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Incorporating the value of changes in price volatility into cost-benefit analysis—an application to oil prices in the transport sector

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A B S T R A C T

This paper contains a tentative suggestion of how to take into account the value of changes in price volatility in real world cost-benefit analyses. Price volatility is an important aspect of security of supply which first of all concerns physical availability, but assuming that consumers are risk averse, security of supply can also be viewed as a matter of avoiding oscillations in consumption originating from volatile prices of for instance oil. When the government makes transport-related choices on behalf of the consumers, the effect on oscillations in general consumption should be included in the policy assessment taking into account the most significant correlations between prices of alternative fuels and between fuel prices and consumption in general. In the present paper, a method of valuing changes in price volatility based on portfolio theory is applied to some very simple transport-related examples. They indicate that including the value of changes in price volatility often makes very little difference to the results of cost-benefit analyses, but more work has to be done on quantifying, among other things, consumers' risk aversion and the background standard deviation in total consumption before firm conclusions can be drawn.

1. Introduction

Does it provide better value to save oil than to save coal? It is often claimed that society's dependency on oil produced in politically unstable regions means that for reasons of security of supply more value should be put on saving oil than on saving other energy carriers. Because of their positive impact on the security of energy supply, oil saving projects and policies – typically in the transport sector – might be more profitable than reflected in most cost-benefit analyses which do not take this aspect into account. But how can we appraise this extra value? This study presents an attempt to answer this question using projects from the transport sector as simple examples.

Egenhofer et al. (2004) make a survey of common definitions of security of supply and concludes that "security of supply is perceived as some sort of cost/risk judgement" and that "security of supply has two equally important constituent parts: physical availability and price". According to Bohi and Toman (1996) energy security refers to the loss of economic welfare that may occur as a result of a change in the price or availability of energy.

The present study focuses on the price side and is confined to a narrow definition of changes in the security of supply since it is simply regarded as a matter of a change in the volatility of general consumption as a consequence of changes in society's sensitivity to fuel price changes. Real physical shortness means that the oil price will increase very fast or be very high and this can be handled within standard cost-benefit calculations but *volatile* prices is a major difficulty for cost-benefit analyses.

The starting point for the study is that consumers are assumed to be risk averse and tend to avoid dependency on goods with volatile prices because they mean volatile real income and thus volatile consumption. Many studies (e.g. Barsky et al., 1997; Bliss and Panigirtzoglou, 2004; Luís, 2001; Meyer and Meyer, 2005) confirm the presence of risk aversion with consumers. When the consumers on their own are confronted with a choice, they presumably take this risk into account, but when the government makes choices on behalf of the consumers, the effect on the volatility of general consumption is normally not taken into consideration. But since a change in the volatility of consumption – i.e. a change in the security of supply – means a change in utility or welfare for the risk averse consumer, the volatility ought to be included.

By means of a *risk premium* (attributed to Pratt, 1964) a change in the volatility of consumption can be evaluated and standard cost-benefit analyses may be adjusted by adding the value of this change to the net present value of the projects. In the study, a correction based on the measure of the consumers' *relative risk aversion* is applied to evaluate the change in total consumption

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volatility caused by the project in question. This measure reflects the consumers' degree of risk aversion which depends on the concavity of the consumers' utility functions. The change in volatility or risk is measured as the change in the standard deviation in real consumption. The standard deviation of consumption is not solely affected by the standard deviation of the project at hand, but also depends on the correlation between the net present value of the project on the one hand and consumption on the other. The standard deviation of consumption stems from the volatility of prices of goods in general. If for instance the consumers, as a consequence of the project, switch from oil whose price is negatively correlated with consumption in general, to another fuel with the same price standard deviation (say biofuels), but without correlation with general consumption, total standard deviation of the real consumption and hence total risk will be reduced.

Thus, it will not be correct just to add a risk premium to the volatile oil price when making cost-benefit analyses. The volatility of the prices of other goods and their correlations with the oil price and consumption in general should also be included in the calculations.

The suggested method for valuing changes in price volatility is here applied to four very simple examples of transport energy related projects. Typically, the value of a change in price volatility turns out to be small compared to the annual benefits, but there is a high degree of uncertainty. In a particular case, a Monte Carlo simulation shows that when security of supply is included, the benefits from the project are changed by 0.3%–15% in 95% of the outcomes.

The outline of this paper is as follows: First, previous research is described shortly. Second, risk aversion and risk premium as a measure of the value of price volatility is introduced and linked to oil consumption, and the application in cost-benefit analyses is discussed. Finally, the approach is applied to simple synthetic projects to get an impression of the potential influence of the value of changes in price volatility to the benefits of the projects.

2. Previous research

There is a comprehensive literature on energy security, primarily on oil. The subject is approached from several different angles. One approach – mainly taken in the US – focuses on market failures and externalities. These studies often try to estimate the cost for oil importing countries stemming from the monopoly profits in the exporting countries (market power). The excess oil price causes a transfer of wealth from oil-importing countries to oil-exporting countries. But many of the studies also include the loss in potential output due to high price levels of an important production factor and the macroeconomic adjustment costs when oil prices are changing dramatically. Many of these results are surveyed in Jones et al. (2004). There seems to be consensus that the asymmetry in the observed effects of oil prices on economic activity (decreases have less impact than increases) stems from the nature and timing of the potential output and macroeconomic adjustment cost. Greene and Ahmad (2005) and Leiby (2007) are examples of this.

Another aspect of the security of supply debate in the literature is the question whether it is the level of oil prices or their volatility that is costly for the economy and to what extent. Ferderer (1996) finds that volatility is more important to GDP in the US than the price level. Hamilton (2003) introduced a transformation of the oil price called NOPI (Net Oil Price Index). He and others (Cuñado and de Gracia, 2003; Guo and Kliesen, 2005) find that this index which extracts surprising oil price increases (increases that are not following decreases) is the best to explain changes in GDP compared to other price measures. Cuñado and de Gracia (2003) among others use NOPI in VAR (vector auto regressive) analyses for a number of countries. The VAR analyses find much larger effects from oil price changes than is predicted by macroeconomic models. The difference is explained (i.e. by Greene and Ahmad, 2005) by differences in analyses and model set-up including the levels of aggregation.

Another approach to value an aspect of the security of supply is focussing on the risk issue. Dependency on oil means running the risk of a volatile economy—in other words high standard deviation in real consumption. The risk aversion of the consumers is the key concept here. This approach is standard in financial portfolio theory, but may also be applied in cost-benefit analyses and this is what is attempted in this paper. The view is taken that there is a trade-off between relatively cheap oil with a volatile price on the one hand and more expensive fuels with a stable price on the other. Walls (2004) suggests using the portfolio theory and a risk premium when making cost-benefit calculations for projects in the oil extraction industry. Referring to Walls (2004), Stæhr (2006) suggests using the same concept to take risks in general into account in cost-benefit analyses. As far as we know, the portfolio theory has not yet been applied to the assessment of security of supply as we propose to do it here. The concepts of portfolio theory and risk premium are presented in the subsequent sections.

3. Expected utility, risk aversion and risk premium

In this paper we use a risk approach to value changes in price volatility. We apply the method to projects within the transport sector, but it can be used generally. For instance, when assessing which is the more efficient method, – to decrease CO_2 emissions in the oil consuming transport sector or in the coal consuming power sector – inclusion of the higher volatility of oil prices in the analysis may in principle tip the outcome. In general, volatility of general consumption stemming from all types of sources should be included, but here we will concentrate on cases where only one or two goods are the source of this risk.

In some respects the choice of transport fuel or transport technology can be seen as a choice between assets with different expected benefits and different effects on the variability of general consumption. For instance, consider a situation where you should choose between an oil-based system and a system based on biofuels. A majority would expect the oil-based system to be less costly, but as the oil price is expected to be more volatile than the biofuel price the oil-based system will also add more to the volatility of the whole economy and to the variability of real consumption. If the consumers are risk averse, this can be counted as a welfare loss in cost-benefit analyses.

Before explaining how this can be done, we will shortly present the basics of risk aversion and the concept of expected utility. Von Neumann and Morgenstern (1944) introduced the notion of *expected utility*. They assume that given a utility function $u(c)$, the utility U from a set of possible consumption possibilities $c'=(c_1, c_2,\dots)$ with the corresponding probabilities $(p_1, p_2,\dots)$ can be described as

$$U(c') = \sum_i u(c_i)p_i \qquad (1)$$

In other words, the expected utility of a set of possible consumption outcomes known only by a probability distribution can be measured as the weighted average of the utility of each outcome using the probabilities of the outcomes as weights.

Normally the utility function $u(c_i)$ is assumed to be concave. A concave utility function means that the consumer has decreasing