector autoregressive (VAR) model to conduct the bounds test for the null hypothesis of no cointegration. Given that the sample size is small, a maximum lag length of 3 was allowed. Using Microfit 5, the estimated VAR model is summarised in Table 2.

--- Insert Table 2 about here ---

The estimated values of the \( F \) and Wald tests as reported in Table 2 exceed the relevant UCBs at the 10% level of significance. Accordingly, with 90% confidence, one can argue that pollution, energy consumption, real GDP and trade openness in Vietnam are cointegrated. In other words, there is a stable long run relationship amongst these variables. However, at the 5% level of significance, the results of both \( F \) and Wald test are inconclusive as the estimated test statistic falls within the relevant LCB and UCB. The results of diagnostic testing results presented in Table 2 suggest the absence of significant autocorrelation.

As there is sufficient evidence of cointegration at the 10% level of significance, we proceed to estimate the underlying long run relationship. It is summarised in Table 3.
In the long run, each of the three variables (energy consumption, real GDP and openness) has a positive and statistically significant effect on pollution in Vietnam. The estimated long-run elasticities of pollution with respect to energy consumption, GDP and openness are about 0.80, 0.85 and 0.37, respectively. Tang and Tan (2015) found the long-run elasticity with respect to energy consumption to be more than double our estimate (1.745) and the elasticity with respect to FDI (which could be considered as another proxy for openness) to be negative, although of a very small magnitude (-0.0646). Of course, given the different specification, one would not expect these estimates to be strictly comparable with those in the present paper. In the case of the GDP variable, we have already explained the implausibility of Tang and Tan’s estimates.

The next step involves estimation of the underlying error correction model. The presence of a significant relationship in first differences of the variables provides evidence of the direction of short-run causation while a significant $t$-statistic pertaining to the error correction term ($ECT$) suggests long run causation. However, it is worth highlighting that the results of the error correction model must be interpreted in a predictive rather than in a deterministic sense. In other words, causality is to be interpreted in the Granger sense. The estimated error correction model is summarised in Table 4.

The ECM suggests that energy consumption has a positive and significant impact on pollution in Vietnam in the short run. The estimated coefficient of the error correction term, which is negative and less than unity as expected, is highly significant. This confirms the presence of a highly stable long run relationship amongst pollution, energy consumption, real GDP and trade openness in Vietnam. As the estimated coefficient (i.e., -0.92945) is close to unity, it can be argued that in response to any shocks to the system, pollution in Vietnam returns to its equilibrium value fairly quickly, about 93% of the adjustment having been made within a year.

While the estimated results presented in this section confirm the presence of a significant long run relationship, we have so far ignored the possibility of a structural break in each of the four variables. In the next section, we test for the presence of cointegration in the presence of a structural break (Gregory & Hansen, 1996).
5.2 Cointegration in the presence of a Structural Break

It has been argued that ignoring structural breaks can reduce the power of cointegration testing procedures. Accordingly, in this section we present the results of the Gregory-Hansen cointegration test, which assumes a single break. We considered the case of a break in the regime and allowed a maximum of 3 lags. The estimated results are presented in Table 5, where the test statistic and critical values for three alternative tests are presented. Based on the estimated results, at the 5% level, two out of three tests suggest the presence of cointegration with a structural break. These results confirm our general conclusion that there is a long run relationship amongst pollution, energy consumption, real GDP and openness to trade in Vietnam.

--- Insert Table 5 about here ---

5.3 Further Evaluation

Based on the selected ARDL model, Figure 2 shows the actual and fitted values of pollution in Vietnam. The estimated value of Theil inequality coefficient is 0.003062. As the estimated value of Theil inequality coefficient is very close to zero, the estimated model can be viewed as highly reliable for forecasting purposes.

--- Insert Figure 2 about here ---

In order to understand how pollution in Vietnam responds to exogenous shocks to factors like energy consumption, real GDP or economic openness, we make use of a Bayesian VAR model with a maximum of three lags. The Bayesian approach has the advantage over a standard VAR procedure in that it does not suffer from over-parameterisation, which tends to reduce the forecasting accuracy of the model. The impulse response of pollution to each of the three factors is shown in Figure 3. An increase in energy consumption and real GDP increases the level of pollution immediately and the pollution level stays at this higher level thereafter. An increase in openness to trade initially leads to a decrease in the level of pollution but this effect does not last long. After period two, the level of pollution increases and stays at the higher level.

--- Insert figure 3 about here ---
6. Conclusion

Due to unavailability of data, very few studies have so far examined the implications of the economic reforms in Vietnam for the connection between economic growth and pollution. As the economy has become more open to trade, the standard of living of the Vietnamese people has improved over time, but energy use has increased and so has the level of pollution.

In order to examine the link between trade openness and pollution in Vietnam, we utilise annual data from 1980 to 2011. Our analysis, based on the ARDL bounds testing approach to cointegration, suggests that there is a long-run relationship amongst pollution, energy consumption, real GDP and trade openness in Vietnam. The estimated long-run elasticities of pollution with respect to energy consumption, GDP and openness to trade are all statistically significant and of plausible magnitudes. We find that, in response to exogenous shocks, the relationship amongst these variables returns to its long-run equilibrium very quickly. Analysis of the impulse response function suggests that an increase in energy consumption and real GDP leads to an immediate increase in pollution in Vietnam. An increase in openness to trade initially decreases the level of pollution but this trend is not sustained.

Given that we find, in the long run, a less than one-for-one impact from any percentage change in energy consumption, GDP or openness on pollution, the Vietnamese economy appears to be growing in a relatively sustainable manner. The effect on pollution of increases in openness is low so that it would be positive to continue to encourage the growth of trade, especially the importation of improved and energy-efficient technologies. This is, of course, not to suggest that the overall increased level of pollution, particularly being concentrated in some areas, has been without its problems. Efforts to reduce the energy-intensity of production and to adopt cleaner energy sources could be expected to lead to a drop in the long-run elasticity of pollution to GDP.

References


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<th>Variable</th>
<th>Phillips-Perron Test (H₀: The variable is non-stationary)</th>
<th>KPSS Test (H₀: The variable is stationary)</th>
<th>Perron Test (H₀: The variable is non-stationary with a structural break)</th>
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<td>Do not reject at the 1% level</td>
<td>Do not reject at the 1% level</td>
<td>Do not reject at the 1% level</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Do not reject at the 5% level</td>
<td>NA</td>
</tr>
<tr>
<td>Openness</td>
<td>Do not reject at the 1% level</td>
<td>Reject at the 1% level</td>
<td>Do not reject at the 1% level</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reject at the 5% level</td>
<td>Do not reject at the 1% level</td>
</tr>
</tbody>
</table>
Table 2: Autoregressive Distributed Lag Estimates

<table>
<thead>
<tr>
<th>Dependent variable is POL</th>
</tr>
</thead>
<tbody>
<tr>
<td>29 observations used for estimation from 1983 to 2011</td>
</tr>
<tr>
<td>ARDL(3,0,1,2) selected based on Schwarz Bayesian Criterion</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Regressor</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>t-ratio [Prob]</th>
</tr>
</thead>
<tbody>
<tr>
<td>POLt-1</td>
<td>0.054008</td>
<td>0.12411</td>
<td>0.43518 [.669]</td>
</tr>
<tr>
<td>POLt-2</td>
<td>0.33081</td>
<td>0.10525</td>
<td>3.1432 [.006]</td>
</tr>
<tr>
<td>POLt-3</td>
<td>-0.31430</td>
<td>0.099760</td>
<td>-3.1505 [.006]</td>
</tr>
<tr>
<td>ENCt</td>
<td>0.74769</td>
<td>0.10027</td>
<td>7.4565 [.000]</td>
</tr>
<tr>
<td>RGDPt</td>
<td>-0.26224</td>
<td>0.44811</td>
<td>-0.58521 [.566]</td>
</tr>
<tr>
<td>RGDPt-1</td>
<td>1.0539</td>
<td>0.43543</td>
<td>2.4203 [.026]</td>
</tr>
<tr>
<td>OPNt</td>
<td>0.10376</td>
<td>0.098849</td>
<td>1.0497 [.308]</td>
</tr>
<tr>
<td>OPNt-1</td>
<td>-0.080934</td>
<td>0.10406</td>
<td>-0.77775 [.447]</td>
</tr>
<tr>
<td>OPNt-2</td>
<td>0.32490</td>
<td>0.10926</td>
<td>2.9737 [.008]</td>
</tr>
<tr>
<td>Constant</td>
<td>2.8615</td>
<td>0.61053</td>
<td>4.6870 [.000]</td>
</tr>
<tr>
<td>Trend</td>
<td>-0.054479</td>
<td>0.017854</td>
<td>-3.0514 [.007]</td>
</tr>
</tbody>
</table>

| R-Squared | 0.99907 |
| Adjusted R-Squared | 0.99855 |
| S.E. of Regression | 0.028081 |
| F-Statistic | F(10,18) = 1933.4 [.000] |
| Mean of Dependent Variable | 3.5926 |
| S.D. of Dependent Variable | 0.73825 |
| Residual Sum of Squares | 0.014194 |
| Equation Log-likelihood | 69.3729 |
| AIC | 58.3729 |
| SBC | 50.8528 |
| DW Statistic | 2.3943 |

Testing for existence of a level relationship among the variables in the ARDL model

<table>
<thead>
<tr>
<th>F-statistic</th>
<th>95% Lower Bound</th>
<th>95% Upper Bound</th>
<th>90% Lower Bound</th>
<th>90% Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.4192</td>
<td>4.7061</td>
<td>5.9341</td>
<td>3.8968</td>
<td>4.9766</td>
</tr>
<tr>
<td>W-statistic</td>
<td>95% Lower Bound</td>
<td>95% Upper Bound</td>
<td>90% Lower Bound</td>
<td>90% Upper Bound</td>
</tr>
<tr>
<td>21.6767</td>
<td>18.8243</td>
<td>23.7362</td>
<td>15.5873</td>
<td>19.9066</td>
</tr>
</tbody>
</table>

If the statistic lies between the bounds, the test is inconclusive. If it is above the upper bound, the null hypothesis of no level effect is rejected. If it is below the lower bound, the null hypothesis of no level effect cannot be rejected. The critical value bounds are computed by stochastic simulations using 20000 replications.

### Diagnostic Tests

<table>
<thead>
<tr>
<th>Test Statistics</th>
<th>LM-test</th>
<th>F-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Serial Correlation</td>
<td>CHSQ(1) = 4.0847 [.043]</td>
<td>F(1,17) = 2.7870 [.113]</td>
</tr>
<tr>
<td>B: Functional Form</td>
<td>CHSQ(1) = 1.0952 [.295]</td>
<td>F(1,17) = 0.66723 [.425]</td>
</tr>
<tr>
<td>C: Normality</td>
<td>CHSQ(2) = 0.23507 [.889]</td>
<td>Not applicable</td>
</tr>
<tr>
<td>D: Heteroscedasticity</td>
<td>CHSQ(1) = 0.010026 [.920]</td>
<td>F(1,27) = 0.0093378 [.924]</td>
</tr>
</tbody>
</table>

### Notes

A: Lagrange multiplier test of residual serial correlation
B: Ramsey's RESET test using the square of the fitted values
C: Based on a test of skewness and kurtosis of residuals
D: Based on the regression of squared residuals on squared fitted values
### Table 3: Estimated Long Run Coefficients using the ARDL Approach

<table>
<thead>
<tr>
<th>Regressor</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>t-ratio[Prob]</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENC</td>
<td>0.80441</td>
<td>0.14824</td>
<td>5.4262[.000]</td>
</tr>
<tr>
<td>RGDP</td>
<td>0.85170</td>
<td>0.38369</td>
<td>2.2198[.040]</td>
</tr>
<tr>
<td>OPN</td>
<td>0.37410</td>
<td>0.15476</td>
<td>2.4173[.026]</td>
</tr>
<tr>
<td>Constant</td>
<td>3.07860</td>
<td>0.75028</td>
<td>4.1033[.001]</td>
</tr>
<tr>
<td>Trend</td>
<td>-0.05861</td>
<td>0.016721</td>
<td>-3.5053[.003]</td>
</tr>
</tbody>
</table>

Testing for existence of a level relationship among the variables in the ARDL model:

- **F-statistic**
  - 95% Lower Bound: 4.7061
  - 95% Upper Bound: 5.9341
  - 90% Lower Bound: 3.8968
  - 90% Upper Bound: 4.9766

- **Wald-statistic**
  - 95% Lower Bound: 18.8243
  - 95% Upper Bound: 23.7362
  - 90% Lower Bound: 15.5873
  - 90% Upper Bound: 19.9066

Dependent variable: POL

Number of Observation: 29

ARDL(3,0,1,2) selected based on Schwarz Bayesian Criterion
### Table 4: Error Correction Representation for the Selected ARDL Model

ARDL(3,0,1,2) selected based on Schwarz Bayesian Criterion

Dependent variable is dLP

29 observations used for estimation from 1983 to 2011

<table>
<thead>
<tr>
<th>Regressor</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>t-ratio [Prob]</th>
</tr>
</thead>
<tbody>
<tr>
<td>dPOLt-1</td>
<td>-0.016507</td>
<td>.11173</td>
<td>-1.4774 [.884]</td>
</tr>
<tr>
<td>dPOLt-2</td>
<td>0.31430</td>
<td>.099760</td>
<td>3.1505 [.005]</td>
</tr>
<tr>
<td>dENCt</td>
<td>0.74769</td>
<td>.10027</td>
<td>7.4565 [.000]</td>
</tr>
<tr>
<td>dRGDPt</td>
<td>-0.26224</td>
<td>.44811</td>
<td>-5.8521 [.565]</td>
</tr>
<tr>
<td>dOPNt</td>
<td>0.10376</td>
<td>.098849</td>
<td>1.0497 [.306]</td>
</tr>
<tr>
<td>dOPNt-1</td>
<td>-0.32490</td>
<td>.10926</td>
<td>-2.9737 [.008]</td>
</tr>
<tr>
<td>dTrendt</td>
<td>-0.054479</td>
<td>.017854</td>
<td>-3.0514 [.006]</td>
</tr>
<tr>
<td>ECTt</td>
<td>-0.92949</td>
<td>.11448</td>
<td>-8.1193 [.000]</td>
</tr>
</tbody>
</table>

dPOL = POLt-POLt-1

dLPOLt-1 = POLt-1-POLt-2

dPOLt-2 = POLt-2-POLt-3

dENC = ENCt-ENCt-1

dRGDP = RGDPt-RGDPt-1

dOPN = OPNt-OPNt-1

dOPNt-1 = OPNt-1-OPNt-2

dTrend = Trendt-Trendt-1

ECTt = POLt -0.80441ENCt -0.85170RGDPt -0.37410OPNt -3.0786 Constant + 0.058613 Trend
Table 5: Gregory-Hansen Test for Cointegration with Regime Shifts

Model: Change in regime and trend, Number of Observations: 32, Maximum Lags = 3

<table>
<thead>
<tr>
<th>Test</th>
<th>Estimated Test Statistic</th>
<th>Breakpoint Date</th>
<th>Asymptotic Critical Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1%</td>
</tr>
<tr>
<td>ADF</td>
<td>-6.80</td>
<td>1994</td>
<td>-6.89</td>
</tr>
<tr>
<td>$Z_a$</td>
<td>-7.13</td>
<td>1994</td>
<td>-6.89</td>
</tr>
<tr>
<td>$Z_a$</td>
<td>-45.35</td>
<td>1994</td>
<td>-90.84</td>
</tr>
</tbody>
</table>
Figure 1: Vietnam 1980-2011
Natural logs of Energy Consumption, Pollution, GDP and Openness
Figure 2: Actual and Fitted Values of Pollution in Vietnam
Figure 3: Impulse Response of Pollution to Energy Consumption, Real GDP and Openness to Trade