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Trade linkages and macroeconomic effects of the price of oil

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Contents

Iikka Korhonen[1] and Svetlana Ledyaeva[2]

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Abstract

In this paper we assess the impact of oil price shocks on oil-producer and oil-consumer economies. VAR models for different countries are linked together via a trade matrix, as in Abeysinghe (2001). As expected, we find that oil producers (Russia and Canada here) benefit from oil price shocks. For example, a large oil shock, leading to a price increase of 50%, boosts Russian GDP by some 12%. However, oil producers are hurt by indirect effects of oil shocks, as economic activity in their export countries suffers. For oil consumers, the effects are more diverse. In some countries, output drops in response to an oil price shock, while other countries seem to be relatively immune to oil price changes. Finally, indirect effects are also detected for oil-consumer countries. Those countries trading more with oil producers receive indirect benefits via higher demand from the oil producing countries. In general the largest negative total effects from positive oil price shocks are found in China, USA and Japan while European countries seem to fare quite well during recent positive oil-price shocks.

Key words: oil, macroeconomic fluctuations, trade linkages, Russia
JEL codes: C32, E32, F43, Q43

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Iikka Korhonen and Svetlana Ledyaeva

Trade linkages and macroeconomic effects of the price of oil

Tiivistelmä

Tässä keskustelualoitteessa tutkitaan öljyn hintasokkien vaikutusta öljyä tuottaviin ja öljyä kuluttaviin talouksiin. Eri maiden VAR-mallit liitetään toisiinsa kauppamatriisin avulla kuten Abeysinghen (2001) tutkimuksessa. Kuten voidaan odottaa, öljyä tuottavat maat (tässä tutkimuksessa Venäjä ja Kanada) hyötyvät öljyn hinnan noususta. Esimerkiksi 50 prosentin hinnannousu johtaisi tasoltaan 12 % suurempaan Venäjän bruttokansantuotteeseen. On kuitenkin huomattava, että öljyntuottajat kärsivät epäsuorasti korkeammasta öljyn hinnasta, koska taloudellinen aktiivisuus niiden vientimarkkinoilla supistuu. Öljyn kuluttajamaissa hintasokin vaikutukset ovat erilaisia. Joissain maissa bruttokansantuote supistuu selvästi, kun taas jotkin maat näyttävät olevan varsin immuuneja öljyn hinnan vaihteluille. Öljyn hintasokkien epäsuoria vaikutuksia voidaan havaita myös öljyä kuluttavissa maissa. Maat, jotka käyvät paljon kauppaa öljyn tuottajamaiden kanssa, hyötyvät epäsuorasti hintojen kalleudesta, koska niiden vienti kasvaa. Öljyn hintasokkien negatiiviset vaikutukset ovat suurimmat Kiinan, Yhdysvaltain ja Japanin kannalta, kun taas vaikutukset Euroopan maihin ovat keskimäärin pienempiä.

Asiasanat: öljy, suhdannevaihtelut, kauppalinkit, Venäjä

1 Introduction

In this paper we study how changes in the price of a country's key export good affects its economy when it trades with other countries that are net importers of that good. More specifically, we look at how GDP growth of an energy-exporting country reacts to changes in energy prices. The direct effect is expected to be positive, as it gets more export revenues, but there are also indirect effects, ex ante expected to be negative. For energy-importers, a jump in energy prices constitutes a negative supply shock, which will slow their economic growth. This, in turn, reduces the (energy and other) exports of the energy-exporter. Therefore, the gain in growth for the energy-exporter is not as large as one could assume at first glance. On the other hand, energy-importers can benefit from higher energy prices if they are able to export more to the energy-producing country.

Energy – and more specifically oil – is one of the most important raw materials in the modern economy. Oil products are widely utilised e.g. in transportation and power generation, and oil is also used in manufacturing of chemical products. Therefore, the price of oil is one of the key prices in the international economy, even more so because it is widely used as reference value for other energy resources.

At least since the first oil crises in 1973 the macroeconomic effects of energy prices have been studied extensively. For example, Hamilton (1983) concludes that almost all recessions in the USA have been preceded by a large increase in the price of oil. Also, there is some evidence that the effect of oil prices on economic growth may be non-linear (Hamilton, 2000). Negative growth effects of large oil price increases are more substantial (in absolute size) than the positive effects of similarly-sized oil price decreases. However, in recent years a growing body of research has indicated that the macroeconomic importance of oil prices may be waning. But these results of course usually relate to countries which are net importers of oil and other energy products. On the other side of the equation, energy exporters can be expected to benefit from higher energy prices. Their terms of trade improve, and higher export revenues can be used for more of both consumption and investment.[3] For example, Rautava (2004) shows that in Russia higher oil prices lead to higher GDP growth.

[3] Of course, in the long run excessive reliance on revenue from raw materials may lead to sub-standard growth. The so-called resource curse is well documented in the literature; see for example Sachs and Warner

Our research question is somewhat different. We are interested in how oil price shocks affect growth in different countries, but we also assess the interplay of such shocks across countries. Foreign trade is the key channel of transmission. We are especially interested in how the positive growth effects of higher oil prices for an oil-producing country are altered if one takes into account that economic growth in most other countries slows. If demand in net importers of energy decreases, oil exporters are able to export less to these countries, ceteris paribus. This will then have a negative effect on their economic growth. (Of course, the problem may be less acute for energy-only exporters.) While we expect the net effect of higher oil prices to be positive for energy exporters, it is of interest to see how the situation changes when trade linkages are taken explicitly into account. And, on the other hand, when an oil exporter experiences an economic boom because of higher oil prices, other countries are able to export more to it.

To study this question, we utilise the methodology first formulated by Abeysinghe (1998, 2001). Abeysinghe (2001) measures the direct and indirect effects of oil prices on GDP growth of 12 economies (ASEAN4 and NIE4 countries, China, Japan, USA, and the rest of OECD as one country). The oil price variable is included in the model as an exogenous variable. Abeysinghe (2001) found that because of the indirect effect, which is transmitted through a trade matrix, even net oil exporters like Indonesia and Malaysia cannot escape the negative influence of high oil price. Positive direct and negative indirect effects offset each other for these two oil producers, and the net effect is nil.

We estimate a model where countries' growth rates depend not only on oil-price changes but also on other countries' growth rates via a bilateral export matrix. The idea is that higher growth in one country boosts other countries' exports to that country, which in turn spurs economic activity in the other countries. We are then able to derive impulse responses for oil price shocks.

To study the question at hand we utilise quarterly data from a large oil exporter, Russia, as well as from its most important trading partners[4] between the first quarter of 1995 and the third quarter of 2006. Russia is one of the most important oil exporters in the

(2001). Collier and Goderis (2007) show that positive short-term effects and negative long-term effects of higher raw material prices can be reconciled within a single error-correction model.

[4] Germany, Italy, the Netherlands, China, USA, United Kingdom, Switzerland and Finland. In addition, we use data from four countries which are important for the aforementioned eight countries, namely Belgium, Canada, France and Japan. Unfortunately we had to leave out two of Russia's main trading partners, Ukraine and Kazahkstan because of a lack of data.

world, and in 2004-2006 it was the second biggest world oil producer after Saudi Arabia[5]. It is also large economy that influences other countries' growth rates via its demand for their exports. Currently, energy products account for some 60% of Russia's exports, and therefore the country's other exports are likely to suffer if high energy prices compress demand in its major trading partners.

Our main results can be summarised as follows. Oil price growth has a clear and positive effect on the oil-producer's GDP growth. However, the large positive direct effect is tempered somewhat by the negative indirect (albeit small) effect, as Russia[6] is less able to export to the countries adversely affected by the oil price shock. In most oil-importing countries, the net effect of higher oil prices is negative. Of the countries considered, the largest negative direct effects of a positive oil price shock are found for the USA, Japan and China. According to our results, European countries would be less harmed by the recent positive oil price shocks. Moreover, to our knowledge no one has tried to distinguish between the direct and indirect effects of an oil price shock for our sample of countries.

The study is structured as follows. In the following section we present a selective literature survey. The third section presents the estimation methodology in more detail, and the fourth section describes our data in more detail. The fifth section presents our results and the sixth adds some conclusions.

2 Literature survey

As noted above, we utilize a methodology that combines the direct and impact effects of an oil price shock on growth. In the previous literature this distinction is usually not made. In this section we review the literature dealing with both trade linkages and economic activity, as well as the macroeconomic effects of oil price shocks.

[5] http://www.eia.doe.gov/emeu/cabs/topworldtables1_2.htm
[6] Canada is also a net exporter of energy products. In our model, an oil price shock has a definite positive effect on Canadian GDP.

2.1 Trade linkages and macroeconomic activity

In a seminal paper Frankel and Rose (1997, 1998) argue that countries with more intense trade links have more similar business cycles. Many subsequent studies (see, e.g., Baxter and Kouparitsas (2005), Inklaar, Jong-A-Pin and Haan (2007)) have supported this fact. The underlying intuition is quite clear: More extensive trade links help to transmit shocks from one country to another. However, Krugman (1993) points out that the impact of more intense trade may actually be the reverse. As countries become more integrated, they increasingly specialise. That is, the importance of asymmetric or sector-specific shocks increases as economic integration progresses.

Arora and Vamvakidis (2004) estimate the impact of trading partners' growth on domestic growth using a fixed-effects panel regression for the period 1960-99 for 101 industrial and developing economies. To measure this impact they introduce into a standard growth regression model some additional explanatory variables: trading partners' real per capita GDP growth; the ratio of domestic real per capita GDP to trading partners' real per capita GDP; and in a simple alternative specification trading partners' real per capita GDP. Arora and Vamvakidis (2004) conclude that a 1 percentage point increase in economic growth among a country’s trading partners (everything else fixed) is correlated with an increase in domestic growth of as much as 0.8 percentage point. In addition, the level of foreign income relative to domestic income matters, in the sense that the ratio of average per capita GDP of trading partners relative to a country’s own per capita GDP is positively correlated with growth. One interpretation of this result is that conditional convergence is the stronger, the richer the country’s trading partners.

In several papers Abeysinghe (see Abeysinghe, 1998, 2001, and Abeysinghe and Forbes, 2001, 2005) has developed a structural VAR model to measure how a shock to a country can affect other-country GDPs. The model focuses on two types of cross-country linkages: direct effects via bilateral trade and indirect effects via output multipliers. It uses trade linkages to estimate the multiplier effects of a shock as it is transmitted through other countries’ output fluctuations. The paper introduces a new specification strategy that significantly reduces the number of unknowns in the estimation and allows cross-country relationships to vary over time.

In Abeysinghe and Forbes (2001, 2005) this model is used to examine the impact of shocks to 11 Asian countries, USA and the rest of the OECD. Impulse-response matrices suggest that the multiplier effects are large and significant, and can transmit shocks in patterns that are very different than those predicted from a bilateral-trade matrix. For example, due to these output-multiplier effects, a shock to one country can have large impacts on countries that are relatively minor bilateral trading partners.

Abeysinghe and Lu (2003) use the same methodology to estimate the impact of China's rising economic power of the past two decades on the economic growth of ASEAN4 and NIE4 countries, Japan, USA and the rest of the OECD countries. They find empirical evidence that China had quickly emerged as a growth engine for the region even before China joined the WTO.

2.2 Oil prices and macroeconomic activity

Many empirical studies have looked at the impacts of oil price shocks on economic activity. For a survey, see Lardic and Mignon (2006). At least until recently, macroeconomists have viewed changes in the price of oil as an important source of economic fluctuations. However, there are several recent studies that indicate that macroeconomic effects of oil prices shocks have become less pronounced.

In a recent paper, Blanchard and Galí (2007) stress that the events of the past decade indicate that oil prices are not a significant source of economic fluctuations. They find that there are at least four reasons for the milder effects on inflation and economic activity of the recent increase in the price of oil: (a) good luck (i.e. lack of concurrent adverse shocks), (b) smaller share of oil in production, (c) more flexible labour markets, and (d) improvements in monetary policy.

Kilian (2008) in his empirical study found that some countries (like Italy, France and Japan) have fared much better – as measured by cumulative inflation and growth – than others (like Germany) when faced with exogenous oil price shocks.

Segal (2007) assesses several arguments as to why high oil prices over the past three years do not appear to have led to a slowing of the world economy. The most important are 1) that oil prices have never been as important as commonly thought and 2) that high oil prices have not restrained growth in the past three years because they no longer pass through to core inflation, which obviates the typical (growth-slowing) monetary tightening in response to a positive oil price shock.

The other relatively recent and important development in estimating the impacts of oil price shocks on domestic economic activity is the investigation of nonlinear (asymmetric) relationships between oil prices shocks and macroeconomic variables. The most influential such studies were provided by Mork (1989), Hamilton (1996) and Lee et al (1995). It appears that positive oil price shocks have larger macroeconomic effects (in absolute size) than negative shocks of the same magnitude.

Recently, Huang, Hwang and Peng (2005) used a multivariate threshold model to analyze the impacts of an oil price change and its volatility on economic activities in USA, Canada and Japan during the period from 1970 to 2002. The most important finding is that in the two-regime model, responses of economic activities are rather limited in regime I, but become much more noticeable in regime II, where an oil price change or its volatility exceeds its threshold level.

3 Estimation methodology

We use a framework developed by Abeysinghe (see Abeysinghe, 1998, 2001, and Abeysinghe and Forbes, 2001, 2005). Using reduced form bilateral export functions, Abeysinghe derived the following system of simultaneous equations to capture the inter-linkages between GDP growth rates of different economies:

$$(B_0 * W_t)y_t = \lambda + \sum_{j=1}^{p}(B_j * W_{t-j})y_{t-j} + \sum_{j=0}^{p}\Gamma_{1j}z^*_{1t-j} + \ldots + \sum_{j=0}^{p}\Gamma_{Kj}z^*_{Kt-j} + \varepsilon_t \qquad (1),$$

where y_t is an $(n \times 1)$ vector of GDP growth series, the $z^*_i (i = 1,...,k)$ are $(n \times 1)$ vectors of exogenous variables, W_t is a known matrix of weights derived from bilateral export shares, Bs are unknown parameter matrices, $\Gamma_1,...,\Gamma_K$ are diagonal parameter matrices, and ε_t is a random vector with zero mean and $Var(\varepsilon_t) = \Omega$ (a diagonal covariance matrix estimated empirically). In our notation *n* is the number of countries considered in the model and * stands for the Hadamard product.

Using the compact notation $B^w(L) = (B_0 * W_t) - (B_1 * W_t)L - \ldots - (B_p * W_t)L^p$ and $\Gamma^i(L) = \Gamma^i_0 + \Gamma^i_1 L + \ldots + \Gamma^i_p L^p$, where L is the lag operator, Model (1) can be written as

$$y_t = \lambda + B^w(L)^{-1}\Gamma^1(L)z^*_{1t} + \ldots + B^w(L)^{-1}\Gamma^p(L)z^*_{kt} + B^w(L)^{-1}\varepsilon_t. \qquad (2)$$

Using eq. (2) the impulse responses with respect to the ith exogenous variable can be obtained from $B^{w}(L)^{-1}\Gamma^{i}(L)$. Unlike standard VAR or VARX models, which produce fixed impulse responses, the impulse responses produced by model (2) change over time as the trading pattern changes. This allows one to compute impulse responses at any point in time using a given trade matrix W_t. Abeysinghe suggests using 12-quarter moving averages of export shares, so that they change slowly over time. However, we restrict ourselves to 4-quarter moving averages of export shares, due to our relatively short time series.

In our baseline estimations, the only exogenous variables are the oil price shock measures in model (1). Our baseline model of simultaneous equations system is

$$y_{1t} = \lambda_1 + \sum_{k=1}^{4}\phi_{1k} y_{1t-k} + + \sum_{k=0}^{4}\beta_{1k}(w_{12}\cdot y_{2t-k} + \ldots + w_{1n}\cdot y_{nt-k}) + \sum_{k=0}^{4} g_{1k} os_{1t-k} + \varepsilon_{1t}$$

...

$$y_{13t} = \lambda_{13} + \sum_{k=1}^{4}\phi_{13k} y_{nt-k} + \sum_{j=0}^{4}\beta_{13k}(w_{13,2}\cdot y_{13,t-k} + \ldots + w_{13,3-1}\cdot y_{13-1,t-k}) + \sum_{j=0}^{4} g_{13k} os_{13t-k} + \varepsilon_{13t} \qquad (3),$$

where y_{it} (i=1,…,13) is GDP growth rate in country i; w_{ij} is the share of exports of country i to country j (in country i's total exports); os_{it} is a measure of oil price shock to country I, and the, $\phi`s$ , $\beta`s$ and $g`s$ are parameters to be estimated.

The estimation of simultaneous equations system (3) can be done by 1) single equation/limited information estimation methods for simultaneous equations systems – ordinary least square (OLS) and two-stage least square (2SLS) and by 2) system method of estimation - three-stage least square (3SLS). 2SLS and 3SLS are instrumental variables estimation methodologies; Abeysinghe (2001) suggests using four lags of each y_{it} (i=1,2,…,13) and four lags of os_{it} of country i as instruments.

4 Data

4.1 Endogenous variable: GDP growth rates

In our analysis we focus on Russia and its main trading partners, as summarised in Table 1. However, because of a lack of data, we could not include other former republics of the

USSR (Ukraine, Belarus and Kazakhstan). This leaves us with nine countries: Russia and its 8 main trading partners - Germany, Italy, the Netherlands, China, USA, United Kingdom, Switzerland and Finland. While omitting Ukraine and Belarus is regrettable, their inclusion would also present problems. For the period studied here, they received energy supplies from Russia at prices considerably below the prevailing market prices. Therefore, estimated effects of oil price shocks on these countries might be spurious. Of course, for Kazakstan the situation is different, as it is net exporter of energy, like Russia.

Table 1 Main trading partners of Russia, 1994-2005

Country – trading partner	Per cent of total Russian foreign trade volume
Germany	9.8
Ukraine	7.4
Belarus	5.7
Italy	5.6
The Netherlands	5.2
China	5.0
USA	4.9
United Kingdom	3.4
Kazakstan	3.3
Switzerland	3.2
Finland	3.2

Source: Rosstat

In accordance with Abeysinghe`s methodology, countries in the model must have close trading links. In order to reduce the bias of foreign variables' estimators in each equation, each country in the data set must have several of the others as its major trade partners. To alleviate this problem, we include four countries which can be considered major trading partners of most of our countries: Belgium, Canada, France and Japan. Belgium is among the major trading partners for Germany, Netherlands, UK and France; Canada for USA, Japan and UK; France for Belgium, Germany, Italy, Netherlands, UK; and Japan for China, France and USA.

To estimate our model we use quarterly data in the period from quarter 3 of the year 1995 to quarter 3 of the year 2006. For GDP growth series, we use log-difference of quarterly real GDP, seasonally adjusted. The GDP series are from the IMF's International Finance Statistics and World Economic Outlook databases. Quarterly data on bilateral trade shares are from the IMF Direction of Trade database.

First we test all the series for presence of a time trend. Time trends were detected for the GDP growth rates of China, Finland, Netherlands and Russia. These series were detrended using the Hodrick-Prescott filter. The descriptive statistics of the GDP series (after detrending) are shown in Appendix 1.

Secondly, we test the series for unit roots using the Augmented Dickey-Fuller and KPSS tests. The results are presented in Appendix 2. In general for all the series we are not able to reject the null hypothesis of stationarity.

4.2 Measures of oil price shock

We define the oil price in real terms, as the ratio of the simple average of three crude oil price measures - Petroleum West Texas Intermediate, Petroleum UK Brent and Petroleum Dubai - in US dollars per barrel to the US GDP deflator. As a robustness check, we also used the nominal oil price deflated by the US producer price index. Because the results were very similar, we retain the GDP deflator in the baseline model. In the context of the methodology followed here, our definition of real oil prices represents a common shock to all countries. However it is noteworthy that the economic impact of the oil shock could be different in countries other than US because of changes in bilateral exchange rates. As a robustness check, we also estimated the model using oil prices converted into domestic currencies and deflated by each country's CPI. Again, we did not find any significant differences in the results and so retained the real oil price in US dollars in our main analysis.

In addition to the simple log-difference of the real oil price, $\Delta\ln(o_{it})$, we also consider three non-linear transformations of oil prices: 1) an asymmetric specification in which increases and decreases in the price of oil are considered as separate variables; 2) a scaled specification (Lee et al, 1995) which takes the volatility of oil price into account; and 3) a net oil price increase measure, introduced by Hamilton (1996). For more details see Appendix 3.

5 Empirical results

5.1 Testing for joint significance of the model's coefficients

In this section we investigate the joint significance of estimated coefficients for the current and lagged values of both foreign variables and oil price shock measures. Wald tests have the null hypothesis that all of the foreign variables or oil price shocks (current value and four lags) are jointly zero in each equation of our system. The test results are displayed in Appendix 5.

With respect to foreign variable we conclude that the null hypothesis can be rejected for most countries in the set except Canada, China, Finland and Japan.

For the oil price shock measures we did not reject the null hypothesis of coefficients' joint insignificance for any of the specifications. This result was expected and is supported by earlier findings; see, e.g., Jiménez-Rodríguez and Sánchez (2004). Moreover, the sum of the coefficients on positive oil price shock measures is negative for most oil importers and positive for oil exporters, as expected (see Table 5A.4 in Appendix 5). However, the sums are statistically significantly different from zero only for Russia, Japan and the USA. As for the sums of coefficients of negative oil price shocks measures, only Japan's response is statistically significant.

It should be noted here that these tests do not consider the indirect effects that concern us. What we need are tests of the significance of impulse responses. However, Abeysinghe (2001b) points out that the related theoretical work remains to be done. Moreover, Kilian and Chang (2000) stress that existing methodologies do not necessarily provide reliable confidence intervals for large VAR models. Therefore, we will remain somewhat agnostic concerning the statistical significance of our results, unless the point estimates are large in absolute terms.

Second, we assess the goodness of fit of the four different model specifications for each country. Given that these models are not nested, we look at selection criteria such as the Akaike Information Criterion (AIC) and Schwarz Bayesian Information Criterion (BIC). Table A5.3 in Appendix 5 reports the AIC and BIC for all countries obtained from each econometric specification. On the basis of these two criteria, we conclude that linear specification with oil price change as a measure of oil price shock and asymmetric specification are preferable in terms of the system's goodness-of-fit. However, as the Wald test indicates a higher joint significance of the coefficients of the negative oil price growth rate variable, we employ as baseline model the asymmetric specification, in which increases and decreases in the price of oil are considered to be separate variables.

Thus our baseline model becomes

$$y_{1t} = \lambda_1 + \sum_{k=1}^{4} \phi_{1k} y_{1t-k} + + \sum_{k=0}^{4} \beta_{1k} (w_{12} \cdot y_{2t-k} + \ldots + w_{1n} \cdot y_{nt-k}) + \sum_{k=0}^{4} g_{1k} os^{+}{}_{1t-k} + \sum_{k=0}^{4} g_{1k} os^{-}{}_{1t-k} + \varepsilon_{1t}$$

$$\ldots \qquad (4)$$

$$y_{13t} = \lambda_{13} + \sum_{k=1}^{4} \phi_{13k} y_{nt-k} + \sum_{j=0}^{4} \beta_{13k} (w_{13,2} \cdot y_{13,t-k} + \ldots + w_{13,3-1} \cdot y_{13-1,t-k}) + \sum_{k=0}^{4} g_{1k} os^{+}{}_{1t-k} + \sum_{k=0}^{4} g_{1k} os^{-}{}_{1t-k} + \varepsilon_{13t}$$

where os^{+} and os^{-} represent positive and negative oil price changes, respectively.

5.2 Baseline results

We present results from model (4) estimated by OLS, as we did not find notable differences between the OLS, 2SLS and 3SLS estimations.[7] Moreover, because of the short sample period we cannot use four lags of instruments (we are limited to two lags). The lack of available instruments is the second argument for using OLS estimators.

We also tested the stability of the OLS estimates of oil price coefficients using the Hansen test. The results are presented in Appendix 6. We did not find any evidence of instability for individual coefficients. The Hansen test did not provide any evidence of model instability as a whole for any country either.

After estimating the model parameters, impulse responses were generated by fixing the W_t matrix as the average for the period from quarter 3 of the year 1998 to quarter 3 of the year 2006. We chose this period to account for possible changes in trade patterns between Russia and its trading partners after the major financial crisis in Russia, which led to a sharp depreciation of the rouble. Moreover, the crisis was followed by several positive oil price shocks, which also influenced Russia's foreign trade.

As a robustness check, we also calculated the impulse responses by fixing the W_t matrix as the average for the pre-crisis period, i.e. for quarter 3 of the year 1995 to quarter

[7] 2SLS and 3SLS results are available upon request.

2 of the year 1998. However, the results are very similar to those for our baseline model and hence are not reported.

The cumulative impulse responses (multiplier effects) of GDP growth in response to a 50% increase in the positive oil price growth rate are plotted up to 20 quarters in Fig. 1 and 2. Table 2 provides a summary. In the table, the short run effects reported in the table are the cumulative sums of four quarters of impulse responses and the long run effects are the cumulative sums for 20 quarters.

Figure 1 Direct, indirect and total impact of a 50% increase in oil price on Russia's cumulative GDP growth

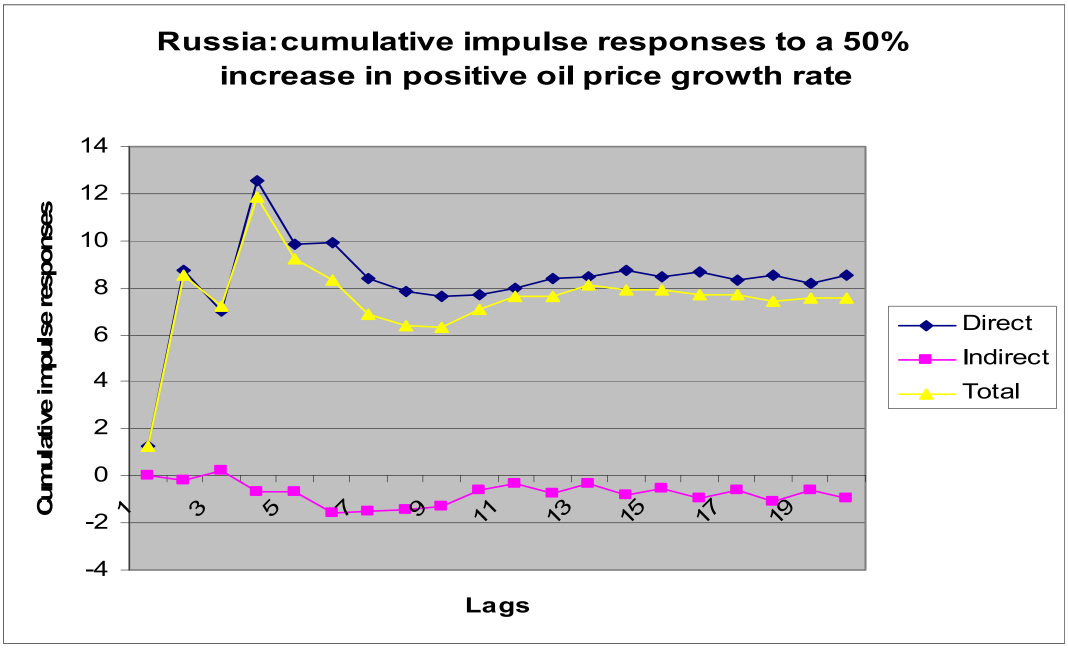
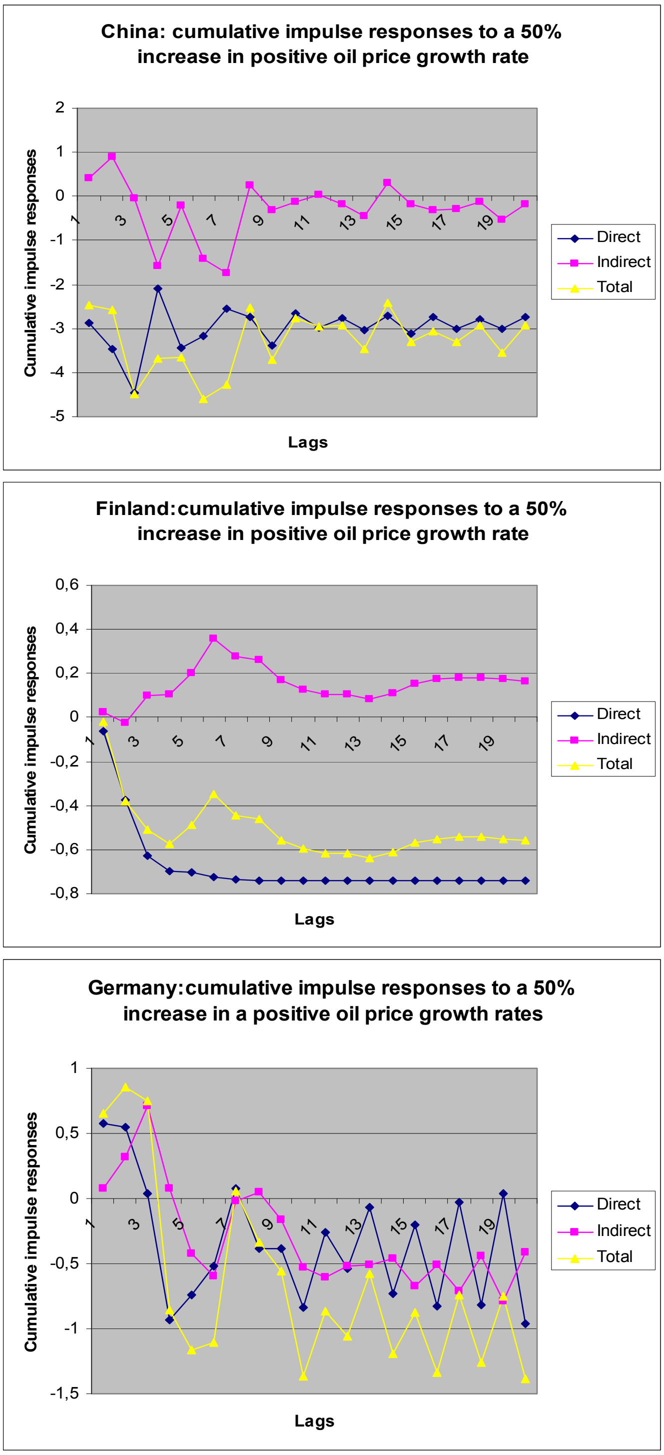
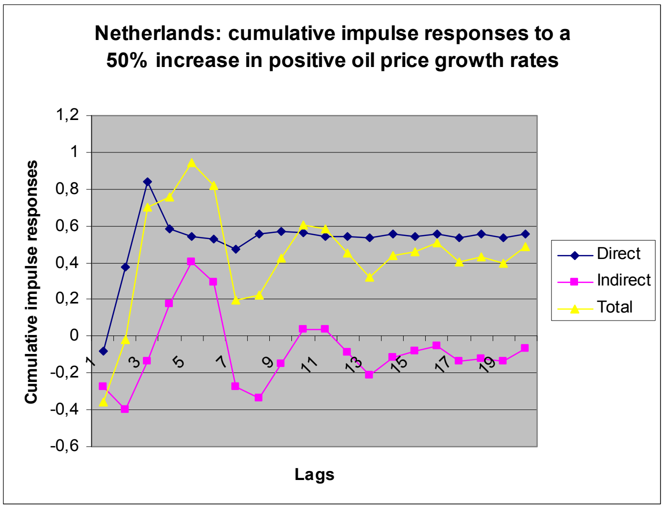
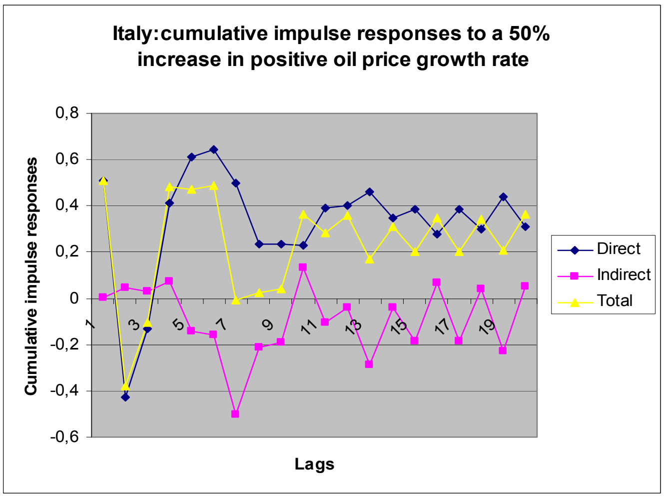


Figure 2 Direct, indirect and total impact of a 50% increase in oil price on cumulative GDP growth of Russia's main trading partners and Belgium, Canada, France and Japan




Netherlands: cumulative impulse responses to a 50% increase in positive oil price growth rates
Cumulative impulse responses
Lags
Direct
Indirect
Total


Italy:cumulative impulse responses to a 50% increase in positive oil price growth rate
Cumulative impulse responses
Lags
Direct
Indirect
Total

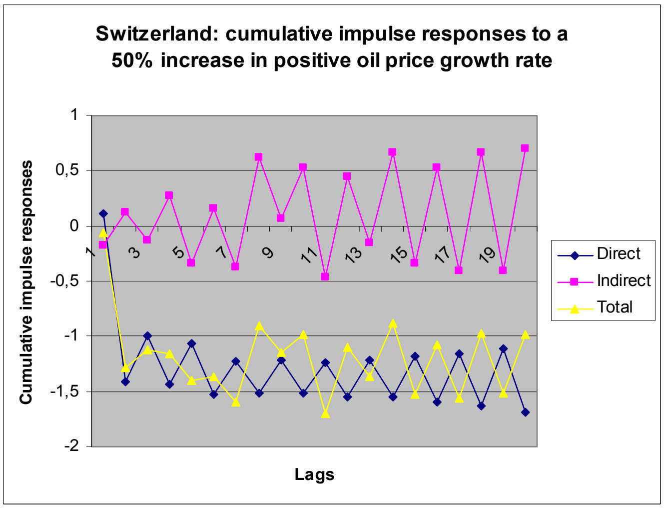
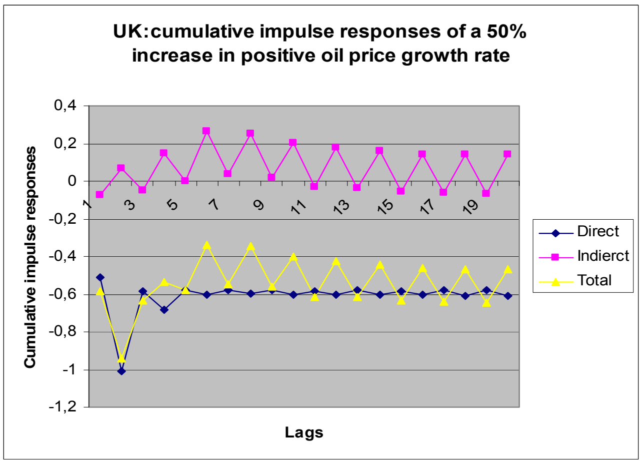
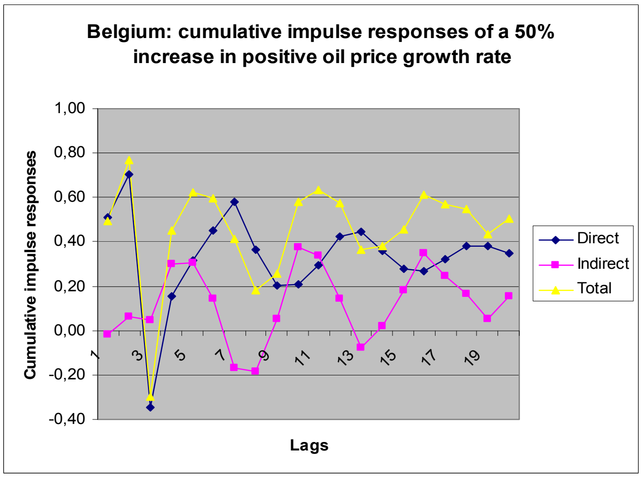
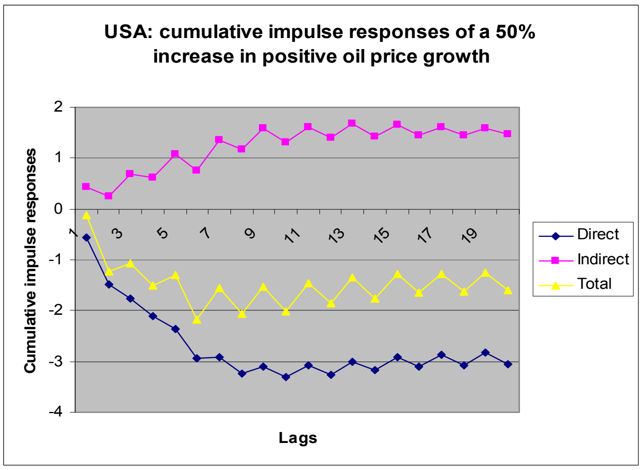
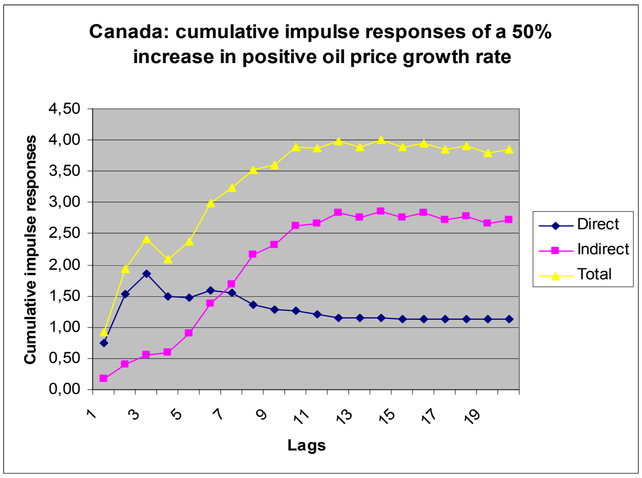

Switzerland: cumulative impulse responses to a 50% increase in positive oil price growth rate
Cumulative impulse responses
Lags
Direct
Indirect
Total

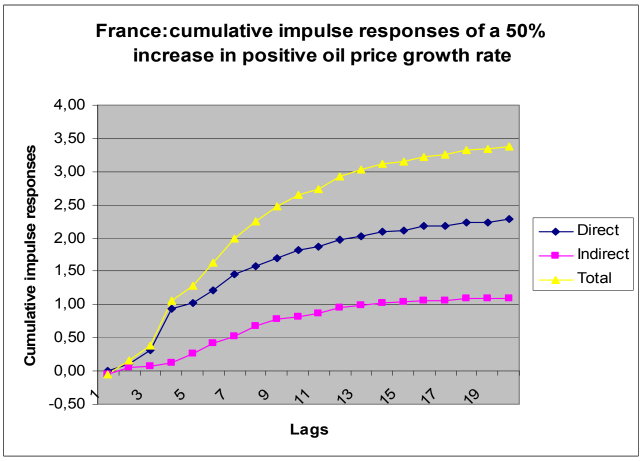
Figure 2 Direct, indirect and total impact of a 50% increase in oil price on cumulative GDP growth of Russia's main trading partners and Belgium, Canada, France and Japan (continuation)








Canada: cumulative impulse responses of a 50% increase in positive oil price growth rate
Cumulative impulse responses
Lags
Direct
Indirect
Total


France:cumulative impulse responses of a 50% increase in positive oil price growth rate
Cumulative impulse responses
Lags
Direct
Indirect
Total

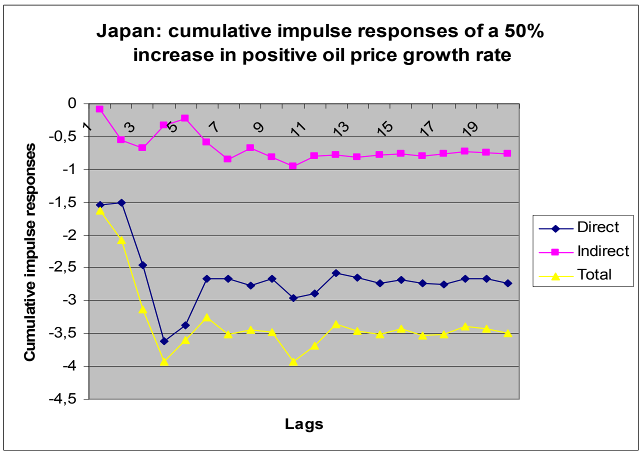

Japan: cumulative impulse responses of a 50% increase in positive oil price growth rate
Cumulative impulse responses
Lags
Direct
Indirect
Total

Table 2 Cumulative impact of a 50% increase in positive oil price growth rate on GDP (%)

Country	Effect	Direct impact	Impact through trading partners	Total impact
China	Short run (4 quarters)	-2.10	-1.59	-3.69
	Long run (20 quarters)	-2.75	-0.18	-2.93
Finland	Short run (4 quarters)	-0.70	0.12	-0.57
	Long run (20 quarters)	-0.74	0.18	-0.56
Germany	Short run (4 quarters)	-0.93	0.07	-0.86
	Long run (20 quarters)	-0.97	-0.42	-1.38
Italy	Short run (4 quarters)	0.41	0.07	0.48
	Long run (20 quarters)	0.31	0.05	0.37
Netherlands	Short run (4 quarters)	0.59	0.17	0.76
	Long run (20 quarters)	0.56	-0.07	0.49
Russia	Short run (4 quarters)	12.56	-0.68	11.89
	Long run (20 quarters)	8.52	-0.99	7.54
Switzerland	Short run (4 quarters)	-1.44	0.27	-1.16
	Long run (20 quarters)	-1.68	0.70	-0.99
UK	Short run (4 quarters)	-0.68	0.15	-0.54
	Long run (20 quarters)	-0.61	0.14	-0.47
USA	Short run (4 quarters)	-2.12	0.62	-1.50
	Long run (20 quarters)	-3.06	1.46	-1.60
Belgium	Short run (4 quarters)	0.15	0.30	0.45
	Long run (20 quarters)	0.35	0.15	0.50
Canada	Short run (4 quarters)	1.49	0.60	2.09
	Long run (20 quarters)	1.14	2.72	3.86
France	Short run (4 quarters)	0.94	0.13	1.06
	Long run (20 quarters)	2.29	1.10	3.38
Japan	Short run (4 quarters)	-3.61	-0.32	-3.94
	Long run (20 quarters)	-2.73	-0.76	-3.49

Not very surprisingly, we conclude that Russia, as a net oil exporter, gains from oil price shocks in both the short and long run. Moreover, the positive effect is quite large, indicating that a 50% increase in the positive oil price growth rate in the current quarter leads to 12.6 and 8.52 percentage point increases in cumulative GDP after 4 and 20 quarters, respectively. The indirect impact from the main trading partners is negative, as expected, albeit small relative to the positive direct effect.

The second net oil exporter in our sample, Canada, also gains from a positive oil price shock. However, the magnitude of the effect is considerably smaller than for Russia. This means that the Canadian economy, other things equal, is less dependent on oil world prices than is the Russian economy.

Of the countries considered, the largest negative direct effects of a positive oil price shock are found for the USA, Japan and China. The result for Japan is somewhat unexpected, as in recent studies by Blanchard and Galí (2007), Kilian (2008) and Jiménez-Rodríguez and Sánchez (2004) the findings are the reverse, i.e. they conclude that Japan has recently fared relatively well in the face of exogenous oil price shocks. However, in our study, we separate the effects of positive and negative oil price effects and control for the latter. In the studies mentioned above, the positive and negative oil price shocks are not separated or are not controlled for negative shocks. Moreover, the effect of a negative oil price shock (as measured by the sum of oil shock coefficients; see Appendix 5) for Japan is highly significant and positive, while the effect of a positive oil price shock is negative and significant (albeit smaller in absolute size). When we estimate the symmetric specification (in which the measure of oil price shock is just the log-difference), the effect is positive, although not statistically significant. In the specification in which we control only for the positive oil price shock, using the Hamilton measure, the effect is negative but small and statistically insignificant. These differences in results of different specifications partly explain the deviation of our results for Japan from those of other similar studies.

The result for China may be somewhat surprising, as in recent years China experienced robust growth. However our results indicate that if oil prices had been stable in the period studied, the Chinese economy would have experience even higher economic growth.[8]

Indirect effects are negative for China, Germany, Russia and Japan. For Russia, this is to be expected, as all its main trading partners are net oil importers, which for the most part suffer from positive oil price shocks and hence are able to absorb fewer exports compared to periods of stable oil prices.

[8] Of course, China's rapid growth has probably contributed to higher raw material prices. We do not explicitly take this possibility into account, as oil price is modelled as an exogenous variable.

In general the indirect effects are determined within the system of countries under consideration and thus depend on the structure of a particular country's exports to the other countries in the set. That is, if a particular country exports more to countries like Russia, Canada, France, Netherlands, Italy and Belgium (which can be considered as gainers from positive oil price shocks), the indirect effect can be positive. And vice versa: if the country exports mostly to losers from oil price shocks such as USA, China, Japan, and Switzerland, the indirect effect tends to be negative. However this is not the only determinant of the magnitude of an indirect effect under this estimation framework. The indirect effect also depends on the magnitude of coefficients of the foreign variable and its lags.

We also look at the matrix of indirect effects from each country to a particular country as depicted in Table 3.

Table 3 Matrix of long-run (cumulated over 20 quarters) indirect effects between countries

	China	Fin-land	Ger-many	Italy	Nether lands	Russia	Swit-zer-land	UK	USA	Belgi-um	Cana-da	France	Japan
China	**-2.75**	0.00	0.07	-0.01	0.00	**0.06**	0.01	0.04	-0.35	0.01	-0.94	-0.04	0.98
Finland	-0.03	**-0.74**	-0.03	0.00	0.02	**0.39**	-0.01	-0.02	-0.17	0.00	0.02	0.01	0.00
Germany	0.21	0.04	**-0.97**	0.29	-0.16	**-1.26**	0.54	0.22	0.60	-0.04	-0.29	-0.95	0.39
Italy	-0.03	0.00	0.05	**0.31**	0.00	**0.21**	-0.11	-0.03	-0.21	0.00	0.01	0.18	-0.02
Netherlands	-0.05	0.00	0.18	-0.04	**0.56**	**0.14**	-0.08	0.01	-0.07	-0.09	0.04	-0.04	-0.06
Russia	**0.89**	**-0.16**	**0.08**	**-0.07**	**0.35**	**8.52**	**-0.40**	**-0.03**	**-1.44**	**0.03**	**-0.06**	**0.02**	**-0.20**
Switzerland	-0.01	0.00	0.39	-0.26	0.01	**0.53**	**-1.68**	-0.08	0.10	0.05	-0.02	0.09	-0.10
UK	0.00	0.00	0.07	-0.04	-0.03	**0.10**	-0.05	**-0.61**	0.25	0.01	-0.02	-0.07	-0.06
USA	0.17	0.00	0.05	-0.04	0.00	**0.06**	-0.02	0.00	**-3.06**	-0.01	1.08	0.08	0.10
Belgium	-0.03	0.00	0.01	-0.05	0.12	**0.08**	-0.03	-0.01	-0.10	**0.35**	-0.02	0.17	0.00
Canada	-0.05	0.00	0.00	0.01	-0.01	**-0.01**	0.01	0.02	2.68	0.00	**1.14**	-0.05	0.11
France	-0.02	0.00	0.21	-0.08	-0.08	**-0.03**	0.19	0.14	0.88	0.04	-0.06	**2.29**	-0.11
Japan	-1.16	0.00	-0.02	0.00	-0.01	**-0.03**	0.00	-0.02	0.09	0.00	0.37	0.02	**-2.73**

Note: Bold black numbers are direct effects of positive oil price shock, bold red numbers are indirect effects from Russia to other countries, and bold green numbers are indirect effects from other countries to Russia.

In general indirect effects between countries are very small. However, there are some interesting patterns in the matrix.

First, indirect effects from Russia to its trading partners are mostly positive, as might be expected. The largest ones affect Switzerland and Finland. It is surprising that Germany gets the largest negative indirect effect from Russia, as it is one of Russia's main trading partners.

On the other hand, the indirect effects of a positive oil price shock from other countries to Russia are mostly negative, as expected. The largest negative effect is from the USA, and the largest positive effect from China. This positive effect may be an artefact of the data in the sense that China's growth was very strong throughout the sample period, regardless of the level of oil prices. This strong growth may also show up as a positive indirect effect for Russia.

USA and Canada appear to induce mutual positive indirect effects during positive oil price shocks. This may reflect their high degree of economic integration; Canada gains from exporting oil and other energy products to the USA, while USA gains from increasing demand in Canada for US consumption and investment goods in times of high oil prices.

What accounts for the size of oil-price effect? With the exception of China, all the net importers of oil in our sample are high-income countries. Some have slightly higher service shares in GDP than others, but the countries do appear to differ in terms of energy efficiency. To assess whether there is any relationship between energy efficiency in an oil-importing country and the estimated effect of oil price shock, we also checked the correlation between the size of the negative effect of the oil price shock in the oil-importing countries of our sample and the GDP per kg oil-equivalent energy in them. We found some evidence (albeit small) that the more energy-efficient countries, i.e. those that achieve a higher GDP with a given level of energy use, suffer less when the price of oil rises. The resulting scatterplots are in Appendix 7. Obviously, we are dealing only with a very limited number of countries here and so cannot draw statistically significant conclusions. Nonetheless, the results do conform to economic intuition. A country's energy-efficiency can be influenced by its production structure. For example, if a country's service sector accounts for a large share of GDP, it may consume less energy per unit of GDP, whereas the opposite obtains if the country specialises in heavy industry. Geographic size and population density may also matter. More compact countries need to spend less energy on transportation, ceteris paribus. Also taxation of energy inputs will have an impact on energy efficiency. In most European countries energy is taxed more than in the US, for example. Moreover, in China e.g. fuels are actually subsidised by the central government, which of course encourages their use.

6 Conclusions

In this paper we have studied the cross-country transmission of a shock in the price of an important raw material. More specifically, we are interested in the direct and indirect effects of such a price shock on an important raw material producer, in this case Russia. The direct effect is expected to be positive and the indirect effect negative. Countries importing such a raw material face a negative supply shock, which will have a dampening effect on their growth. Lower growth leads to lower import demand, which then curtails the raw material producer's exports.

To study this phenomenon, we used data from Russia – an important oil producer – and its main trading partners. In general we conclude that the direct effect for Russia from a positive oil price shock is positive and very large, as expected. The indirect effect is negative but very small, and so the net effect is always positive. However, the evidence for oil-importing countries is mixed. The direct effects of positive oil price shocks are negative for China, Finland, Germany, Switzerland, UK, USA and Japan. The indirect effects are negative for China, Germany, Netherlands and Japan. Our estimations are based on an asymmetric specification with separate metrics for positive and negative oil price shocks.

While the results are not particularly surprising as such, to our knowledge this is the first time the direct and indirect effects of a raw material price shock to a major raw material producer and its main trading partners have been estimated this way. While the positive effect for the Russian economy is to be expected, the variety of responses in the oil-importing countries are also interesting. In general we conclude that the largest negative total effects from positive oil price shocks are found in China, USA and Japan while European countries seem to fare quite well during recent positive oil-price shocks.

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Appendix 1

Table A1.1 Summary Statistics, 1995:3 - 2006:3

Variable	Mean	Median	Minimum	Maximum	Std. Dev.	C.V.	Skewness	Ex. kurtosis
Belgium	0.005	0.006	-0.008	0.015	0.005	0.911	-0.596	0.072
Canada	0.008	0.009	-0.002	0.016	0.005	0.592	-0.176	-0.853
China	-0.001	-0.002	-0.020	0.063	0.013	22.718	2.493	9.492
Finland	0.000	0.000	-0.014	0.012	0.006	undefined	-0.085	-0.367
France	0.005	0.005	-0.005	0.012	0.004	0.823	-0.117	-0.754
Germany	0.004	0.003	-0.007	0.016	0.006	1.565	0.287	-0.789
Italy	0.003	0.004	-0.008	0.013	0.005	1.413	-0.163	-0.457
Japan	0.003	0.004	-0.020	0.018	0.007	2.387	-0.675	1.078
Netherlands	0.000	0.000	-0.009	0.011	0.004	746.505	0.173	0.475
Russia	-0.001	0.000	-0.064	0.031	0.017	23.476	-1.166	3.154
Switzerland	0.004	0.005	-0.012	0.019	0.006	1.497	-0.218	0.675
UK	0.007	0.007	0.001	0.013	0.003	0.362	0.124	-0.048
USA	0.008	0.008	-0.004	0.018	0.005	0.608	-0.007	-0.008

Appendix 2

Table A2.1 Stationarity tests of GDP growth rate time series

	ADF test without constant*	ADF test with constant*	ADF test with constant and trend*	KPSS with trend (critical value at 10%: 0.119)**	KPSS without trend (critical value at 10%: 0.35)**
Belgium	-2.8 (0.008)	-4.65 (0.0005)	-4.6 (0.003)	0.065	0.065
Canada	**-1.6 (0.1)**	-3.6 (0.009)	-3.7 (0.03)	**0.119**	0.165
China	-6.9 (0.0000)	-6.8 (0.0000)	-6.7 (0.0000)	0.06	0.06
Finland	-8.9 (0.0000)	-8.8 (0.0000)	-8.7 (0.0000)	0.06	0.06
France	-1 (0.28)	-5.2 (0.0000)	-5.2 (0.0005)	0.118	0.169
Germany	**-0.87 (0.34)**	-5.9 (0.0000)	-5.8 (0.0000)	0.117	0.116
Italy	-3.26 (0.002)	-3.6 (0.007)	-3.5 (0.004)	0.083	0.1
Japan	-2.4 (0.02)	-5 (0.0001)	-5 (0.001)	0.096	0.14
Netherlands	-6.25 (0.0000)	-6.2 (0.0000)	-6.1 (0.0000)	0.09	0.09
Russia	-5.8 (0.0000)	-5.7 (0.0000)	-5.6 (0.0001)	0.04	0.04
Switzerland	-4.14 (0.0001)	-5.5 (0.0000)	-5.5 (0.0001)	0.076	0.078
UK	-0.85 (0.35)	-5.5 (0.0000)	-5.6 (0.0001)	0.056	0.16
USA	**-1.14 (0.23)**	-2.9 (0.04)	**-3.13 (0.1)**	0.11	0.2

* test down from maximum lag order
**10% critical value in parenthesis
Note: Bold numbers indicate failure to reject the null hypothesis of non-stationarity.

Appendix 3

The asymmetric specification distinguishes between the positive oil price growth rate, o_t^+, and the negative oil price growth rate, o_t^-, which are defined as

$$o_t^+ = \begin{cases} o_t & if \quad o_t > 0 \\ 0 & otherwise \end{cases}$$

$$o_t^- = \begin{cases} o_t & if \quad o_t < 0 \\ 0 & otherwise \end{cases}$$

where o_t is the real oil price growth rate.

The scaled and net specifications were developed by Lee et al (1995) and Hamilton (1996) to account for the fact that oil price increases following a long period of price stability have more dramatic macroeconomic consequences than those that are merely corrections to greater oil price decreases during previous quarter. In order to do this, we use several different transformations of the oil price variable. Lee et al. (1995) proposed the following AR(4) GARCH(1,1) representation of oil prices:

$$\begin{aligned} & o_t = a_0 + a_1 o_{t-1} + a_2 o_{t-2} + a_3 o_{t-3} + a_4 o_{t-4} + e_t \\ & e_t \left| I_{t-1} \right. \sim N(0, h_t) \\ & h_t = \gamma_0 + \gamma_1 e_{t-1}^2 + \gamma_2 h_{t-1} \\ & SOPI_t = \max(0, \hat{e}_t / \sqrt{\hat{h}_t}) \\ & SOPD_t = \min(0, \hat{e}_t / \sqrt{\hat{h}_t}) \end{aligned}$$

where SOPI is the scaled oil price increase and SOPD the scaled oil price decrease.

Hamilton (1996) argues forcefully that oil price changes as such or their non-linear transformations are clearly an unreliable instrument for macroeconomic analysis of post-1986 data.

Hamilton has proposed a more complicated measure of oil price changes - the net oil price increase - which distinguishes between oil price increases that establish new highs relative to recent experience and increases that simply reverse recent decreases. For quarterly data, the net oil price increase compares the price of oil each quarter to the maximum value observed during the preceding four quarters. If the value for the current quarter exceeds the previous year's maximum, the percentage change over the previous year's maximum is plotted. If the price of oil in quarter t is lower than it had been at some point during the previous four quarters, the date t value is set at zero, i.e.

$$NOPI_t = \max\left\{0, p_t - \max\left(p_{t-1}, p_{t-2}, p_{t-3}, p_{t-4}\right)\right\}.$$

Hamilton's measure captures oil price increase-type shocks while neglecting the impact of oil price declines. This is inspired by earlier evidence that oil price decreases had played a smaller role in US business cycles.

Appendix 4

Table A4.1 ADF and KPSS tests for unit roots of oil-price-shock metrics

	ADF test without constant*	ADF test with constant*	ADF test with constant and trend*	KPSS with trend (critical value at 10%: 0.119)**	KPSS without trend (critical value at 10%: 0.35)**
Real oil price growth rate (ROPgr)	-5 (0.0000)	-5.1 (0.0001)	-5.2 (0.0006)	0.04	0.16
”+” ROPgr	-3.3 (0.0015)	-4.8 (0.0003)	-4.7 (0.002)	0.05	0.11
”-” ROPgr	-2.1 (0.03)	-2.9 (0.05)	-6.5 (0.0000)	0.056	0.21
Hamilton measure	-3.4 (0.0012)	-4.3 (0.0013)	-4.3 (0.008)	0.06	0.1
SOPI	**-1.5 (0.14)**	-3.6 (0.007)	-4.1 (0.005)	0.05	**0.42**
SOPD	**-3.3 (0.001)**	-7.8 (0.0000)	-7.7 (0.0000)	0.05	0.06

Table A4.2 Summary Statistics, 1995:3 - 2006:3

Variable	Mean	Median	Minimum	Maximum	Std. Dev.	C.V.	Skewness	Ex. kur-tosis
Real oil price growth rate (ROPgr)	0.024	0.044	-0.288	0.316	0.119	4.889	-0.416	0.737
”+” ROPgr	0.059	0.044	0.000	0.316	0.071	1.210	1.520	2.508
”-” ROPgr	-0.035	0.000	-0.288	0.000	0.069	1.995	-2.319	4.931
Hamilton measure	0.041	0.000	0.000	0.240	0.062	1.495	1.346	0.946
SOPI	0.406	0.105	0.000	1.668	0.525	1.294	1.065	-0.145
SOPD	-0.288	0.000	-1.592	0.000	0.465	1.615	-1.552	1.205

Table A4.3 Correlation coefficients, 1995:3 - 2006:3
5% critical value (two-tailed) = 0.2940 for n = 45

	ROPgr	”+” ROPgr	”-” ROPgr	Hamilton measure	SOPI	SOPD
ROPgr	1	0.85	0.84	0.70	0.71	0.79
”+” ROPgr		1	0.42	0.84	0.79	0.50
”-” ROPgr			1	0.34	0.40	0.84
Hamilton measu-re				1	0.55	0.42
SOPI					1	0.49
SOPD						1

Appendix 5

Table A5.1 Joint significance of foreign variable coefficients (Wald test; F-statistics) The null hypothesis is that coefficients are jointly zero

	Bel-gium	Canada	China	Finland	France	Germany	Italy	Japan	Nether-lands	Russia	Switzer-land	UK	USA
Test statistics	5.4*	0.47	1.6	1.6	3.53*	5.34*	2.7*	2.2	8.4*	2.9*	5.5*	3.3*	4.4*

Critical value at 5% level, F(5,31,0.05)=2.53, * indicates rejection of null hypothesis

Table A5.2 Joint significance of oil shock coefficients (Wald test; F-statistics)
The null hypothesis is that coefficients are jointly zero

Specification / Country	Oil price growth rate	Asymmetric specification			Scaled specification			Hamilton net oil price increase
		"+" oil price growth rate	"-" oil price growth rate	both	SOPI	SOPD	both	
Belgium	0.49	0.57	1.03	0.75	0.63	0.58	0.75	0.46
Canada	0.53	0.56	0.4	0.46	0.31	0.74	0.46	0.95
China	1.9	1.4	0.43	1.1	1.4	0.9	1.13	1.4
Finland	0.72	0.75	1.57	1.2	1.04	0.73	1.2	0.26
France	0.28	0.42	0.67	0.46	0.5	1.01	0.46	0.28
Germany	3.37*	0.63	2.82*	2.57*	1.024	3.45*	2.6*	1.7
Italy	0.4	0.83	0.71	0.7	0.62	0.55	0.7	0.65
Japan	1.13	1.6	2.6	1.8	0.96	0.85	1.8	0.64
Netherlands	0.57	0.45	0.81	0.57	0.67	0.73	0.57	0.5
Russia	1.9	2.5	1.55	1.9	0.8	1.4	1.9	1.98
Switzerland	0.97	1.24	2.28	1.5	1.2	1.05	1.5	1.4
UK	1.05	1.4	1.2	1.3	0.66	0.5	1.33	1.1
USA	0.89	1.98	1.3	1.4	0.75	0.72	1.4	1.4
Average F statistics	1.1	1.1	1.34	1.2	0.81	1.02	1.22	0.98

Critical value at 5% level F(5, 26, 0.05)=2.59, * indicates rejection of null hypothesis
Critical value at 5% level F(5, 21, 0.05)=2.66, * indicates rejection of null hypothesis
Critical value at 5% level F(10, 21, 0.05)=2.3, * indicates rejection of null hypothesis

* The null hypothesis is that coefficients are jointly zero

Table A5.3 AIC and BIC results

Specification / Country	Oil price growth rate		Asymmetric specification		Scaled specification		Hamilton net oil price increase	
	AIC	BIC	AIC	BIC	AIC	BIC	AIC	BIC
Belgium	<u>-325.505</u>	<u>-299.801</u>	-324.354	-290.083	-322.302	-288.03	-325.253	-299.55
Canada	-314.411	-288.707	-308.535	-274.264	-309.749	-275.478	<u>-317.336</u>	<u>-291.632</u>
China	<u>-227.242</u>	<u>-201.538</u>	-222.045	-187.774	-225.037	-190.765	-224.128	-198.424
Finland	-297.516	<u>-271.812</u>	<u>-299.451</u>	-265.18	-294.545	-260.274	-295.183	-269.48
France	<u>-332.552</u>	<u>-306.848</u>	-328.442	-294.17	-328.442	-294.17	-332.521	-306.817
Germany	-326.653	<u>-300.95</u>	-328.893	-294.621	<u>-332.5</u>	-298.228	-317.651	-291.947
Italy	-319.603	-293.9	-318.319	-284.048	-318.032	-283.76	<u>-321.373</u>	<u>-295.67</u>
Japan	-283.151	<u>-257.447</u>	<u>-290.367</u>	-256.096	-278.829	-244.557	-279.86	-254.156
Netherlands	-338.624	<u>-312.92</u>	-334.189	-299.917	<u>-338.536</u>	-304.264	-338.111	-312.407
Russia	-224.487	-198.784	<u>-227.908</u>	-193.637	-219.398	-185.127	-224.873	<u>-199.17</u>
Switzerland	-304.466	-278.762	<u>-309.765</u>	-275.493	-306.1	-271.829	-307.269	<u>-281.566</u>
UK	-370.413	-344.71	<u>-372.976</u>	-338.705	-363.606	-329.334	-370.759	<u>-345.055</u>
USA	-326.942	-301.238	<u>-331.291</u>	-297.019	-319.996	-285.725	-330.039	<u>-304.335</u>
Average	-307.043	***-281.34***	**-307.426**	-273.154	-305.278	-271.006	-306.489	-280.785

Note: Minimum values of AIC and BIC for each country are underlined.

Table A5.4 Sum of oil shock coefficients

	Oil price growth rate	Asymmetric specification		Scaled specification		Hamilton net oil price increase
		"+" oil price growth rate	"-" oil price growth rate	SOPI	SOPD	
Belgium	0.014 (1.3)	-0.0007 (-0.023)	0.03 (0.83)	0.002 (0.6)	0.004 (1)	0.03 (1.2)
Canada	0.003 (0.23)	0.03 (0.6)	-0.03 (0.56)	-0.003 (-0.88)	0.003 (0.66)	0.03 (1.3)
China	0.11 (2.05)*	0.03 (0.2)	0.17 (1.3)	0.007 (0.62)	0.002 (0.15)	0.17 (1.6)
Finland	-0.017 (-1.1)	-0.016 (-0.28)	-0.01 (-0.18)	-0.004 (-0.9)	-0.002 (-0.28)	-0.003 (-0.1)
France	0.004 (0.35)	0.02 (0.7)	-0.009 (-0.23)	-0.003 (-1)	0.006 (1.6)	0.023 (0.99)
Germany	-0.015 (-1.4)	-0.008 (-0.27)	-0.02 (-0.63)	-0.002 (-0.63)	-0.007 (-1.8)*	-0.03 (-1)
Italy	-0.004 (-0.33)	0.018 (0.57)	-0.03 (-0.7)	-0.003 (-0.98)	0.001 (0.22)	0.008 (0.35)
Japan	0.013 (0.53)	-0.1 (-2.3)**	0.22 (2.8)***	0.002 (0.4)	-0.003 (-0.4)	-0.01 (-0.23)
Netherlands	0.009 (0.93)	0.04 (1.3)	-0.03 (-0.8)	0.002 (0.73)	0.003 (0.89)	0.02 (1.2)
Russia	0.05 (1.4)	0.19 (1.7)*	-0.1 (-0.98)	0.004 (0.35)	-0.002 (-0.11)	0.1 (1.2)
Switzerland	-0.003 (-0.24)	-0.05 (-1.4)	0.05 (1.2)	0.002 (0.63)	-0.004 (-0.7)	0.007 (0.24)
UK	-0.002 (-0.32)	-0.02 (-1.4)	0.03 (1.3)	-0.0006 (-0.38)	0.0004 (0.12)	-0.007 (-0.47)
USA	-0.007 (-0.64)	-0.07 (-1.9)*	0.05 (1.6)	-0.0009 (-0.32)	0.003 (0.55)	-0.02 (-0.85)

Note: t-statistics of the sum in parentheses; *** significant at 1% level, ** significant at 5% level, * significant at 10% level.

Appendix 6

Table A6.1 Hansen instability test for model and individual parameters (oil shock coefficients) in baseline (asymmetric) model

	Bel-gium	Can-ada	China	Finland	France	Ger-many	It-aly	Ja-pan	Nether-lands	Russia	Switzer-land	UK	USA
Stability test of oil price coefficients individually													
pos	0.04	0.15	0.13	0.03	0.04	0.07	0.07	0.06	0.36	0.09	0.31	0.51	0.20
pos1	0.07	0.03	0.14	0.05	0.22	0.06	0.21	0.04	0.18	0.15	0.41	0.21	0.10
pos2	0.06	0.10	0.19	0.14	0.13	0.05	0.18	0.12	0.07	0.24	0.32	0.14	0.07
pos3	0.20	0.22	0.48	0.12	0.05	0.06	0.59	0.08	0.55	0.08	0.28	0.25	0.11
pos4	0.20	0.03	0.21	0.33	0.12	0.22	0.26	0.04	0.21	0.03	0.19	0.31	0.28
neg	0.12	0.24	0.12	0.09	0.18	0.13	0.07	0.24	0.07	0.07	0.42	0.15	0.05
neg1	0.20	0.22	0.11	0.27	0.12	0.13	0.06	0.07	0.32	0.15	0.21	0.05	0.05
neg2	0.04	0.09	0.08	0.15	0.19	0.09	0.28	0.12	0.11	0.22	0.23	0.19	0.06
neg3	0.10	0.06	0.14	0.08	0.10	0.08	0.22	0.17	0.45	0.24	0.33	0.10	0.21
neg4	0.15	0.07	0.27	0.32	0.13	0.05	0.13	0.09	0.11	0.10	0.04	0.07	0.03
Joint sta-bility of the model	3.4	2.7	3.61	3.4	4.1	3.3	4.3	2.8	4.2	3.35	3.7	3.5	2.9

Note: The null hypothesis of the Hansen test is parameter stability; the 5 percent significance level for the individual stability test is 0.470; the 5 percent significance level of the joint stability test is 4,52; pos is the positive oil price growth rate variable and neg the negative oil price growth rate variable.

Appendix 7

Figure A7.1 Short-run total cumulative effect and energy efficiency

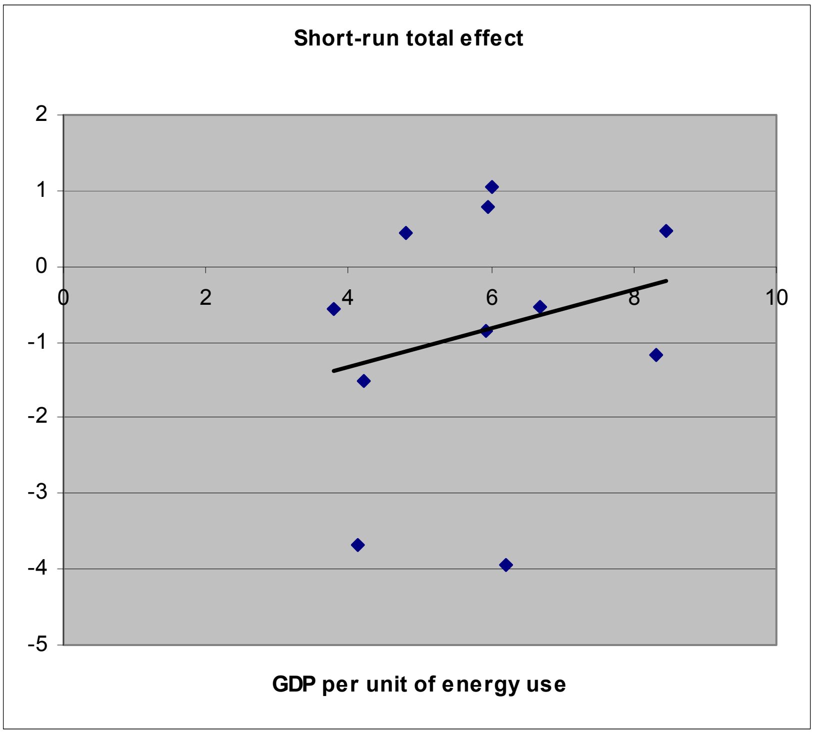


Figure A7.2 Short-run direct cumulative effect and energy efficiency

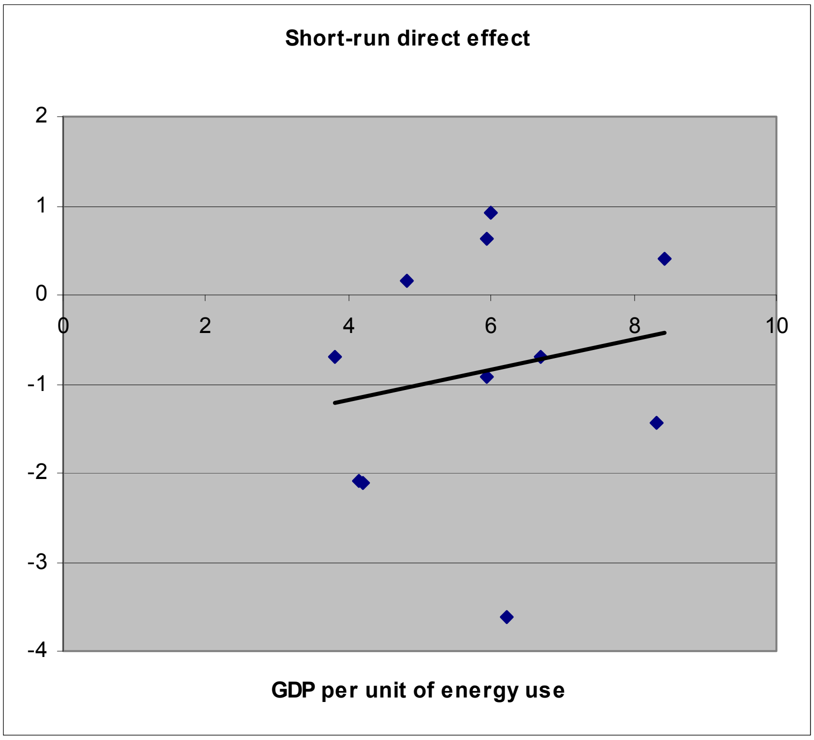


Figure A7.3 Long-run total cumulative effect and energy efficiency

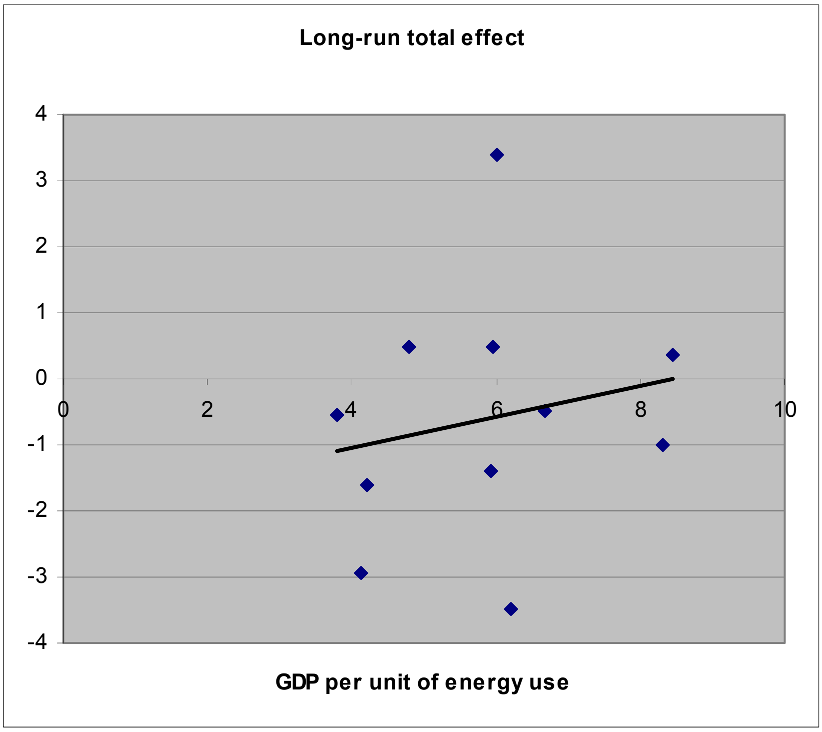
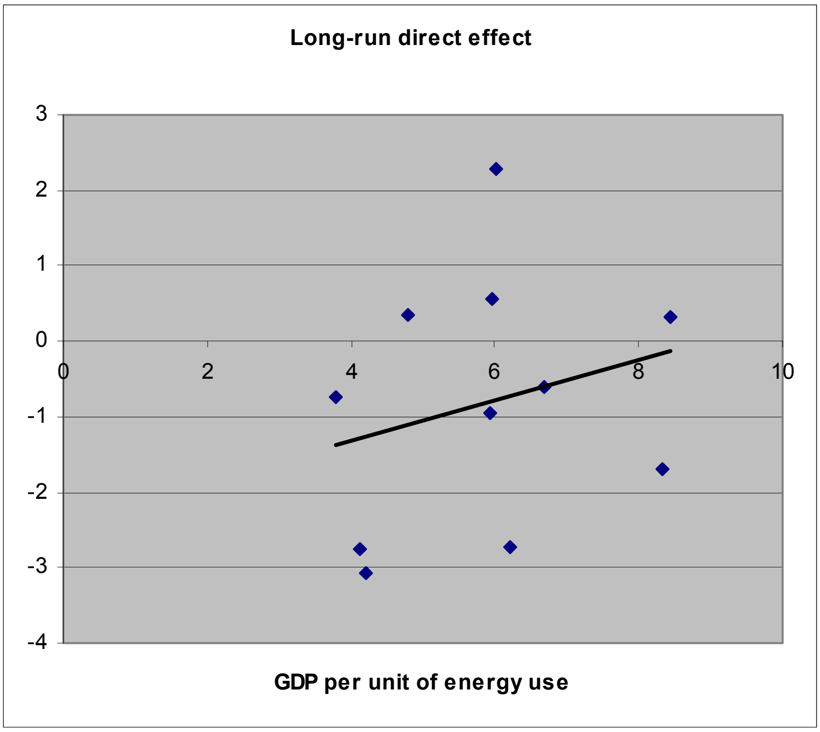


Figure A7.4 Long-run direct cumulative effect and energy efficiency


Long-run direct effect
3
2
1
0
-1
-2
-3
-4
0
2
4
6
8
10
GDP per unit of energy use

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